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Goldstein

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[54] **ELECTRODE INSERTION DEVICE FOR NEUROELECTRICAL RECORDINGS**

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[52] **U.S. Cl.** ..... **128/2.1 E,** 128/DIG. 4, 128/303 B

[51] **Int. Cl.**..... **A61b 5/04**

[58] **Field of Search**..... 128/2.1 E, 2 E, 2 N, 2 T, 128/410, 418, 303 B, 303.18, 303.19, 2.05 E, 128/2.1 R, DIG. 4; 73/80; 269/20; 33/169 B, 33/174 D, DIG. 2

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[57] **ABSTRACT**

An electrode insertion device is disclosed capable of atraumatically obtaining single cell neuroelectrical recordings from an exposed pulsating human cortex. The electrode insertion device comprises an electrode disposed within a sleeve which, in turn, is mounted in a frictionless manner by means of fluid bearings in a fixed housing. The electrode protrudes a desired distance from the sleeve for insertion into the cortex, the sleeve and the electrode therein "riding" or floating on the surface of the brain cortex, thereby continuously maintaining the electrode tip next to a nerve cell in spite of the pulsatile motion of the cortex. Counterbalancing means comprising a gravity-operated variable pressure valve together with a piston attached to the sleeve are provided in the housing to reduce the contact force on the cortex surface effected by the weight of the sleeve and the electrode. The counterbalancing means automatically compensates for variations in electrode orientation with respect to vertical. A mechanism including a plurality of fins mounted and constrained within a second set of frictionless fluid bearings contained in a rotating block is further provided whereby the protrusion of the electrode can be adjusted in a frictionless manner and so as not to interfere with the free up-and-down floating movement thereof.

12 Claims, 3 Drawing Figures

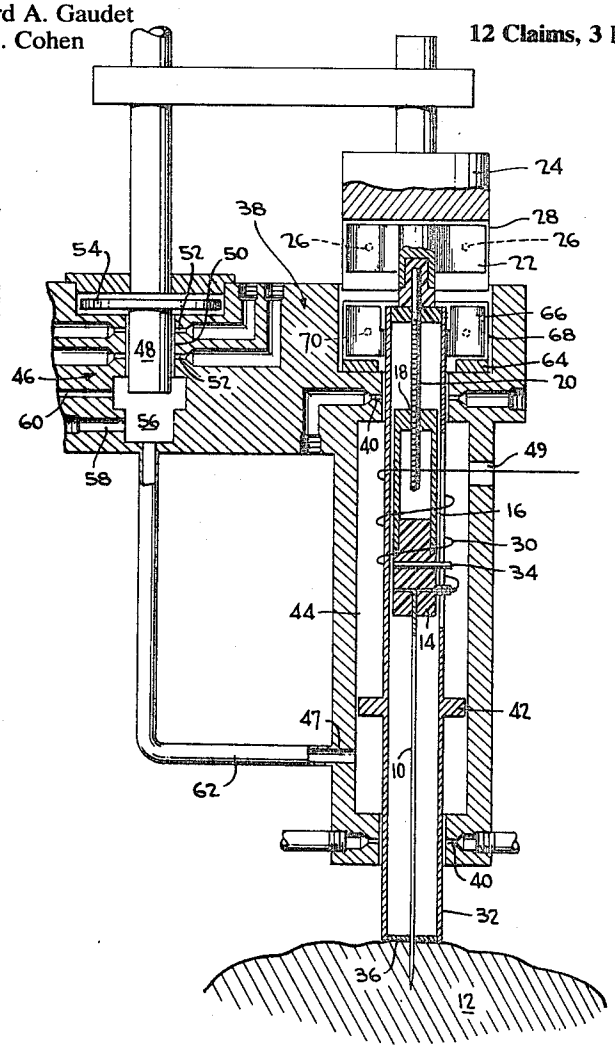


FIG. 1

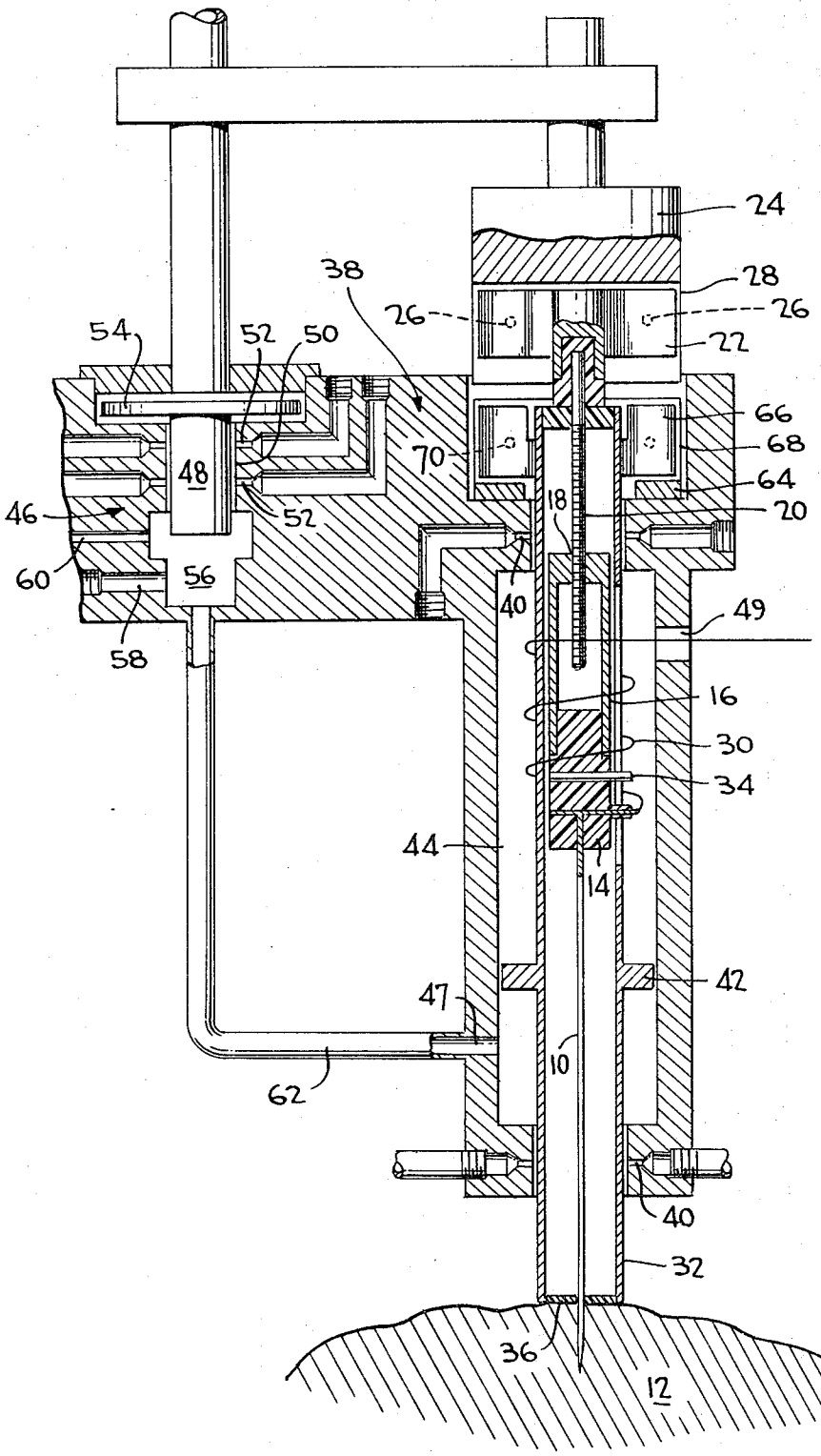

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FIG. 2

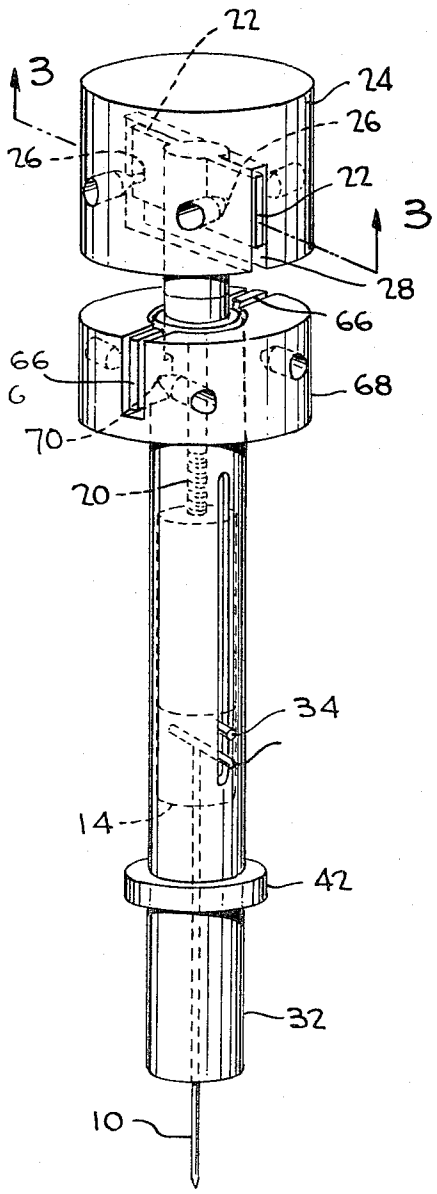
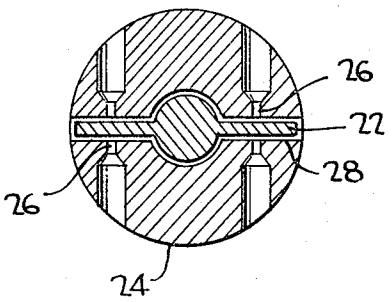


FIG. 3



ELECTRODE INSERTION DEVICE FOR NEUROELECTRICAL RECORDINGS

BACKGROUND OF THE INVENTION

This invention generally relates to the medical recording arts, and particularly concerns an electrode insertion device capable of atraumatically obtaining single cell neuroelectrical recordings from an exposed pulsating human cortex.

Neurophysiologists, in their investigations of brain functions, require a convenient technique and device by which single cell neuroelectrical records can be obtained from the human cortex. A problem exists with respect to obtaining such single cell recordings when the piece of skull overlying a given area of the cortex has been removed, thus exposing the cortex, since a pulsatile, up-and-down motion of the cortex will occur, Typically, such pulsatile motions are on the order of 3 millimeters, peak-to-peak, due to blood pressure and respiration, once the overlying piece of skull has been removed. Yet, to obtain an adequate neuroelectrical recording, relative movement between the submerged electrode tip and any adjacent neurons of interest must be less than approximately 10 microns, 10 microns being a typical diameter of an active neuron. As such, the normal cortical pulsations which occur are of a magnitude which precludes the utilization of conventional, rigidly mounted recording electrodes which are incapable of "following" the cortical movement.

The situation is further complicated in that recordings are required to be made of various neurons at variable depths of from 0 to 10 millimeters beneath the cortical surface, while the cortex is pulsating.

In an effort to solve this problem so that single cell recordings can be obtained from the human cortex at variable depths, various techniques have been utilized in the prior art. For example, mechanical mechanisms have been devised whereby displacement of the brain during a recording period is restricted. This technique, however, is one involving relatively high risk to the patient, in that restricting brain displacement by mechanical means could cause minor though still unacceptable damage to the cortex. In addition, the mechanical apparatus oftentimes interferes with surgical procedures.

An alternative prior art technique involved reducing the cortical pulsations by exposing a lesser amount of the brain, typically by introducing the electrode through a small hole in the skull which is subsequently sealed to prevent fluid loss. This technique, however, suffers its own disadvantages in that visibility is lacking and that a limited region for recording is produced.

SUMMARY OF THE INVENTION

It is therefore apparent that a need still exists in the art for an instrument by which single cell neuroelectrical recordings can be obtained from an unrestrained human cortex in the presence of cortical pulsations at variable depths up to ten millimeters by an electrode which is positioned with a high degree of accuracy and resolution. It is the primary objective of the instant invention to provide an electrode insertion device which satisfies this need.

A further objective of the instant invention is the provision of an electrode insertion device by which single cell neuroelectrical recordings can be obtained with minimum risk to the patient.

Yet another objective of the instant invention concerns the provision of an electrode insertion device which atraumatically obtains recordings from a pulsating cortex.

These objects, as well as others which will become apparent as the description proceeds, are implemented by the instant invention which, in its broad or general format, is constructed so that the electrode freely "rides" or floats on the surface of the brain cortex with extremely small contact forces. This floating action serves to compensate for the up-and-down pulsatile motion of the cortex and keep within small limits the amount of relative movement between the electrode and the particular neuron of interest. As such, the instant invention will be seen to eliminate the need and the resulting danger of physically restraining cortical movement during electrode measurements, thus constituting a marked advantage over prior art techniques of inserting an electrode through a small hole in the skull, which techniques limit the area of the brain available for recordings to the vicinity of the small hole.

In its preferred constructional form, the electrode insertion device of the instant invention will be seen to include an electrode of standard type adapted for insertion into the cortex of a patient. The electrode is supported and positioned within an elongated holder means, such as a sleeve, such that the electrode protrudes a selected though variable distance from the lower end thereof, this selected distance being representative of the desired depth of penetration of the electrode into the cortex. The lower end of the elongated holder means or sleeve defines a contact area which is disposed on the surface of the cortex. A housing means is provided for the elongated electrode holder and the electrode therein, the housing means, in use, being maintained in a relatively stationary position with respect to the cranium of the patient above the area of electrode insertion. Importantly, the housing incorporates a bearing assembly therein, a series of fluid journal bearings in the preferred embodiment, which assembly supports the electrode holder and the electrode in a substantially frictionless manner for free up-and-down movement with respect to the housing along the longitudinal axis of the holder. As such, the electrode holder and the electrode therein can freely follow the pulsatile movement of the cortex during recording of other operation.

Since the electrode holder or sleeve is in actual contact with the surface of the cortex, a technique is desired and, indeed, is provided by the instant invention wherein the pressure or weight of the electrode holder and associated apparatus on the cortex surface is minimized or removed altogether. To this end, the instant inventive device incorporates a counterbalancing means which applies an upward force to the electrode holder or sleeve so as to compensate for the weight thereof on the cortical surface. In its preferred constructional format, this counterbalancing means will be seen to comprise a gravity-operated variable pressure valve applying a variable fluid pressure to a piston assembly attached to the electrode holder, the amount of pressure being varied in accordance with the orientation of the electrode holder and the gravity-operated valve such that changes in the gravitational normal component of the electrode holder weight ef-

fected by varying orientation of the housing with respect to the vertical are automatically compensated for.

An adjusting mechanism is further provided by which the selected distance of protrusion of the electrode from the electrode holder or sleeve can be adjusted, thus varying the depth of penetration of the electrode, the adjustment not interfering with the up-and-down pulsations of the cortex. In the preferred embodiment, such adjusting means or mechanism comprises a rotary lead screw coupled between the electrode and the sleeve, which screw, when rotated, serves to adjust the distance of electrode protrusion. However, since the electrode holder or sleeve and electrode therein are mounted in the housing in a substantially frictionless manner for free up-and-down movement, a mechanism must be provided whereby rotation of the electrode holder and electrode is prevented when the lead screw is rotated. To this end, the lead screw is rotated by an attached plurality of fins mounted and constrained within a second set of frictionless fluid bearings contained in a rotating block.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention itself will be better understood, and further features and advantages thereof will become apparent, from the following detailed description of the preferred inventive embodiment, such description making reference to the appended sheets of drawings, wherein:

FIG. 1 depicts the instant inventive electrode insertion device in side elevation, broken away for illustrative clarity;

FIG. 2 depicts the electrode holder or sleeve and associated parts as removed from the assembly of FIG. 1; and

FIG. 3 is a top elevational view taken along lines 3—3 of FIG. 2 illustrating a typical fluid bearing assembly utilized to provide frictionless operation of the electrode insertion device.

Like parts have been designated by the same reference numerals throughout the various views of the drawings.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawings, and particularly to FIG. 1 thereof, the novel electrode insertion device of the instant invention, in its preferred form, constitutes an electrode **10** adapted for insertion to a preselected depth into the cortex **12** of a patient, so that single cell neuroelectrical recordings from the exposed pulsating cortex can be made. It should be appreciated, however, that while the device of the instant invention has been described as being useful for obtaining neuroelectrical recordings, the inventive device as well as the electrode **10** thereof can be utilized for other surgical-medical purposes.

The electrode is connected at its upper end to an electrically insulating synthetic plastic material or block **14** which can comprise an insulating elastomer plug, electrode **10** thereby being securely held in place. Pressed into the plug **14** is a yoke or U-shaped nut **16** having a threaded aperture **18** at the upper end thereof into which the fine lead screw **20** is threaded. Lead screw **20** terminates, at its upper end, in a finned arrangement **22** maintained within a rotary bearing block **24** having a plurality of fluid thrust bearings **26** therein, as can best be seen in FIGS. **2** and **3**. Upon application of fluid, such as air or an inert gas, to the bearing openings **26**, the finned assembly **22** is maintained centered in slot **28** of the rotary bearing block **24** in a frictionless manner. As bearing block **24** is rotated manually by an operator, the finned assembly **22** will be caused to rotate, causing rotation of the lead screw **20** and a relative raising or lowering of the electrode **10** in an up-and-down direction. The slot **28** in the bearing block **24** is depicted as being elongated, so as to accommodate the up-and-down pulsations of the cortex without interfering with lead screw rotation.

Electrical connection to electrode **10** can be made by means of an extremely thin lead wire **30** and its socket connected thereto, as illustrated in FIGS. **1** and **2**.

Electrode **10**, plug **14**, nut **16**, and rotary lead screw **20** are supported and maintained in position within an elongated holder means constituting an encircling sleeve or rider **32**, as illustrated in FIG. **2**, the electrode **10** and related components being capable of vertical adjustment within the sleeve **32** by rotation with respect to the sleeve **32** due to the provision of a key and slot arrangement generally designated by reference numeral **34**. As is illustrated, the electrode **10** is adapted to protrude a selected distance from the lower end of the sleeve **32** into the underlying cortex **12** of the patient, while the lower end of the holder means or sleeve contains a guide and seal with a contact area **36** which rides or is disposed on the surface of the cortex, as shown in FIG. **1**.

A housing means generally designated by reference numeral **38** is provided for the elongated electrode holder means or sleeve **32** and the electrode **10** disposed therein, the housing means **38** being adapted, in use, to be maintained in a relatively stationary position with respect to the cranium of the patient above the area of electrode insertion. To this end, the housing means **38** can be clamped on the cranial surface of the patient or, alternatively, other equivalent securing methods can be utilized as is common in the art.

The housing means **38** contains a bearing assembly means constituting, in the preferred inventive embodiment, a series of fluid journal bearings **40** which are disposed about and encircle the rider or sleeve **32**, supporting the electrode holder **32** in a substantially frictionless manner for free up-and-down movement with respect to the housing **38**. As such, the electrode holder **32** and the electrode **10** therein are capable of freely following the pulsatile movement of the cortex during recording, all the while maintaining a desired depth of electrode penetration of the electrode **10** from the lower surface or end **36** of the sleeve **32**. Fluid pressure, such as an inert gas or air, is applied to the thrust bearings **40** by any suitable though non-illustrated mechanism, such as an external pressure generator and tubing connected thereto.

As explained above, adjustment of the distance of protrusion of electrode **10** from the surrounding holder or sleeve **32** is effected by rotating the lead screw **20** via the rotary thrust block or bearing **24**. However, since the electrode holder or sleeve **32** is maintained within housing **38** in a substantially frictionless manner allowing free movement, a mechanism must be provided whereby rotation of the sleeve **32** is prevented when the lead screw **20** is rotated. Thus, the instant inventive device contemplates the provision of the further fluid

thrust bearing 64 of similar construction to bearing 24, but disposed in a stationary manner within housing 38. As is illustrated in FIGS. 1 and 2, a plurality of fins 66 are attached to the external surface of sleeve 32 at the top end thereof, which fins fit within elongated slots 68 disposed within the stationary thrust bearing 64. Again, the provision of the elongated slots allows free up-and-down movement of the electrode holder or sleeve, and the application of fluid to the orifices 70 of bearing 64 maintains fins 66 centered in the slot in a frictionless manner and serves to prevent any rotation of the electrode holder or sleeve 32.

As so far described, an electrode has been illustrated which is capable of being inserted to an adjustable depth into the cortex of the patient and which is capable of following the pulsatile cortex movement by utilizing a surrounding rider or sleeve which virtually floats on the cortex surface, the rider or sleeve constituting the holder means which is mounted in a substantially frictionless manner in the housing by means of fluid thrust bearings. Yet, as mentioned at the outset, it is desirable that all, or substantially all, of the weight of the electrode holder and electrode assembly therein which presses on the cortex surface be eliminated. To this end, the invention contemplates the provision of a counterbalancing means which serves to actually apply an upward force to the electrode holder means so as to compensate for the weight thereof.

In the preferred inventive embodiment, and as shown in FIG. 1, the counterbalancing means will be seen to comprise a fluid piston assembly incorporating a piston 42 which surrounds the sleeve 32 and fits with a small but finite clearance with the side wall of an internal cylindrical bore 44 within the housing 38, in which cylindrical bore the electrode holder 32 and electrode 10 therein ride up and down. A fluid pressure generator means generally designated by reference numeral 46 is maintained within the same housing 38 as the electrode holder 32 and serves to provide a controlled and variable pressure to the lower side of the encircling piston 42 via a port 47 communicating with the interior of the cylindrical bore 44. As can be appreciated, the higher the pressure of fluid applied to the underside of the piston 42, the lesser will be the weight of the electrode holder or sleeve 32 and electrode 10 therein which presses on the surface of the cortex 12 via the contact area 36. In fact, and at a sufficiently controlled pressure, substantially all of the weight of the electrode holder on the exposed cortical surface can be eliminated. An exhaust port 49 allows flow which has leaked by the piston to excape so that pressure does not build up above the piston.

The pressure generator means 46, in the preferred inventive embodiment, constitutes a gravity-operated variable pressure valve disposed in housing means 38 and includes a sliding piston 48 disposed in a bore 50 and supported for substantially frictionless free up-and-down movement by a plurality of fluid journal bearings 52 similar in construction to journal bearings 40 previously discussed. Application of fluid to the journal bearings 52 via the inlet openings schematically depicted therein serves to center the piston 48 and support same without friction. The upper end of piston 48 terminates in a disc-like cap 54 disposed within an enlarged portion of the bore 50 as shown. The lower end of the piston 48 communicates with a chamber 56 having an inlet orifice 58 therein constituting a supply orifice for fluid at a contact pressure generated by the non-illustrated means described abive, and opening 60 constituting an exit orifice leading to a vent or plenum, such as the atmosphere. The positioning of the piston 48 within the bore 50, and particularly the dimensions in the longitudinal or axial direction of piston 48, is such that as piston 48 moves in a downward direction, for example, the area of the outlet orifice 60 is reduced, thus increasing the pressure within the chamber 56, which pressure is communicated via line 62 through opening 47 to the lower side of the piston 42 surrounding the electrode holder or sleeve 32. Proper adjustment of the mass of the piston 48, the outlet area of the exit orifice 60, and the supply pressure through orifice 58 is such as to ensure compensation of the weight of the electrode holder 32 and associated components through the application of a sufficiently high upward pressure thereto.

As should be appreciated, the amount of pressure exerted by the electrode holder 32 and particularly by its contact area 36 on the surface of the cortex 12 depends, in part, on the position of the apparatus relative to gravitational normal, since such pressure is effected through gravitational weight. The counterbalancing means of the instant invention above-discussed is constructed such that a constant regulation or variation of the upward force applied to the lower side of the piston 42 is obtained as the position of the device varies from gravitational normal. Specifically, the amount of downward movement of piston 48 of the pressure generating means 46 is directly related to the angular position of housing 38 relative to gravitational normal, and, as the housing is inclined, the pressure applied to piston 42 is reduced automatically since piston 48 will not drop down as far and thus will not block as much of the exit area of orifice 60 as would be the case if housing 38 were maintained in a perfectly upright or gravitational normal position. Unwanted oscillatory motions of piston 48 are suppressed by the damping force generated when fluid in the gap above cap 54 is squeezed out of place by vertical motion. This "squeeze film damping" action is desirable to ensure proper operation of the pressure generation system.

While a preferred inventive embodiment has been described in detail, it should be appreciated that variations thereto and modifications thereof can readily be effected by those skilled in the art within the general teachings and scope of the invention, as defined by the appended claims. It should further be appreciated that the objects set forth initially at the outset of this specification have successfully been achieved.

I claim:

1. An electrode insertion device for atraumatically obtaining single cell neuroelectrical recordings from an exposed pulsating cortex, said device comprising:

an electrode adapted for insertion into the cortex of a patient;

an elongated holder means for supporting and positioning said electrode therein such that said electrode protrudes a selected distance from an end thereof, said selected distance being representative of the desired depth of penetration of said electrode into the cortex, said end of said holder means defining a contact area for disposition on the surface of the cortex;

a housing means for said elongated electrode holder means adapted in use to be maintained in a rela-

tively stationary position with respect to the cranium of the patient above the area of electrode insertion, said housing means having bearing assembly means for supporting said electrode holder means and said electrode therein in a substantially frictionless manner for free up-and-down movement with respect thereto along the longitudinal axis of said holder means; and means for connecting the electrode to an external device;

whereby said electrode means and said electrode therein freely follow the pulsatile movement of the cortex during recording.

2. A device as defined in claim **1,** further including a counterbalancing means for applying an upward force to said electrode holder means to compensate for the weight thereof, irrespective of vertical orientation of said electrode holder means, whereby the contact force of said holder means on the cortex surface is minimized.

3. A device as defined in claim **2,** wherein said electrode holder means further includes adjusting means for adjusting in a frictionless manner the selected distance of protrusion of said electrode therefrom.

4. A device as defined in claim **3** wherein said bearing assembly means of said housing comprises a series of fluid journal bearings disposed about said elongated electrode holder means.

5. A device as defined in claim **4** wherein said counterbalancing means comprises a fluid piston assembly coupled to said electrode holder means, and a fluid pressure generator means for actuating said piston assembly with a controlled pressure.

6. A device as defined in claim **5,** wherein said fluid generator means provides a controlled pressure to said fluid piston assembly which automatically varies to compensate for changes in the normal component of said electrode holder weight effected by varying positions of said housing means with respect to the cranium of the patient.

7. A device as claimed in claim **6,** wherein said electrode holder means comprises an encircling sleeve disposed about said electrode, said electrode protruding from a surface thereof, which surface defines said cortical contacting area of said holder means, said sleeve being disposed for up-anddown movement in a cylindrical bore in said housing means with said fluid journal bearings being placed adjacent said bore in surrounding relationship with respect to said sleeve; said piston assembly comprising a piston disposed about said sleeve in said bore and an opening in said bore at a location below that of said piston communicating with said fluid pressure generator means.

8. A device as defined in claim **7,** wherein said fluid pressure generator means constitutes a gravity-operated variable pressure valve disposed in housing means.

9. A device as defined in claim **1,** wherein said electrode holder means further includes adjusting means for adjusting in a frictionless manner the selected distance of protrusion of said electrode therefrom.

10. A device as defined in claim **9,** wherein said electrode holder means includes a sleeve disposed about said electrode with said electrode protruding therefrom, and wherein said adjusting means comprises a rotary lead screw coupled between said electrode and said sleeve, and means to prevent rotation of said sleeve and said electrode therein when said lead screw is rotated.

11. A device as defined in claim **10,** wherein said adjusting means further comprises a plurality of fins attached to said lead screw, said fins being mounted and constrained within a further set of frictionless fluid bearings contained in a rotation block, rotation of said block effecting rotation of said lead screw and advancement of said electrode.

12. A device as defined in claim **10,** wherein said means to prevent rotation of said sleeve and said electrode therein when said lead screw is rotated, comprises a plurality of fins attached to said sleeve, said fins being mounted and constrained within a further set of frictionless fluid bearings contained in said stationary block disposed within said housing means.

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