

- [54] APPARATUS AND METHOD FOR ELECTRICALLY STIMULATING LEG MUSCLES
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- [22] Filed: Feb. 16, 1971
- [21] Appl. No.: 115,786

**Related U.S. Application Data**

- [63] Continuation of Ser. No. 783,004, Dec. 11, 1968, abandoned.
- [52] U.S. Cl. .... 128/423; 128/411
- [51] Int. Cl. .... A61n
- [58] Field of Search ..... 3/1.1, 1.2; 128/404, 411, 128/419-424

[56] **References Cited**

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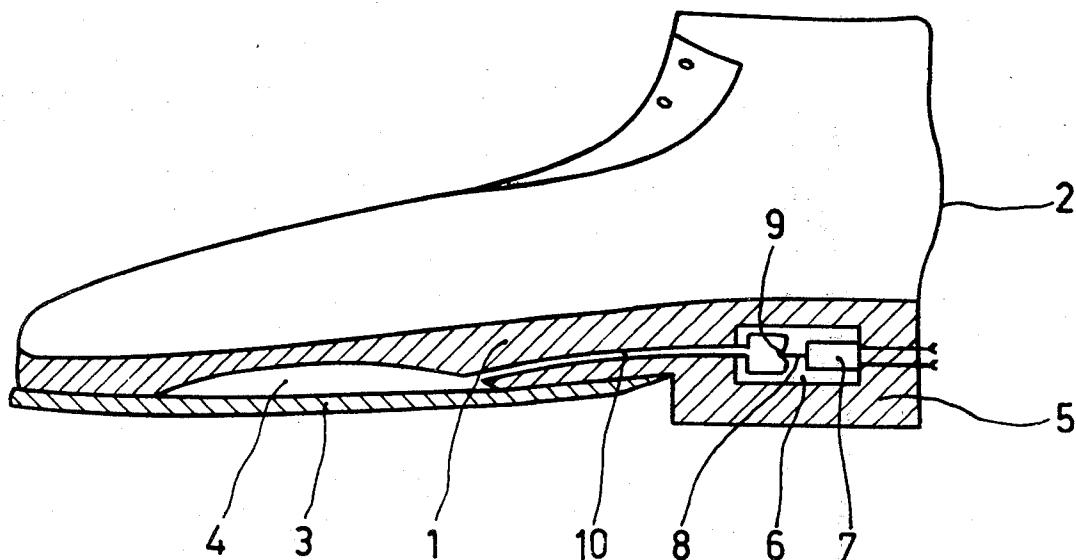
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*Primary Examiner*—William E. Kamm  
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[57] **ABSTRACT**

Apparatus for electrically stimulating a leg muscle includes an air-filled chamber located in the sole of the shoe beneath the ball of the foot and coupled to a microswitch in the heel by an air channel or a thin hose and a diaphragm. The switch in turn activates an electric pulse generator in synchronism with the normal walking pattern. The pulse generator supplies electric pulses to a pair of electrodes attached to the leg muscles to be stimulated.

**11 Claims, 3 Drawing Figures**



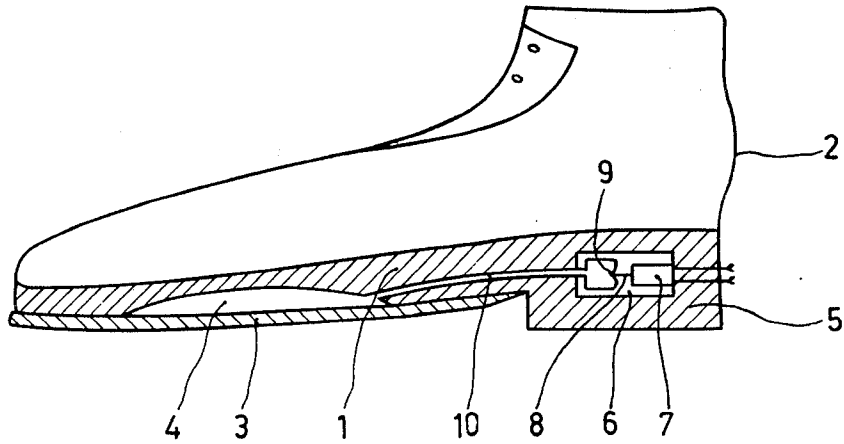


FIG. 1

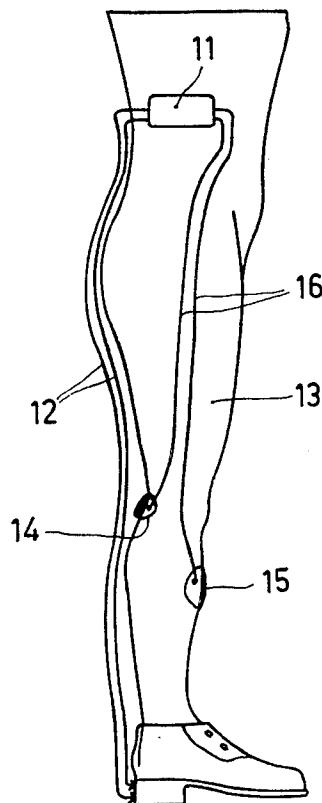


FIG. 2

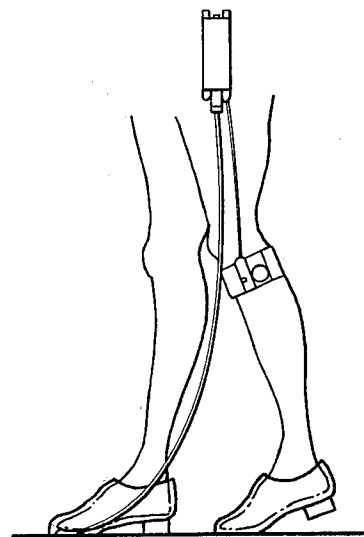


FIG. 3

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## APPARATUS AND METHOD FOR ELECTRICALLY STIMULATING LEG MUSCLES

This application is a continuation of application Ser. No. 783,004, filed Dec. 11, 1968, now abandoned, and relates to electrical therapy devices for use by humans with muscular disfunction, and more particularly to an improved electro-therapy device for electrically stimulating leg muscles of a human.

The present invention relates to electrical therapy devices for use by humans with muscular disfunction, and more particularly to an improved electro-therapy device for electrically stimulating the leg muscles of a human.

For electro-therapeutical purposes electrical activation currents of different frequencies and waveforms are employed which serve to stimulate given rhythmical physical functions.

Usually the start and the termination of the activation at the correct instant form an essential condition for effective use of this kind of device.

There are known devices of this kind operating on available physiological pulses of constant or substantially constant frequency for starting and interrupting the activation currents, using, for example, the distension and constriction of the heart for the blood circulation or the respiration motions of the thorax.

If such physiological pulses are lacking or weakened to a high extent, the activation pattern is controlled in a different manner. A known example is the electrical stimulation of locomotion of muscular or nervous tissues, the natural stimuli of which operate inadequately due to morbid symptoms somewhere else in the body so that the normal gait is seriously disturbed. This stimulation is termed functional electrical stimulation ( F. E. S. ). The purpose is to provide synchronized activation of one or more tissue groups by electrical pulses so that, under the action of a given frequency and a given amplitude variation of the current, the normal muscle stimulus for an important phase of the locomotive pattern is approached and a locomotive pattern is obtained which substantially corresponds with the normal pattern.

Effective activation of muscles or muscular groups by electrical pulses for walking so as to approach the natural function of the muscles depends primarily upon the instant of beginning and upon the duration of the activation. A possibility of ensuring synchronized activation resides in processing a signal derived from a normally operating muscular tissue by means of electronic circuitry. This signal is applied with a given delay to the muscular tissue to be stimulated, which requires an accurate adjustment and a correct choice of the place where the signal has to be taken. A simpler system comprises a stimulator actuated by a switch arranged in the heel of a shoe. When the body weight bears on the foot there is no activation and the leg is distended. No activation is required for the time the foot is on the ground. By lifting the foot the activating pulses are initiated.

In practice, the use of a switch in the heel of the shoe has proven that the obtainable locomotive pattern is useful, it is true, but it exhibits deviations from the natural locomotive pattern which seriously impede the patient's adaptation to the locomotion stimulus. Acquiring a new locomotive pattern may give rise to balance disturbance. A switch arranged in the heel of the shoe

is switched on and off at an advanced instant by the displacement of the body weight.

The invention has for an object to avoid these disadvantages and relates to an electro-therapeutical apparatus for applying electrical activation currents to muscular or nervous tissues for stimulating locomotion and is based on the condition that correct actuation of the activation currents should be achieved when the body weight is displaced from one foot to the other. According to the invention an air-filled chamber is provided beneath the foot-sole where the ball of the foot bears on the sole of the shoe. This chamber actuates pneumatically an electric switch, which is part of an electric pulse generator, by means of the pressure variations produced by the displacement of the body weight. The pressure variations produced in the air chamber affect a movable partition, the displacements of which open or close the contacts of a micro-switch. By using an air hose between the air chamber and the movable partition the micro-switch may be arranged at any place outside the shoe. There may be used a shoe having two soles, between which the air chamber is arranged. This requires a special shoe structure. It is simpler to provide a separate sole comprising two layers between which the air chamber is located, which sole can be put into any shoe and may be employed over again. For the pneumatic actuation of the switch the air chamber may communicate with the movable partition by means of a flexible hollow tube.

The invention will now be described in greater detail with reference to the accompanying drawing which shows a preferred embodiment of the invention in which:

FIG. 1 shows a shoe suitable for use with the apparatus according to the invention.

FIG. 2 shows the required parts of the apparatus in a practical arrangement.

FIG. 3 shows another embodiment of the invention, and

FIG. 4 shows a further embodiment of the invention.

Between a rigid inner sole 1 of a shoe 2 and the bottom sole 3 an air chamber 4 is formed. The volume thereof must not be affected by foot motions not associated with the locomotive pattern so that the rigidity of the inner sole 1 has to be such that external pressure is prevented from varying said volume. Therefore, the bottom sole 3 has to be slightly flexible to provide the volume variations of the enclosed chamber 4 when the body weight bears on the sole. The conventional high rigidity of the heel 5 permits of making a space 6 therein for accommodating the micro-switch 7. The control-pin 8 of the micro-switch 7 is connected with a diaphragm 9, one side of which is in contact with the air chamber 4 through the air channel 10 extending in a recess of the double sole. The channel may be formed by a thin rubber hose. The air chamber 4 may be formed by an envelope of plastic material arranged in the space between the two soles.

When the foot is in contact with the ground, the bottom sole 3 bending under the weight of the body compresses the air in the chamber 4 and the diaphragm 9 responds to the propagation of this pressure so that the micro-switch 7 interrupts the activation current. When the foot is lifted, the air-chamber 4 resumes its initial shape so that the micro-switch 7 switches on the activation current for stimulating the subsequent displacement of the foot.

Of the parts of the apparatus shown in FIG. 2, the transistorized pulse generator 11 is carried in the pocket of the jacket or in a shoulder bag or preferably fastened by a belt to the hip. Connecting wires 12 for the switch may be passed along the leg 13 and an active electrode 14 and a counter-electrode 15 are connected by conductors 16 to the output of the pulse generator 11. By means of adhesive plaster or other suitable fastening means the electrodes 14 and 15 are stuck to places on the leg most suitable for a most effective muscular stimulation by the activation currents.

It is not necessary to arrange the control-means of the stimulator beneath the foot of the leg to be activated. The activation currents may also be controlled by air pressure means placed beneath the foot of the sound leg, as shown in FIG. 4 if the stimulator is provided with means with the aid of which the rhythmical production of the activation pulses is adjustable with respect to opening and closing of the switch in a manner such that the functional stimulation is brought about by the rhythmical motions of the sound leg.

What is claimed is:

1. An electro-therapeutic apparatus for electrically stimulating the muscular or nervous tissues in a leg which has inadequate neurological control to obtain normal locomotion comprising, means for generating activation currents that are switched on and off by the change-over of the body weight from one foot to the other, an electric switch connected to said current generating means, an air-filled chamber having a flexible wall and adapted to be located beneath the foot-sole at the point where the ball of the foot is in contact with the sole of a shoe, pneumatic coupling means coupling the air chamber to the switch for providing pneumatic actuation of the electric switch in response to the increase and decrease in pressure produced by the displacement of the body weight on the ball of the foot during walking, a pair of electrodes adapted to be placed in contact with the leg muscles to be stimulated, and means connecting said electrodes to the output of said current generating means.

2. An apparatus as claimed in claim 1 further comprising a movable partition member mechanically coupled to the switch and to said pneumatic coupling means so that displacement of the partition member due to air pressure variations in the air-filled chamber will open or close the contacts of said electric switch, and wherein the air-filled chamber is adapted to be included in the sole of the shoe.

3. An apparatus as claimed in claim 2 further comprising a shoe with a recess in the heel and wherein the switch comprises a micro-switch, said microswitch with the movable partition member being arranged in said recess in the heel of the shoe, and said pneumatic coupling means includes an air channel in the sole of said shoe for establishing pneumatic communication between the air chamber in the shoe sole and the movable partition member in the heel recess.

4. Apparatus as claimed in claim 2 wherein said pneumatic coupling means includes a thin flexible hose and said partition member comprises a flexible diaphragm one side of which communicates with the air chamber via said thin flexible hose, and wherein said

air chamber includes an envelope of plastic material adapted to be located in a recess provided in the shoe.

5. An apparatus as claimed in claim 1 wherein the air chamber comprises two layers of flexible material forming together a separate sole with said air chamber therebetween and adapted to be located inside the shoe in the area where the ball of the foot contacts the shoe.

6. An apparatus as claimed in claim 5 further comprising a movable partition member mechanically coupled to the switch and said pneumatic coupling means includes a flexible hollow tube, and characterized in that for pneumatic actuation of the switch the air chamber communicates with the movable partition member by means of said flexible hollow tube so that the displacements of the movable partition member open and close the contacts of the switch.

7. An apparatus as claimed in claim 1 wherein the air-filled chamber is adapted to be located beneath the ball of the foot of the normal leg so that the electric switch is actuated in response to the change in pressure produced by the displacement of the body weight on the ball of the foot of the normal leg.

8. A therapeutic apparatus for electrically stimulating the nerve tissues controlling the muscles in a leg having inadequate neurological control in order to obtain a normal walking pattern comprising, means for generating activation current pulses, an air-filled chamber having a flexible wall and adapted to be located beneath the ball of the foot of the sound leg, pneumatic coupling means coupling the air chamber to the pulse generating means for periodically actuating said pulse generating means in response to the change in pressure in the air chamber produced by the displacement of the body weight on the ball of the sound foot during walking, a pair of electrodes adapted to be placed over said nerve tissues on the defective leg, and means connecting said electrodes to the output of said pulse generating means.

9. Apparatus as claimed in claim 8 wherein the air chamber comprises a separate shoe sole including at least one layer of flexible material, said separate shoe sole being adapted to be located within a shoe in the area where the ball of the foot normally contacts the shoe, and wherein said pneumatic coupling means comprises a thin flexible tube coupling the air chamber to the pulse generating means.

10. Apparatus as claimed in claim 8 wherein said pulse generating means further comprises a micro-switch actuated by the pneumatic coupling means.

11. A method of electrically stimulating the muscles of a human leg under abnormal neurological control in order to produce a normal walking pattern comprising, attaching electrode means to a part of the abnormal leg to be stimulated, connecting a source of electric energy to the electrode means, placing an air-filled chamber under the ball part of the foot of the normal leg, and pneumatically coupling the air chamber to an electric switch connected to said energy source in a manner to provide pneumatic actuation of the switch and hence the energy source in response to the change in pressure produced by the displacement of the body weight on the ball of the normal foot during walking.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,881,496 Dated May 6, 1975

Inventor(s) Jakob Vredendregt et al. Page 1 of 3

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Sheets 1 and 2 of the drawing should appear as shown on the attached sheets.

Signed and Sealed this  
Tenth Day of August 1976

[SEAL]

*Attest:*

**RUTH C. MASON**  
*Attesting Officer*

**C. MARSHALL DANN**  
*Commissioner of Patents and Trademarks*

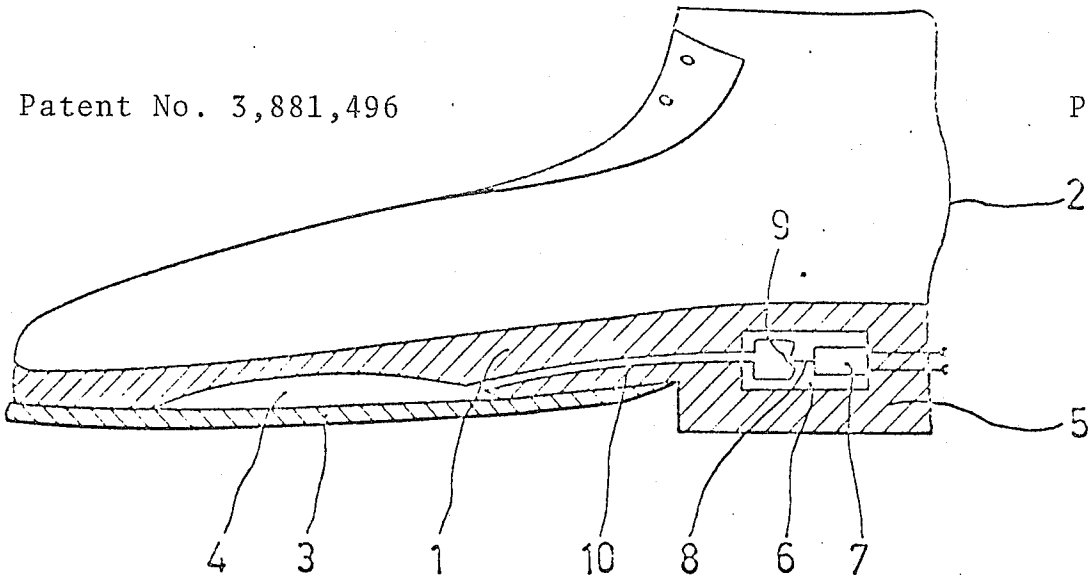


FIG. 1

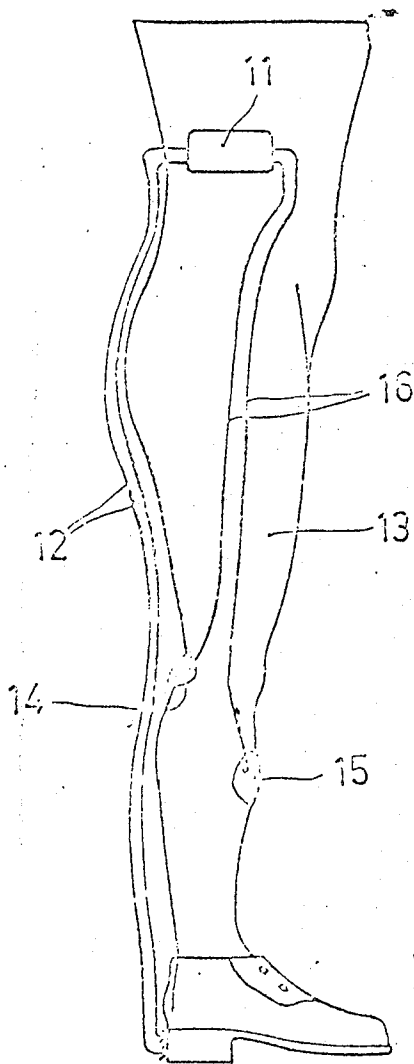


FIG. 2

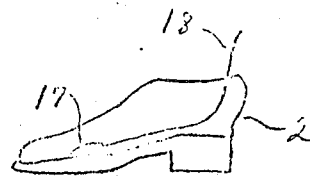


FIG. 3

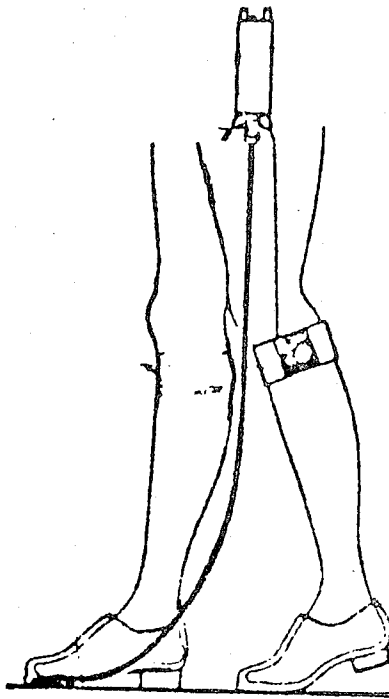


FIG. 4

UNITED STATES PATENT AND TRADEMARK OFFICE  
CERTIFICATE OF CORRECTION

PATENT NO. : 3,881,496  
DATED : May 6, 1975  
INVENTOR(S) : JAKOB VREDENBREGT ET AL

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

ON THE TITLE PAGE

Below "Appln.No.: 115,786" insert --

Foreign Application Priority Data

December 22, 1967 Netherlands 6717637 --;

Signed and Sealed this

ninth Day of December 1975

[SEAL]

*Attest:*

RUTH C. MASON  
*Attesting Officer*

C. MARSHALL DANN  
*Commissioner of Patents and Trademarks*