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(54) **Continuous passive motion device for treatment of the knee joint**

(57) The invention relates to a knee rehabilitation device, comprising a foot assist that can be attached to the leg, and a motion device which moves the assist in a given direction.

The essence of the invention lies in that the leg is

supported in a heel case (1) placed on the heel, where the heel case (1) is coupled to an appropriate frame, and the device contains an actuator that moves the leg set in the heel case (1) in a vertical direction with given amplitude, and the actuator is joined to the axis of a motor (15), which is coupled to a control unit (16).

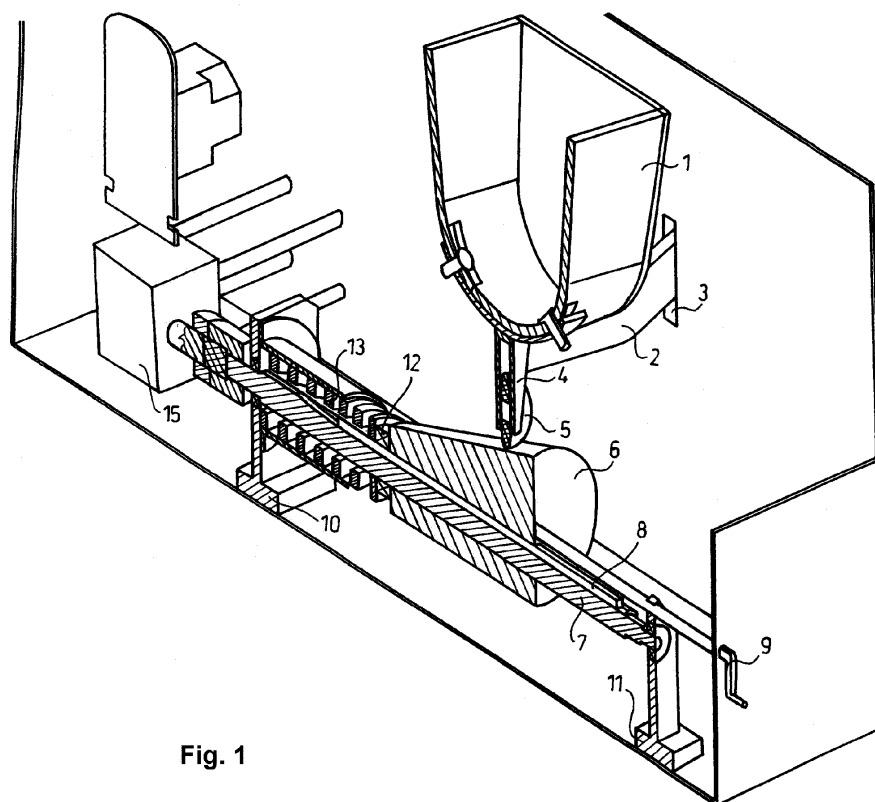


Fig. 1

Description

[0001] The present invention relates to a motion device that operates with a heel assist for exercising the knee joint by the passive extension of the knee, preferably for rehabilitation purposes.

[0002] A frequent occurrence after knee joint replacement surgery is flexion contracture, meaning that knee motion is restricted. There are a number of known solutions to the treatment of the knee joint in such cases.

[0003] One of the known solutions is an exercise device for rehabilitating knees, disclosed in the patent specification US 6,010,434. The solution comprises a framework, an adjustable seat, exercise pedals and reciprocating shuttles which are mounted on supporting tracks and can be used to perform various exercises. The patent specification US 7,695,416 also features a device and method for knee joint rehabilitation. The device generally includes a frame, a lever member pivotally coupled to the frame at a first location, and an actuator pivotally coupled to the frame at a second location. The frame supports the patient in a manner that allows motion of the patient's knee joint, and the lever member bears against a portion of the patient's body below the knee joint. The actuator is also pivotally coupled to the lever member. When the device is in operation the actuator generates a translational input that rotates the lever member relative to the frame and thereby stretches the patient's knee joint in a desired direction. A further solution is described in patent JP 8196585, where the patient is in a lying position with the knee bent, the lower leg part on the supporting part of an arm, which is fixed on the leg of the patient with a jig. The leg of the patient is moved by a force applied from the first arm, bending the knee joint of the patient as well.

[0004] In general, all known solutions are based on methods in which all or part of the patient's lower leg is supported, and the knee joint is stretched by the motion of the lower leg or the whole lower limb.

[0005] The recognition of the present invention lies in that the full extension of the knee joint is performed with the use of a relatively simple device which supports the lower limb at the heel, and it is the heel part that is rhythmically vibrated in a vertical direction, with said rhythmic vibration being transmitted to the knee. The device is used to create a cyclic motion, the frequency and amplitude of which are adjustable, not only supporting the heel, but also enabling to heel to be placed in any chosen angle in a way that the motion thus created is perpendicular to the transverse axis of the knee. Therefore in the present solution the exercising of the knee is performed by holding the tarsus and thus moving the knee, without supporting the knee or the lower leg.

[0006] The invention relates to a knee rehabilitation device, comprising a foot assist that can be attached to the leg, and a motion device which moves the assist in a given direction.

[0007] The essence of the invention lies in that the leg

is supported in a heel case placed on the heel, where the case is coupled to an appropriate frame, and the device contains an actuator that moves the leg set in the heel case in a vertical direction with given amplitude, and the actuator is joined to the axis of a motor, which is coupled to a controlling unit.

[0008] One of the preferred embodiments of the actuator coupled to the heel case further comprises a swivel arm coupled to the heel case, and a roller is coupled to said arm. The roller is placed on the lateral surface of a control cone, in a way that the roller can be moved with an amplitude-adjusting threaded arm. The control cone is placed on an eccentric axle in a way that it can revolve. The axle is equipped with bearings in two bases coupled to the device, where the threaded arm is routed in one of the bases, while the control cone is supported with a support bearing and a spring on the other base.

[0009] In another preferred embodiment of the invention a rope is attached to the heel case, which is preferably attached to a pivot placed on a disk preferably through a worm drive, where the disc is coupled to a motor through a power unit, and for the adjustment of the amplitude the pivot is designed in a way so that it can be adjusted radially along the disc. The angle of the foot and the length of the heel case are preferably adjustable at the junction of the heel case and the rope.

[0010] The control unit attached to the motor preferably contains a manual actuating unit, an emergency switch and an automatic actuating unit, all of which are connected to the motor through a mode switch.

[0011] The device according to the invention will now be described in detail with reference to the accompanying drawings of the preferred embodiments, in which

Figure 1 is a perspective view of the first preferred embodiment in partial section

Figure 2 is a lateral section of the first preferred embodiment

Figures 3.a and 3.b feature/illustrate a further preferred embodiment of the invention

Figure 4 is a block diagram of the actuating controlling unit performing the motion.

[0012] The perspective view in Figure 1 is the section of a preferred embodiment of the invention. The device comprises a heel case 1, which is substantially made up of a basically U-shaped component and a sole prop which closes up the U-shaped component on one side. The sole prop 1 is coupled at a first location to a swivel arm 2 through a hole 3 to a component supporting and fixing the arm not included in the view and through a bar 4 coupled at a second location to a roller 5. The roller 5 of said heel case 1 thus equipped with a swivel arm 2 and a roller 5 is supported by the lateral surface of a control cone 6, said control cone 6 has an axle 7 placed parallel

to the control cone, and the two ends of said axle 7 are equipped with bearings, resting on two bases 10 and 11. The two bases 10 and 11, as well as the component holding and the fixing the arm are attached to the enclosure of the device. There is also a component adjusting the amplitude, which is substantially a threaded bar 9, attached to the top of one of the bases 11. One end of the threaded bar 9 rests on the base of the control cone 6, while the other end, protruding from the enclosure of the device, enables the adjustment of the amplitude of the motion by moving the control cone 6 along the axle 7, and thus the heel case 1 gets into contact with the roller 5 located on the bar 4 of the heel case 1 on the sections with varying diameters of the control cone 6. The control cone 6 is supported by an appropriate bearing 12, which is supported by the second base 10 coupled to the enclosure of the device with a spring 13. Through a coupling element 14, the axle 7 of the control cone 6 is coupled to a motor 15 that ensures its rotation, and the axle 7 is equipped with a latching component 8. The motor 15 may be operated both in manual and automatic mode, and it is also equipped with an emergency switch 22. The block diagram of the control device coupled to the motor 15 is shown in Figure 4, where the actuating component of the emergency switch 22, such as the push button, is accessible to the patient at all times, therefore the patient is able to switch off the device at any time. When the device is operated, the patient lies on a bed, and places the heel in the heel case 1. The amplitude of the vibration of the heel, i.e. its back-and-forth vertical motion depends on the position of the bar 4 on the lateral surface of the control cone 6, while its speed depends on the rotation speed of the motor 15.

[0013] Figure 2 shows the elements of Figure 1 in a lateral section, illustrating how the control cone 6 can be moved back and forth along the axle 7 with the help of the amplitude adjusting threaded bar 9, and the amplitude of the vertical vibration of the heel case 1 in which the patient's heel rests can be set in the same way.

[0014] Figures 3.a and 3.b show a further preferred embodiment of the invention in lateral view, where the lateral motion of the heel case 1 is due to a worm drive. The drive is developed in a way that the heel case 1 is coupled to a pivot 20 located on a disc 19 with a rope 18 routed over pulleys 17 through a heel case adjusting component 21, where said pivot 20 can be adjusted radially on the dial 19, and the dial 19 is coupled to the motor 15 with an appropriate transmission such as belt-transmission, and the motor 15 is connected to the control device 16. In this preferred embodiment, the amplitude of the motion of the heel depends on the radial position of the pivot 20 located on the disc 19, and the speed of the motion depends on the rotation speed of the motor 15. Therefore the foot resting on the heel case 1 is prompted to move alternately by the rope 18 routed over the pulleys 17, the angle of the lower limb and the length of the heel case 1 can be adjusted at the adjusting component 21, which is a junction, of the heel case 1, coupled to the

rope 18. The frame 27, comprising the pulley 17 and the rope 18, the dial 19 and the whole motor structure, is a structure providing a base that is strong enough and relatively wide.

[0015] In the case of both embodiments the rehabilitation of the knee joint is achieved in a way that only the patient's heel is fixed, and the motion and extension of the knee joint is achieved through the vertical motion, i.e. vibration of the heel.

[0016] Figure 4 is the block diagram of the control device 16 of the motor 15. The control device 16 contains a manual actuating unit 23, an automatic actuating unit 24, a mode switch 25 and an emergency switch 22. If appropriate, a further sensor could be connected with series circuit to either the emergency switch 22 or the automatic actuating unit 24.

[0017] In the manual actuating unit 23 the rotation speed of the motor 15 can be adjusted with an independently known rotation speed control governor, and the amplitude of the motion can be set manually while staying within the limits of vibration frequency and amplitude range.

[0018] The output of the manual actuating unit 23 is connected to the mode switch 25, a further input of which is connected to the output of the automatic actuating unit 24, while a further entry of the mode switch is routed to the output of the emergency switch 22. The block diagram shows that the emergency switch 22 can be operated and switched into both modes, and it can switch off the device.

[0019] The operation of the automatic actuating unit 24 can be achieved with computer or microcomputer control, in which case the required operations are performed by the operating software. In this mode, the frequency can be pre-set according to a pre-set function or programme, or can be even adjusted during treatment. The amplitude can also be adjusted, but only manually. In automatic mode, the connection between the device and the control device can be established with the help of Bluetooth, for example.

[0020] In summary, the motor 15 can be operated essentially in three modes. One of them is operation mode is operation of the emergency switch 22, which is accessible to the patient at all times, with the help of which the patient can switch off the motor 15 at any time. The second mode is the manual mode, wherein the system can be operated manually in a way that it is turned on manually and the rotational speed is set manually. The third mode is the automatic mode. The vibration frequency can be set preferably up to 2 1/s in a stepwise or continuous mode, while the upper limit of the vibration amplitude is preferably 30 mm.

[0021] When the device is in operation, the patient lies on a bed, and places the heel in the heel case 1, where the heel is firmly fixed by a hook-and-loop fastener.

[0022] Therefore with the help of a relatively simple device, a new form of treatment can be achieved, which, among others, has the following advantages.

- The device helps in overcoming restricted motion in a gentle, practically painless way, without requiring the active contribution of the patient. Consequently, there can be no pathological reactions or additional injuries.
- The use of the method is basically only limited by the attitude of the patient. It does not depend on working hours or the availability of a physiotherapist, ensuring faster rehabilitation.
- Apart from reducing the workload of physiotherapists, the device is also expected to reduce the length of rehabilitation and the time spent in hospital as well.

List of reference numbers

[0023]

- 1 - heel case
- 2 - swivel arm
- 3 - hole
- 4 - heel case bar
- 5 - roller
- 6 - control cone
- 7 - axis
- 8 - latching component/part
- 9 - threaded bar
- 10, 11 - base
- 12 - bearing
- 13 - spring
- 14 - coupling
- 15 - motor
- 16 - control device
- 17 - pulley
- 18 - rope
- 19-disc
- 20 - pivot (adjustable)
- 21 - heel case adjuster
- 22 - emergency switch
- 23 - manual actuating unit
- 24 - automatic actuating unit
- 25 - mode switch
- 26 - frame

2. Knee rehabilitation device according to claim 1 **characterized in that** the motion device coupled to said heel case (1) contains a swivel arm (2) coupled to said heel case (1), and said swivel arm (2) is coupled to a roller (5), and said roller (5) is placed on the lateral surface of a control cone (6) in a way that it can be moved with an amplitude adjusting threaded bar (9), the control cone (6) is placed on an eccentric axle (7) in a way that it can revolve, said axle (7) is provided with bearings in two bases (10,11) coupled to the device, where the threaded arm is guided in one of the bases (11), while the control cone (6) is supported with a supporting bearing (12) and a spring (13) on the other base (10).
3. Knee rehabilitation device according to claim 1, **characterized in that** a rope (18) is attached to the heel case (1), which is preferably attached to a pivot (20) placed on a disk (19) through a worm drive (17), where said disc (19) is coupled to a motor (15) through a power unit (19), and for the adjustment of the amplitude the pivot (20) is designed in a way so that it can be adjusted radially along the disc (19).
4. Knee rehabilitation device according to claim 3, **characterized in that** the angle of the foot and the length of the heel case (1) are adjustable at the junction of the heel case (1) and the rope (18).
5. Knee rehabilitation device according to any of claims 1-4, **characterized in that** the control unit (16) attached to the motor (15) contains a manual actuating unit (23), an emergency switch (22) and an automatic actuating unit (24), all of which are connected to the motor (15) through a mode switch (25).

Claims

1. Knee rehabilitation device comprising a foot assist to be attached to the foot and a device that moves said foot assist, **characterized in that** the foot is supported at the heel in the heel case (1), and said heel case (1) is coupled to an appropriate frame, and the device contains a structure which moves the leg vertically with given amplitude, and said structure is coupled to the axle of a motor (15), and said motor (15) is connected to a control device (16).

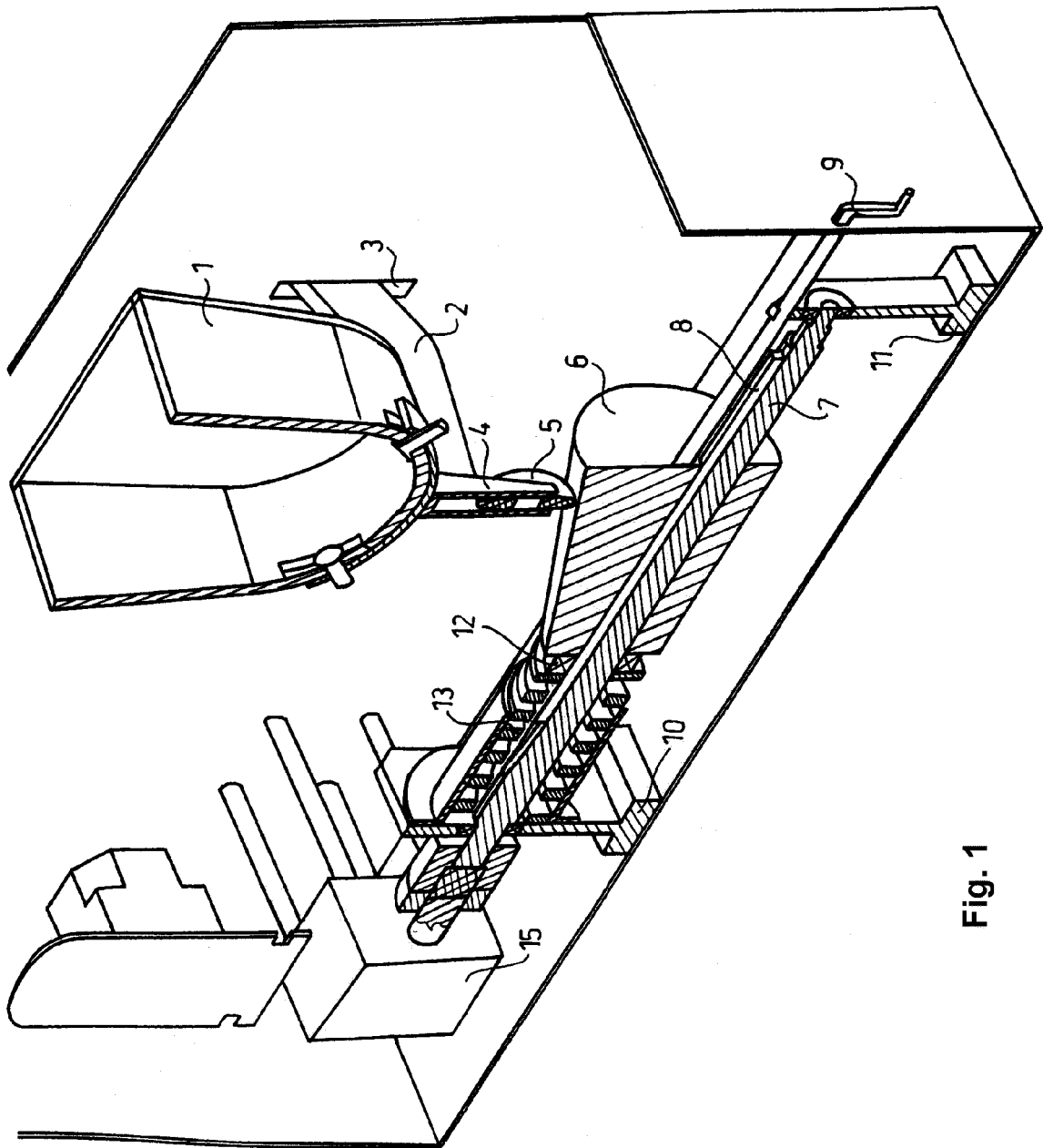


Fig. 1

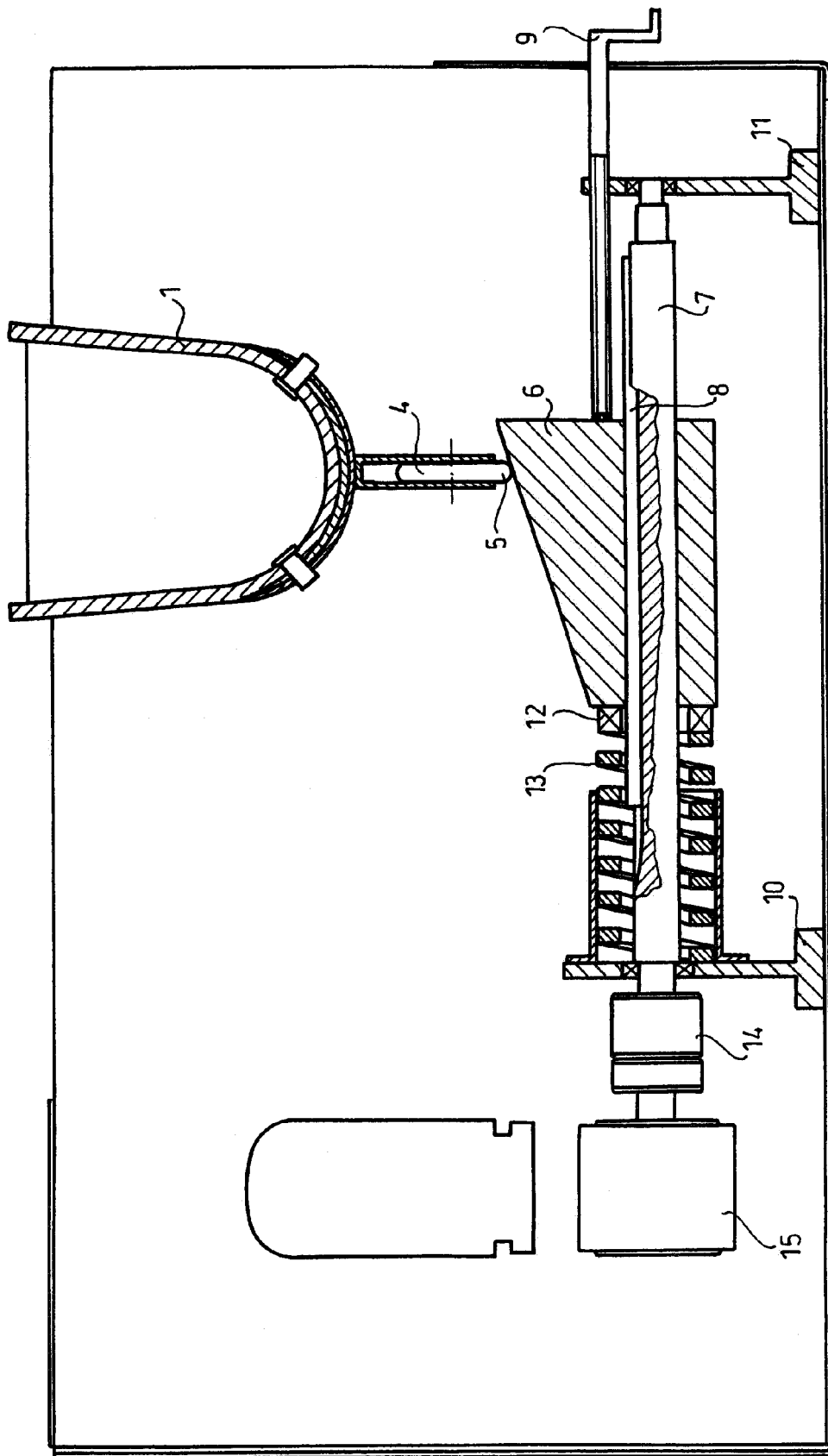


Fig. 2

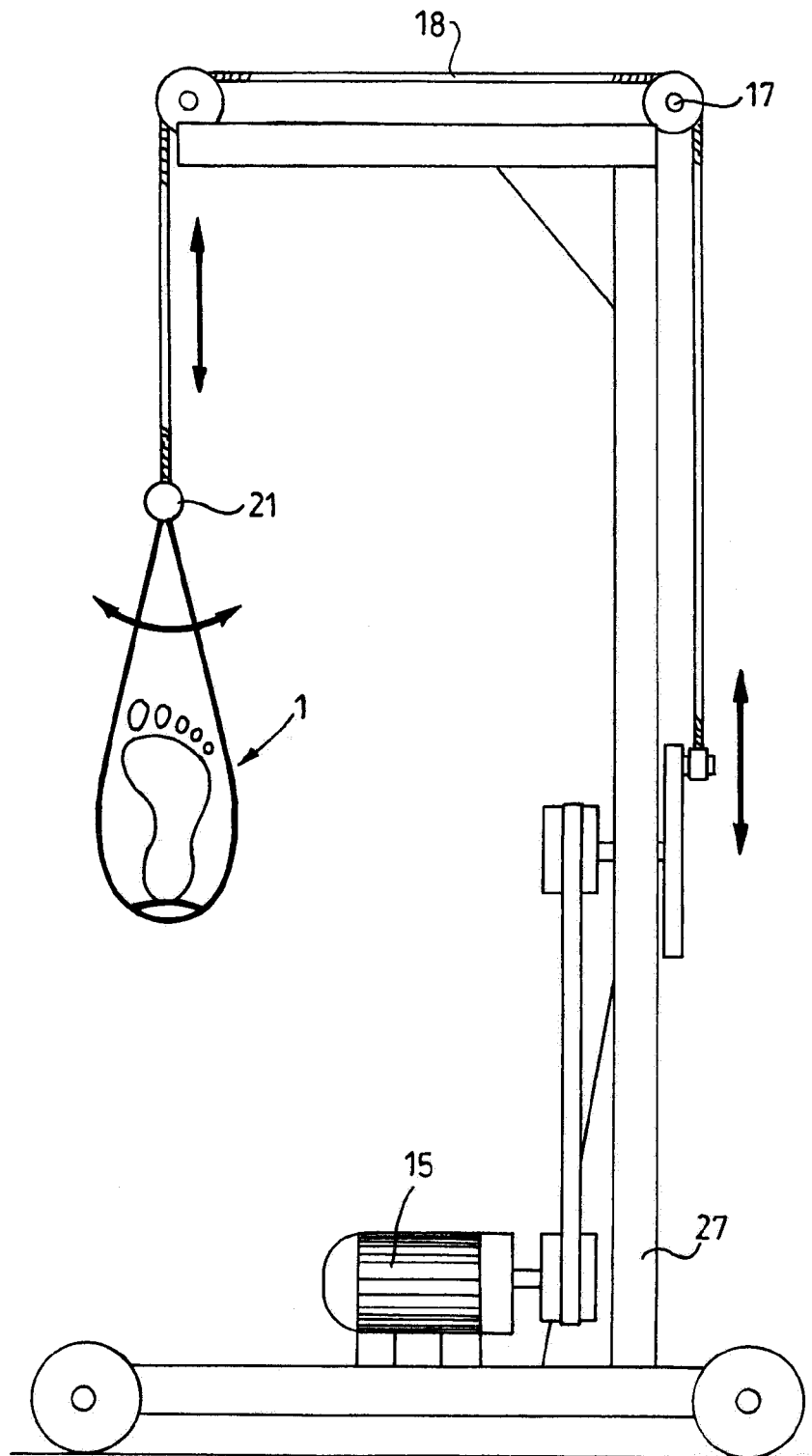


Fig. 3a

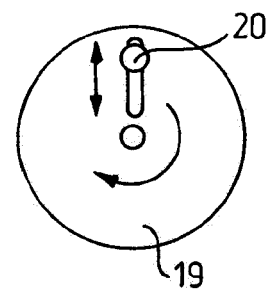


Fig. 3b

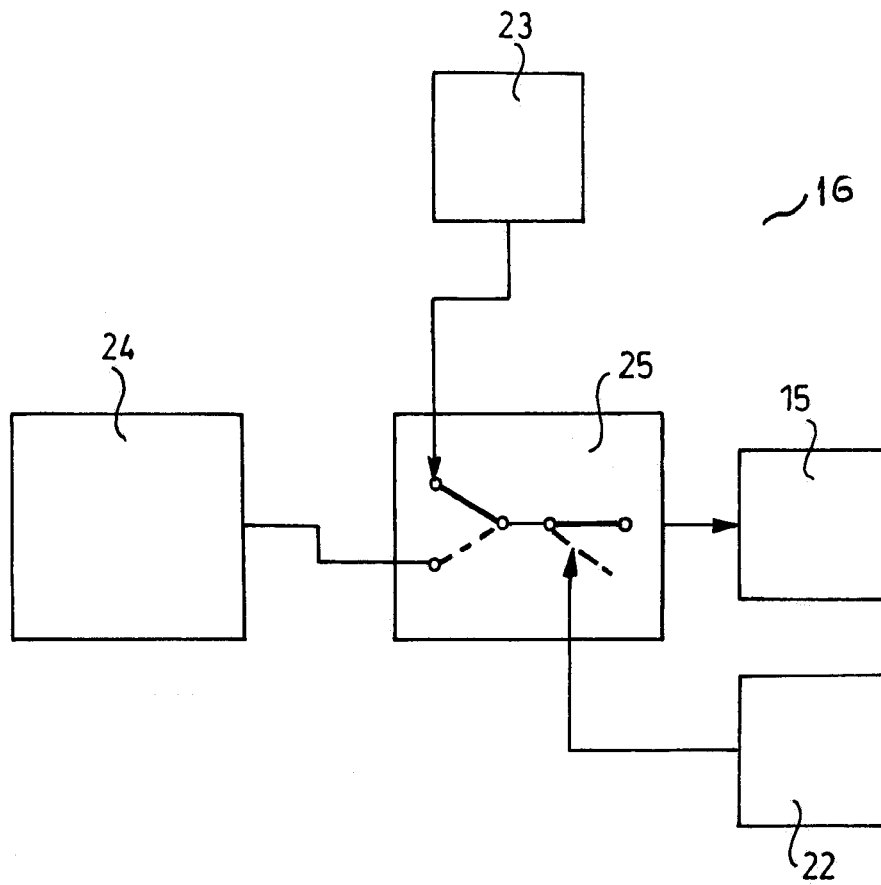


Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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