

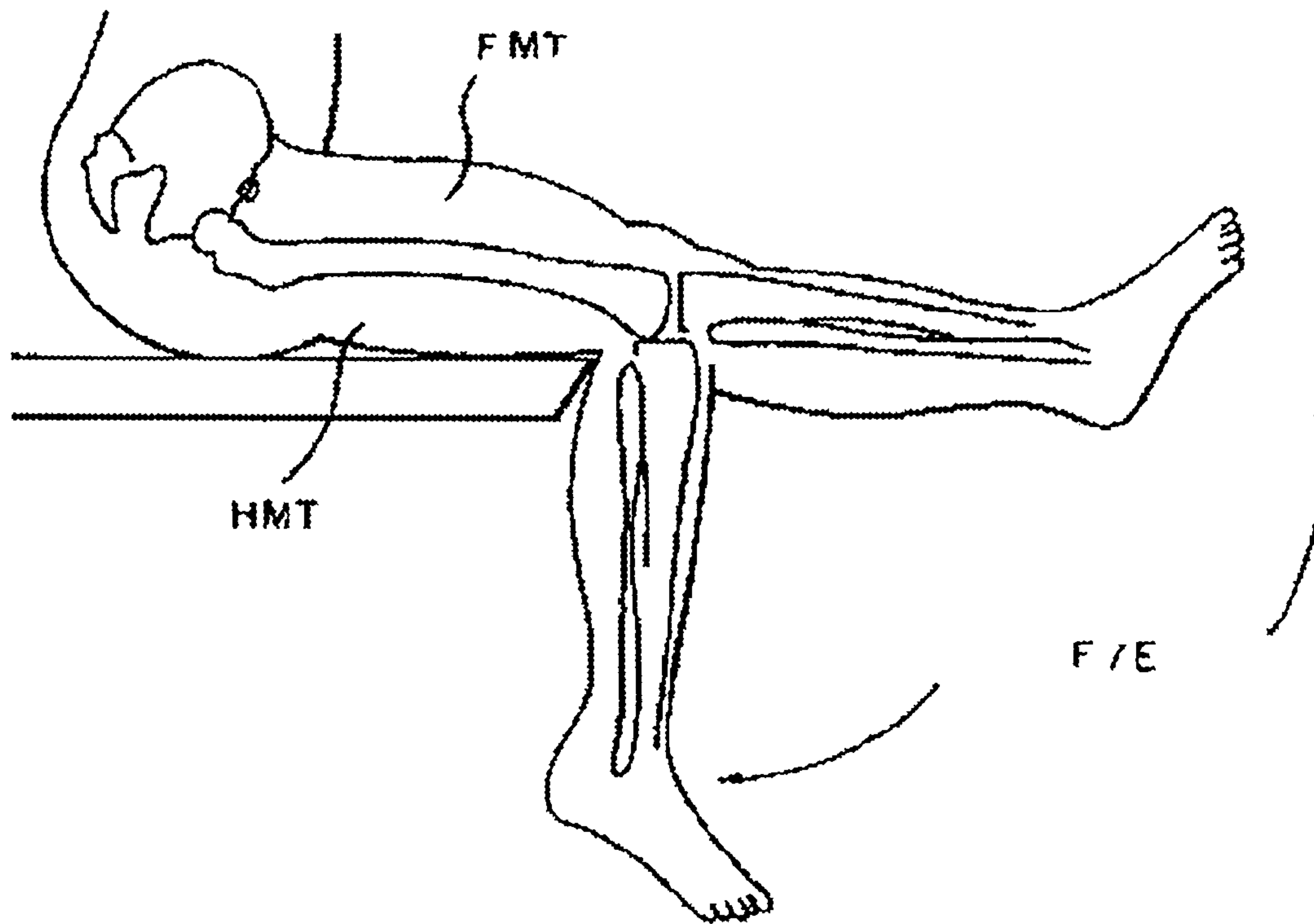


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(54) Titre : RAYON ARTICULE A ROTATION REGLABLE POUR APPAREILS DE GYMNASTIQUE ET TUTEURS POUR GENOU

(54) Title: ADJUSTABLE ROTATION RADIUS ARTICULATED JOINT FOR GYM MACHINES AND KNEE TUTORS



(57) **Abrégé/Abstract:**

An adjustable rotation radius articulated joint for a gym machine and knee tutor situated in correspondence of the knee of a user, comprising a first plate; a second plate; and a group composed of a third plate; first and second plate segments forming a fourth plate; and third and fourth plate segments forming a fifth plate. The first plate and the third plate segment each have an arm. The third plate segment and the second plate segment are fixed to the third plate. The first plate segment and the fourth plate segment are rotatably fixed to the third plate. The fourth plate segment has a first slot which continues into the third plate segment. A center pin is fixed on the first plate. The first plate has a peripheral pin slidably engaged in the first slot. An adjustment screw is engaged between the third plate segment and the fourth plate segment to personalize the joint for use on a knee of a user.

**ABSTRACT**

An adjustable rotation radius articulated joint for a gym machine and knee tutor situated in correspondence of the knee of a user, comprising a first plate; a second plate; and a group composed of a third plate; first and second plate segments forming a fourth plate; and third and fourth plate segments forming a fifth plate. The first plate and the third plate segment each have an arm. The third plate segment and the second plate segment are fixed to the third plate. The first plate segment and the fourth plate segment are rotatably fixed to the third plate. The fourth plate segment has a first slot which continues into the third plate segment. A center pin is fixed on the first plate. The first plate has a peripheral pin slidably engaged in the first slot. An adjustment screw is engaged between the third plate segment and the fourth plate segment to personalize the joint for use on a knee of a user.

- 1 -

Adjustable rotation radius articulated joint for gym machines and knee tutors.

This application is a division of copending Canadian Application Serial No.:  
5 2,252,221 filed April 11, 1997.

#### Technical Field

This invention can be profitably employed in the fields of medicine and sports as it is an indispensable component of knee tutors and of machines used to  
10 strengthen or in rehabilitation to restore the muscles of the knee to their former healthy condition.

The knee is the intermediate articulation of the lower limbs. **As shown in the figures 1-3 and 6**, the movement whereby the knee is extended (**F/E**), or rather, the movement of extending the leg from the thigh is performed by  
15 means of the quadricep muscle (**QM**), which is inserted in the foretuberosity of the tibia, a couple of centimeters below the knee. The movement of bending the knee, that is to say the movement of flexing (**F/E**) the leg from the thigh is performed by means of the hind muscles of the thigh (**HMT**), as illustrated in figure 1. The flexion-extension movement is always executed at the fore-hind  
20 plane.

The articular surfaces that come into contact in the knee are the femoral condyles (**FC**) (the distal, i.e. farther, part of the femur), and the tibia plate (**TP**) (the proximal, i.e. closer, part of the tibia), as illustrated in figure 2. The femoral condyles consist in round surfaces with a bending radius which is rather narrow  
25 but which varies; indeed their profile is very similar to a spiral. The tibia plate, or rather the glenoid cavity of the tibia, has a much wider bending radius than the femoral condyles.

The articular mechanics of the knee is therefore complex, and the type of movement that is made is in direct relation to the angle at which the knee is  
30 open. Let us consider an extended leg to be the starting point at a 0 angle. In the first 20°-25° of the bend (i.e.: the angle of ordinary walking) the articulation's mechanics entail a sheer rotation between the two articular surfaces: each point of the femoral condyles is in contact with a corresponding point on the tibia plate. If the flexing continues, in the subsequent 110°-115°, approximately, there is a combined sliding and

- 2 -

rotating movement of the tibia with reference to the femur. As the leg flexes further the sliding movement gradually progresses and eventually prevails over the rotation and a sheer sliding movement occurs: the femoral condyles slide without rotating on the tibia plate. The knee's ligaments (KL) limit the articular caps during these sliding movements and ensure the knee's fore-hind stability, enabling the execution of hinge movements whereby the articular surfaces remain in contact.

Thus, in the flexion-extension mechanics of the knee there is no fixed centre of rotation. When the leg is flexed starting from an extended position, in the first 20° there is a centre of rotation located 60 mm from the tibia's articular surface. However, as the bending movement continues, the point of rotation moves on and, at the same time, the radius grows narrower, until it reaches a minimum distance of approximately 12 mm from the tibia (as can be seen in figure 2).

This variation in the radius is transformed into a variation in the distance between a point located in the centre of the femoral condyle which has been identified by tests in the first 20°-25° of the flexion-extension and another point situated on the external malleolus. Indeed, by measuring this distance, experiments reveal that in extending from 135° to 0° the variation can increase from 15 to 40 mm (distance  $R_B - R_A$ ), as can be seen in figure 3. The extent of the variation depends on the conformation of the knee in question.

With reference to physiotherapeutic or rehabilitation problems, when it is necessary to support and follow the knee in its movements, one usually resorts to particular mechanical devices which are strapped to the thigh and leg by means of a system of belts (a sling) which guide the articulation in its movements.

These devices are used in knee tutors, in the machines used for passive gymnastics, and in the gym machines for specific muscle training known as

*leg curl and leg extension machines.*

These mechanical devices, which are thus bound to the limb, are hinged to an articulated joint which generally has a fixed centre of rotation and which therefore is unable to provide the combined sliding and rotating movements and change the centre of rotation, thereby producing anomalous tensions. 5 The latter are caused by the different trajectories of the articulated joint's mechanical devices (circle arc) compared to the one theoretically accomplished by the leg (spiral arc). Indeed, as previously described, the leg reduces its radius when it flexes (the above mentioned RB-RA); this causes 10 the mechanical device to rub against the leg, bringing about a friction which is passed on to the belts of the sling and results in a compressive force.

When the leg is extended, the mechanical device tends to withhold the leg along a circular path, while the leg reduces its rotation radius, and therefore tends to be drawn away from the knee. These compressive and tractive 15 forces, which are proportional to the speed of the movement and to the distance of the knee's sling, are then released on the knee caps and on the articulation's cartilage (compressive force), and on the knee's ligaments (tractive force) respectively.

The most sophisticated versions of the knee tutors currently used in sports 20 feature a complex articulated joint which does indeed try to simulate the compromise between the rotation and sliding movements that typically occur in the knee. Knee tutors featuring a double centre of rotation are rather common; however in the positions ranging between 0° and 30° and between 90° and 135° they do not conform to the knee's mechanical physiology. 25 Indeed, in the first arc (0°-30°) no single centre of rotation is identified, whereas in the second (90°-135) the sliding movement does not increase to the point of becoming exclusive. Consequently, at these angles, the knee tutor transmits tractive and compressive forces to the articulation which are released onto the ligaments as anomalous tensions.

30 Attempts to solve this problem have been described in the European Patent

- 4 -

Publication No. EP 0 361 405, in the International Patent Publication No. WO 92/15264, and in the International Patent Publication No. WO 84/03433.

The knee joint described in the European Patent Application No. EP 0 361 405 is based on the physiological concept whereby the flexing of the knee  
5 consists in the fore movement of the femoral condyles with reference to the tibia condyles, followed by a sheer rotation between the condyles of the above mentioned bones. This joint features three plates, of which the two outer ones feature coaxial holes, while the inner one features two openings where a pair of pins that fit through the above mentioned holes in the outer plates are  
10 lodged and guided. One of the openings is small and extends transversally across the longitudinal axis of the tibia and femur, while the other opening is large and is shaped like a circular segment with one end growing wider towards the top.

The first opening, is linear and has the function of reproducing the first fore  
15 movement of the femur with reference to the tibia, while the second opening serves the purpose of guiding the subsequent rotation movement.

The upper end of the circular opening is placed on the extension of the longitudinal axis of the arm of the central plate which passes through the centre of the pin lodged in the linear opening, precisely when the pin is  
20 halfway through the stroke performed by the pin inside this opening. The centre of the circular segment that constitutes the circular opening consists in the centre of the pin lodged in the linear opening when the pin itself is at the end of the said opening, which is the one farthest from the circular opening.

When the leg flexes, in the first 25° the pin lodged in the circular opening  
25 compels the pin in the linear opening to move from its starting position (closer to the circular opening) to its final position (at the end of the linear opening that lies farthest from the circular opening).

- 5 -

As the distance between the centres of the pins is equal to the radius of the circular opening, in this first part of the movement performed by the pin lodged in the linear opening, the pin lodged in the circular opening performs a small vertical movement within and outside the widened part that constitutes  
5 the upper part of the circular opening. In this first phase of the flexing movement the two outer plates slide forward with respect to the inner plate (traction or pulling apart phase of the two plates).

Subsequently the two outer plates rotate onto the inner one as the pin at the end of stroke position in the linear opening acts as a fulcrum and compels the  
10 pin lodged in the circular opening to move (sheer rolling phase).

The joint described in the International Patent Publication No. WO 92/15264 features an improvement of the afore described European Patent Publication EP 0 361 405. As in the previous case, at first there is a horizontal translation of the pin lodged in the linear opening for an angle  $\alpha_1$  of approximately 25°-  
15 35° of the flexing movement, with the leg outstretched in the starting position. As a result, the tibia is made to slide back with reference to the femur. In this joint too in the first phase of the flexing movement the pin lodged in the circular opening moves up and down by a Y quantity at the upper end of the circular opening when the pin lodged in the linear opening passes through the  
20 latter.

This first phase of the movement is followed by a second phase for an angle  $\alpha_2$  which goes as far as 120°-135° of the flexing movement. This second phase is characterised by an essentially single-centred movement: the pin, which at the end of the stroke is positioned in the linear opening acts  
25 as a fulcrum and compels the pin lodged in the circular opening to translate inside the latter.

Compared to the European Patent Publication EP 0 361 405, the improvement of the present joint consists in the attempt to modify the shape and/or the position of the openings whenever the conditions of a given patient

should make this advisable.

The bend of the circular groove which extends beyond 35° of the flexing movement is thus made flatter and the linear groove is extended slightly towards the distal (i.e. farther) end from the circular groove. In the first phase  
5 of the flexing movement (from 0° to 25°, angle  $\alpha_1$ ), the pin lodged in the linear groove moves distally, as a result of which the tibia is made to slide behind the femur in this first phase. Subsequently, from 25° to 35° of the flexing movement (angle  $\alpha_2$ ) the latter pin stays still and thus will constitute the fulcrum around which the pin inside the circular groove will rotate.

10 Lastly, from 90° to approximately 135° of the flexing movement (angle  $\alpha_3$ ), the pin in the linear groove will be forced to draw closer to the circular one when the other pin moves downwards in the flattened part of the circular groove, thereby producing a multi-centred movement in which the tibia moves in front of the femur.

15 Even without engaging in a controversy with the inventor of the aforementioned Patents with reference to his conceptual hypothesis on the physiological movement of the knee, it must be said that although his patents have attempted to tackle these kinds of problems they have not hit the mark. The basic model of the joint he has invented is based on the initial  
20 movement of the pin lodged in the linear groove in all its length and simultaneously on the upward and downward movement (Y) of the other pin. Indeed, in its basic model the joint features two centres - one that performs a rotation whose median axis runs vertically, and the other whose median axis runs horizontally. The first phase of the movement between the plates  
25 occurs around the pin lodged in the circular groove (in this phase, in order to move, the plates are subjected to a traction and are drawn apart from one another).

On the other hand, the second phase of the flexing movement (between 25° and 135°), features the rotation of the pin that is lodged in the circular  
30 groove with the other pin as its fulcrum. In this phase the pin snaps over the

- 7 -

By applying this mechanical principle inside the knee, one might suppose that the latter functions with a series of jerks. This is far from true, as the movement that occurs between the articular caps features no jerks at all and is mostly a rotation movement onto which a sliding movement progressively  
5 prevails.

The movement performed by the plates is not continuous. The personalisation of the curve for each individual patient is therefore absolutely uncertain.

The knee tutor joint described in the International Patent Publication No. WO  
10 84/03433 consists of 5 plates. The two outer ones, connected to the supporting elements of the lower leg, each feature a hole and a linear opening. The two intermediate plates also feature a hole and a linear opening each, but in the opposite position compared to the holes and openings of the outer plates.

15 The central plate, which is connected to the supporting elements of the upper leg, features a central hole and a bending opening which extends completely within the plate itself and which simulates the crosswise course of a flexing point on a given patient's knee.

The plates are locked onto one another and they can each pivot around one  
20 another and around the central shaft. This shaft extends through the linear openings in the outer plates and the central holes of the intermediate and central plates.

A pin passes through the peripheral holes of the two outer plates, the linear  
25 openings in the intermediate plates and the bending opening of the central plate.

The central shaft and the pin lock the plates onto one another in such a way

- 8 -

that the restricted movement of the pin inside the bending groove limits the movements of the supporting elements of the lower leg with respect to those of the upper leg: hence, the flexing and extension of the patient's lower leg is limited.

5 The bending groove lodges some flexible pistons, which act as springs. These can move and are fastened to the ends of the grooves in order to limit the movement of the pin and, consequently, the width of the flexing movement. These flexible pistons are locked by two threaded bolts next to each of which lies an indicator that moves longitudinally to the pistons  
10 themselves. The function of the indicators is to indicate the degrees of movement allowed in the flexing and extension movements: from 0° to 140°. If one postulates that the central plate stays still, in this joint the intermediate plates rotate and move with respect to the central one. The outer plates rotate along with the intermediate ones but they move to the side of the  
15 latter plates along the axis in the direction of the linear grooves in the intermediate and outer plates. In this system the outer plates move (rotate and slide) with respect to the central plate.

The central shaft and the pin that passes through the peripheral holes of the outer plates also change distance in accordance with the angle of the joint in  
20 the flexing movement and in accordance with the bending groove, located on the central plate, which simulates the crosswise course of a flexing point on a given patient's knee.

However, there is no prior identification of the centre of the knee; this centre ought to be aligned with the central shaft. Furthermore, the possibility of  
25 personalising the bending groove is not described other than by referring to the extreme limits imposed on the movements.

In the machines currently used for passive gymnastics,

- 9 -

the hinge rotates around a fixed centre and cannot accompany the flex/extension movement with a physiological trajectory. Hence, anomalous tractive and compressive tensions are formed and released onto the ligaments.

5 Weight-lifting machines are used to strengthen groups of muscles in a voluntary way. As previously mentioned, the machines currently used for the muscles in the knee are the *leg curl* and *leg extension* machines. The former selectively strengthens the knee's flexor muscles, while the latter focuses on the extensor muscles.

10 A *leg extension* machine is very similar to a rather high chair. When seated upon it the feet cannot touch the ground and the thighs are bound to the seat by means of straps or other constraints. A mobile load arm L (figure 6) is located in the centre of the seat (see figure 4), or beside it (see figure 5), and runs vertically, along the longitudinal axis of the leg, rotating around a  
15 fixed centre C, which constitutes the fulcrum of the entire system. Its rotation axis "c" ought to correspond to the horizontal axis which passes through the femoral condyles (which is believed to be the centre of the knee).

An M-shaped horizontal rod is attached to the distal (farther) part of this mobile arm L, and the distal part of the leg exerts pressure on this very rod.  
20 The leg's extension from the thigh, which makes the arm L rotate around axis "c" is withstood by the resistance of weight P, featured by the machine. This weight P can be connected by means of a transmission system (ropes and pulleys) to mobile load arm L itself (as can be seen in figure 3), or to a rotation mechanism (figure 5). In the latter case, a driving shaft N (with a  
25 rotation axis that coincides with the aforementioned "c" axis) connects the mobile arm L to the articulated joint.

When the lower part of the leg stretches, with the thigh bound to the machine's seat and the lower part of the leg free to move, mechanical shear and bending stresses are exerted.

30 When the flex/extension movement of the lower part of the leg occurs, a

- 10 -

number of rebound phenomena take place which are proportional to the load (weight P) and to the velocity with which the load itself is lifted.

In order to avoid exerting these stresses, especially in patients who have just undergone surgery in the crossed ligaments, the lower part of the leg  
5 should also be bound in several points by some sort of sling (see figure 7), so as to make it as integral as possible to mobile load arm L. The latter, which is hinged to the frame of the weight-lifting machine, releases rebound phenomena on the central rotation pin, thereby sparing the crossed ligaments.

10 The major flaw in the machines currently on the market lies in the fact that the leg sling (figure 7) cannot be made to rotate around a fixed centre because the knee, as previously stated, has no single centre of rotation and therefore cannot, as it moves, run along a circular path, but rather must perform a spiralling movement towards the centre. Hence, if the limb is fixed  
15 to mobile arm L of the machine, it exerts its rotating movement onto the leg, tugging it as it flexes (when the leg gradually reduces the radius of its trajectory, and, vice versa, compressing it as it stretches, thereby creating anomalous tensions which are released on the crossed ligaments, the knee caps and the articular cartilage.

20 In this specific sector some devices are known to exist that are capable of reducing the tensile stresses exerted on the leg. The one described in US Patent No. 5,020,797 is aimed at allowing a leg injured in the knee to exercise, by applying a resistance force onto the leg. The leg can be extended against this resistance in a given direction, at the same time it is  
25 able to prevent a sub-dislocation in another direction close to the abovementioned knee.

This device includes a fastening device connected to a mobile arm which, in turn, is connected to an exercise machine, two shafts, each with its own fulcrum, connected to the aforementioned device, a sling connected to the  
30 fastening device to perform a pivoting movement around the first shaft, and

- 11 -

another sling that is also connected to the fastening device for pivoting around the second shaft and a lever mechanism.

The latter features an upper arm connected to the first sling, a lower arm connected to the second sling, and a lever coupling in proximity to the adjacent ends of the above mentioned arms used to pivot.

The first sling is connected to a protruding part of the upper arm of the lever. One must first apply a supporting force in one direction next to one end of the above mentioned first bone, as this first end is close to the above mentioned articulation. The second sling is connected to a protruding part of the lower arm of the lever. This is where a second resistance force is to be applied in another direction close to another end of the above mentioned first bone.

This device serves the purpose of avoiding a sub-dislocation through means that are applied next to the lower part of the leg. It is entirely unrelated to leg tractions having the knee as the fulcrum.

Indeed, this patent enables the tibia to advance "properly" in the extension movement which turns out to have been "proper" only when the starting position is "improper", that is to say if the centre of the knee is set back (but not excessively so) with reference to the centre of the machine. Should the centre of the knee be casually placed (indeed, no description of how to identify it is available) and therefore be aligned to the centre of the machine or advanced, the above mentioned system brings about the advancement of the tibia and exerts a stress on the fore crossed ligament.

Another device known to exist is described in the published French Model No. FR 2.550.708, which allows the reduction of the pressure in the knee's joint when exercising the quadriceps muscles. This device features an arm endowed with weights pivoted onto a joint, a horizontal shaft that passes through the joint itself and a load arm.

Special slings keep the patient still on a chair so that one thigh is fastened. The rod of the load arm is replaced by a special

- 12 -

fastening shoe which features fastening strips whereby the patient's foot is locked to the shoe itself. The latter is locked onto a staff which is connected to the free end of an arm that constitutes a part of a three-arm lever that can rotate around the shaft.

5 One of the three arms consists in an indicator that indicates on an angular scale the traction or rotation movement of the foot. The said scale is rigidly borne by a sleeve, which can be moved to the resistance arm in an arbitrary position by means of a screw. An elastic component is mounted on a pin which in turn is rigidly fixed to the said sleeve.

10 When the patient is exercising the quadriceps muscle and extends the leg, and makes the foot rotate upward the immobilising shoe is pulled upward and toward the left. This exerts a tensile stress on the foot of the patient. This traction or rotation movement brings about a compression of the elastic component. The width of the compression, which depends on the upward  
15 movement of the shoe, is indicated in the angular scale of the abovementioned indicator.

Hence, a traction occurs in the longitudinal direction of the lower part of the leg. Thus the pressure in the articulation of the knee diminishes and no pain is felt in the knee when taking exercise. The traction is brought about  
20 automatically when the patient extends the leg or moves the lower part of it around the articulation of the knee. The width and the variation of this traction depend both from the characteristics of the elastic component and from the distance between, on the one hand, the trajectory of a point that coincides with the fastening elements of the lower part in the patient's leg  
25 rotating around the articulation of the knee, and, on the other, the trajectory of a point that coincides with the immobilising shoe rotating around the axis of the same joint (that is to say, the distance of the position of the rotation axis of the resistance arm with reference to the position of the articulation of the knee).

30 By placing the rotation axis of the resistance arm of this training device

- 13-

forward and above the articulation of the knee, it is possible to vary the traction curve in such a way that the maximum traction is achieved for a pre-established position (angular) in the movement between the position wherein the knee is completely bent ( $90^\circ$ ) and the one wherein it is  
5 completely extended ( $0^\circ$ ).

By placing the two axes eccentrically in a given position with reference to one another the traction force can be made to increase gradually with the pressure in the articulation.

This device constitutes an attempt to solve the problems related to moving  
10 the knee by using a lever mechanism which is applied to the patient's foot. It rightly assumes that the alignment between the rotation axis of the device's resistance arm and the rotation axis of the articulation of the knee is essential, but instead of acting on the knee itself it tries to increase the tensile stress on the articulation.

15 This last patent brings about a traction of the leg with respect to the thigh during the flex-extension. This occurs in order to counterbalance the cohesive stresses caused by the quadriceps muscle which can contract painfully. The modulation of this tension occurs by placing the centre of the knee in correspondence with the centre of the machine. Hence a system for  
20 the exact identification of the centre of the knee is required.

The problem then consists in accompanying the knee while it moves without allowing other mechanical stresses to interfere in its movement. In this case, once again, we have no personalisation of the trajectory even though each subject has its own flex-extension trajectory.

25 In conclusion to all of the above it can be said that each one of the examined patents has made an attempt to find a solution to a given atypical problem observed in the flex-extension mechanics of the knee.

None of the inventors has thus addressed the issue by making considerations which could connect all these phenomena and identify a  
30 common denominator. This very common denominator can be found in the

- 14 -

definition of an efficient methodology for the assessment of the articulation which must, at first, envisage the identification of an anthropometric point of reference, and subsequently its alignment with a measuring device. This point must always be found in as much as it is essential not just for a correct  
5 assessment but also to align properly any device to be connected to the knee itself (knee tutor, passive gymnastics machines, weight-lifting machines).

Furthermore, the definition of an efficient methodology enables the correct identification of the trajectory made by the knee in the flex-extension, a  
10 trajectory which must surely be accompanied by a drawing of the articular surfaces of the tibia and femur and the succession whereby the rotation and sliding movements are combined.

The above considerations hold true with reference to an average knee. However, the length of the crossed ligaments, their proportions and their  
15 point of insertion (features which characterise articular surfaces), differ considerably from one individual to the next. This means that the spiralling movement made by the knee differs in every individual. In order to examine the actual articular profile of a given knee it is therefore necessary to take X-rays or to measure the distance between the knee and the malleolus of the  
20 individual.

#### **Disclosure of Invention**

**A feature of this invention is to provide users with an articulated joint**

- 15 -

endowed with a mobile arm L that is capable of guiding the flex/extension movements of the leg along a trajectory which may reproduce as naturally and faithfully as possible the movement that is made performed by the knee's articular surfaces: sheer rotation, sliding-rotation and sheer sliding.

5 **Another aim is that of creating a device that can easily be modified, so that it** may be adapted to the anthropometric characteristics of each subject.

These and other objectives are indeed achieved by this invention, which consists in an articulated joint with a variable and controllable rotation radius to be installed in weight-lifting machines (*leg extension* and *leg curl*), on  
10 machines for the passive gymnastics of the lower limbs, and on knee tutors (knee guides).

In its simplest version, this articulated joint consists of two mechanical components, A and B, preferably shaped as round plates.

These two plates A and B can move freely upon one another when neither is  
15 locked to a fixed structure. Alternatively, plate A can be fastened to a fixed structure by means of a fastener (with plate B rotating upon itself), or plate B can be locked to a fixed structure (in which case plate A will rotate upon itself).

When both plates A and B are unlocked the articulated joint may be used in  
20 knee tutors and in passive gymnastics machines, where the thigh and leg move simultaneously; while when either one of the plates is locked the articulated joint is recommended in the *leg extension* and *leg curl* machines, where the thigh is bound to the seat of the machine and the flex/extension movement can only be performed by the leg.

25 The choice of locking either plate A or B to the machine is made according to the type of transmission used for the resistance (weight P) of the machine, which can be attached either to the mobile load arm or directly to the pin of the articulated joint itself. Hence, two cases may occur: an articulated joint with two plates and with the load on mobile arm L, or an  
30 articulated joint with the load on the pin of the joint itself.

- 16 -

If the resistance is attached directly onto the mobile load arm of the machine, plate A will be locked by means of a fastener, such as a bar on the *leg extension* and *leg curl* machines. Plate B is then free to rotate onto plate A with reference to a horizontal axis "c" which must correspond to the axis of  
5 the femoral condyles of the subject when seated.

Plate B features two openings at a right angle to the rotation surfaces of the plates. The first opening is located in the centre and develops lengthwise; it is rectangular in shape and the shorter sides should preferably be rounded; this opening is made by extending an ideal hole and constitutes the axis of  
10 symmetry of mobile load arm L featured by plate B.

The ends of the second opening, located peripherally, should preferably be rounded. The centre of one of the ends of this second opening is located on a point located at a distance "l" from the centre of the aforementioned ideal hole, and lying on radius "b", at a right angle to radius "a" and on the same  
15 plane. The centre of the other end of the second opening is located at 130-140° with reference to radius "b".

The second opening had specific shape: initially, for the first 15-45° with reference to the aforementioned radius "b", it is a circumference whose centre coincides with that of an ideal central hole and whose radius is equal to "l";  
20 subsequently, for the remaining 85-125°, it is a spiral which returns towards the centre of the ideal hole. The sequence of points forming the longitudinal axis of this spiral is derived from the sequence of points of one end of a section of length "l", whose other end moves along the longitudinal axis of the first opening.

25 Alternatively, the above mentioned peripheral opening can also consist in a groove having a similar shape, with its cavity facing the rotation surface of plate A.

The latter features two pins whose longitudinal axis is at a right angle to the rotation surfaces of plates A and B. These pins are located at a distance  
30 equal to "l". The first pin is situated in the central part of plate A and is

- 17 -

housed in the opening at the centre of plate B; the second pin is placed in the peripheral opening of plate B itself.

The pins are cross-through pins and feature, at the distal (i.e. farther) end, a constraint which prevents the two plates from separating. Should the second opening (peripheral) be replaced by a groove, the second pin will not be cross-through and will feature no constraint on its distal end.

Actually, the plate endowed with pins can either be the one locked to the weight-lifting machine (A) or the one that is free to rotate on the former (B). Furthermore, it is possible for each plate A, B to be endowed with a single opening and a single pin, provided that they alternate: one plate will feature an opening and a pin which will be lodged in the opening of the other plate.

In the articulated joint featuring two plates in which the load is attached to the pin of the joint itself, plate B is fastened to the machine, and the resistance of the machine itself (weight P) is transmitted to mobile arm L by means of a driving shaft, whose longitudinal axis is located on the extension of axis "c" of the knee; this shaft acts both as fulcrum for plate A (and for mobile arm L, which constitutes its extension), and as a propeller shaft.

Plate A, which constitutes the proximal (i.e. closer) end of mobile arm L, features the aforementioned central, rectangular opening instead of the central hole.

In the case of the articulated joint featuring two plates in which the load is attached to the pin of the joint itself, the central pin constitutes one end of the propeller shaft, which is endowed on the other end with a feather key lodged in the central, rectangular opening of plate A. In order to prevent the pin/shaft from sliding out of plate A, the latter features (in proximity to the feather key) a threaded area onto which a bolt or other stoppage is screwed. The central opening which in this case is on plate A remains unchanged in its engineering, compared to the description made of plate B in the articulated joint with two plates and with the load on mobile arm L; there is an ideal "central" hole which is the main locating spot. However, the length

- 18 -

of this opening is increased vertically according to the size of the feather key, whose point of symmetry (where the transverse and longitudinal axes meet) must coincide with the ideal hole.

5 Plate B is crossed by a hole whose centre must correspond to the centre of the aforementioned ideal hole, where the central pin/propeller shaft is to be lodged and allowed to rotate freely.

The motion of the shaft does not affect plate B (which is fastened to the machine by means of a fastening bar); rather, the motion is transmitted by means of the feather key inserted in the central opening of plate A to plate A  
10 itself. The latter, in turn, will follow the previously described movement of the second opening on plate B, compelled to do so by the presence of the second pin that is fastened to plate A and lodged in the peripheral opening in plate B.

Even though suitable for an "ideal" knee, an articulated joint thus made  
15 cannot be adjusted to the anthropometric characteristics of each individual. Consequently, each knee requires a plate of its own, with a suitable peripheral opening.

In order to make the articulated joint more versatile, plate B is replaced by five plates C, D, E, F, G, preferably shaped like a disc, or like a fraction of a  
20 disc, and overlapping.

In this case too, with a multiple plate articulated joint, plate A can move independently of the group of plates C, D, E, F, G, as is the case in knee tutors and/or in machines used for passive gymnastics.

Even when applying the multiple plate articulated joint to *leg extension* and  
25 *leg curl* machines, two versions are possible, according to the type of transmission of the resistance (weight P) featured by the machine. The following two cases are therefore possible: a multiple plate articulated joint with the load on mobile arm L, or a multiple plate articulated joint with the load on the pin of the joint. In a multiple plate articulated joint used on a  
30 weight-lifting machine in which the resistance (weight P) is applied directly to

- 19 -

the mobile load arm, plate A is constrained by a fastener, such as a bar on the *leg extension* and *leg curl* machines; another plate H is in turn fastened to plate A and acts as a cover. The remaining five plates or semi-plates C, D, E, F, G are connected to one another and are free to rotate between plates A, H with reference to a horizontal axis "c", which must correspond to the one crossing the femoral condyles of the subject when seated.

The other four semi-plates D, E, F, G arranged in overlapping couples are fastened onto plate C, a little farther away from plate A (close to plate H). These four semi-plates D, E, F, G have a particular conformation. Plate F, which is close to plate A, features the previously described central, rectangular opening. One of the semi-plates C, E, F is endowed with a mobile arm. When the two semi-plates F and G, which are closer to plate A, are side by side they feature the previously described peripheral opening, whose radius "d" divides the opening in two parts: one containing the circle arc and the other containing the spiral arc. An ideal point of rotation is located on radius "d", at a distance "l" from the ideal central hole.

The aforementioned plates D, E, F, G are cut according to axis "e" which goes from this point of rotation to the point of intersection of radius "f" with the outer edge. Radius "f" is therefore in a position which is diametrically opposite to radius "b".

These plates D, E, F, G are arranged in overlapping couples (C, D, and F, E); their overlooking edges have not been cut precisely along the axis "e" but rather (considering the aforementioned ideal point of rotation to be the starting point), they diverge for a few degrees from axis "e" in the direction of the mobile arm, or in the opposite direction. Hence, a distance is created in correspondence with the intersection of axis "e" with radius "f" between the two groups of semi-plates (D, G, and E, F); this allows the rotation of one couple of semi-plates (D, G) on the other (E, F), with the aforementioned ideal point of rotation as the rotation fulcrum. By means of a screw, it is possible to adjust to the micrometer the distance between the two couple of

- 20 -

semi-plates.

In other words, semi-plate D, which is fastened to semi-plate C only by means of the pin located in the aforementioned ideal point of rotation, can rotate with reference to semi-plate E, which is permanently fastened to plate  
5 C. As semi-plate G is fastened to semi-plate D, and semi-plate F to semi-plate E, semi-plate G can rotate with reference to semi-plate F. Given that semi-plate G features the spiralling part of the peripheral opening, the latter's position may vary (owing to the rotation around the above mentioned ideal point of rotation) with reference to the concentric part of the peripheral  
10 opening itself.

Plate A features two holes, one located in the centre, and the other peripherally at a distance equal to "l" with reference to the central hole. In the latter a pin is inserted which is lodged in the central opening of semi-plate F; this pin simply acts as a fulcrum around which plates C, D, E, F, G move. A  
15 pin is placed in the second hole and is lodged in the peripheral opening formed by plates F, G.

By adjusting the micrometric screw which is connected to plates F, G, it is possible to change the distance between these plates (as well as the position of the spiral side of the peripheral opening), so that the rotation of  
20 plates F, G on plate A (by means of the pins featured by the latter) may correspond as much as possible to the flex/extension of the leg of the subject in question.

If the multiple plate articulated joint is used on a machine in which the resistance (weight P) is applied directly to the pin of the joint, the previously  
25 described plates C, D, E, F, G maintain the same function, even though their position is changed. Plates C, E, F are fastened to the machine by means of a fastener, such as a bar, while plate A and the first pin can move freely. Plates D, G, being connected to plate C, are also fastened to the machine, but may rotate partially on plates C, E, F, thanks to the pin located on the  
30 ideal point of rotation.

- 21 -

As described previously for the two plate articulated joint where the load is attached to the pin of the joint, plate A constitutes the proximal (nearer) part of mobile arm L, and is endowed with the aforementioned central, rectangular opening formerly featured by plate F. Furthermore, there is the  
5 previously described central pin/propeller shaft, featuring the feather key lodged in the opening of plate A, and a threaded area onto which another plate H is screwed, or a bolt acting as a cover for the entire system.

Plates C, E, F are crossed by a hole whose centre must correspond to the centre of the previously mentioned ideal hole in which the central  
10 pin/propeller shaft will be lodged and allowed to move freely.

The motion of the propeller shaft does not affect plates C, E, F, which are fastened to the machine by means of a fastening bar; rather, the motion is transmitted by means of the feather key inserted in the central opening of plate A to plate A itself. The latter, in turn, will follow the previously described  
15 movement of the peripheral opening on plates F, G, compelled to do so by the presence of the second pin that is fastened to plate A and lodged in the peripheral hole.

Irrespective of the number of plates and of the fastening system used to bind them to the machine in the proximal part of the mobile arm, an opening  
20 is made in which a mechanical hook is inserted allowing it to run along the opening itself. On this mechanical system the sling to be used for the shins will be fastened, approximately below the knee.

Furthermore, the mobile arm features another opening, located distally, wherein a feather key is lodged which is allowed to run freely between axis  
25 "a" of the mobile arm itself. The foot rest is attached onto this feather key; a pin can lock the feather key to the mobile arm.

The above mentioned foot rest consists in a blade or plate which is bent on one end at 90°, or by two joined blades or plates united at 90°. The vertical part of the rest is joint to the mobile arm, while the horizontal part is the place  
30 where the foot actually rests, locked in position by means of a small belt.

- 22 -

In the weight-lifting machines where the load is applied on the pin of the articulated joint, irrespective of whether a two plate or a multiple plate system is used, the articulated joint can be modified when the central pin/propeller shaft is wider than plate A.

5 In this case, a guide is milled on the central pin/propeller shaft, wherein plate A is placed; the latter's ideal central hole corresponds to the centre of the central pin/propeller shaft, the latter featuring a threaded hole.

A three-part screw featuring head, body and thread, and whose threaded part is engaged in the threaded hole of the central pin/propeller shaft, keeps  
10 plate A within the guide, with its non-threaded section going beyond the central opening. The head of the screw prevents the separation of the two mechanical parts.

When the leg transmits the motion to arm L, which is fastened to plate A, the proximal part of plate A, which is inserted in the guide of the central  
15 pin/propeller shaft, transmits this motion to the central pin/propeller shaft itself through the contact of the sides of plate A with the internal surfaces of the central pin/propeller shaft guide.

The second pin featured by plate A, which is lodged in the peripheral opening of plate B, makes plate A and arm L, which is connected to it, go  
20 along a trajectory with a varying radius, parallel to the one of the leg in the sling of arm L.

This variation in the radius during the flex/extension trajectory of the leg from the thigh makes plate A within the guide translate; the screw/pin, which in turn is inserted in the central opening, does not hamper this translation.

25 In using a multiple plate articulated joint on weight-lifting machines, a degree angular scale is to be drawn in an appropriate spot on a plate. The 0 position will correspond to the longitudinal axis of the mobile arm when the latter is the extension of the bar which joins the device to the machine. The scale develops in the opposite direction in which the peripheral opening is  
30 developed.

- 23 -

Parallel to the distal opening in the mobile arm, on the outer edge or on the side opposite that to which the leg is fastened, a verification linear millimetre scale is located, whose ideal zero is the ideal central hole.

5 Instead of degree scales, two encoders may also be used to measure the movements simultaneously, one located in the place of the linear scale, the other in the place of the angular scale.

The above mentioned pins inserted in the central and peripheral openings can be ellipsoidal, in order to ease their longitudinal motion within the aforementioned openings; they may also be provided with rolling bearings.

10 The number of mobile plates which replace plate B can be even greater, in order to divide the spiralling part of the peripheral opening into several areas, each one featuring its own centre of rotation. Hence, it is possible to adjust even more precisely the position of the aforementioned spiral opening.

15 Plates C, E, F can consist in a single piece.

The device which is the object of this patent application can be used on the machines that exist at present and on future machines by removing the traditional rotation device.

20 It can also be used as an accessory in combination with the traditional mechanism, thereby making the machine more functional. Lastly, the device may also be used as an accessory on other types of machines (or seats), thereby endowing them with the same function as *leg extension* and *leg curl* machines. In the latter case, the fastening bar will be locked onto the machine (or onto the seat) by means of those components that are known to  
25 achieve this aim.

The use of this invention on weight-lifting machines permits the strengthening or re-education of the extensor and/or flexor muscles of the leg with reference to the thigh, so that the anomalous physiological stresses (shear, flex, rebound, tensile and compressive), which occur during motion  
30 may be prevented from releasing harmful tensions on the ligaments. Its use

- 24 -

in knee tutors (knee guides) similarly avoids that the same types of anomalous physiological stresses be released on the knee's ligaments, on the knee-covers, on the articular cartilage of people who have suffered an injury in their knees, or athletes, as they walk, do sports or perform  
5 rehabilitation exercises.

Indeed, this articulated joint is made in order to permit its component parts to make movements which reproduce as faithfully as possible the sequence that occurs in the variation of the knee's centre of rotation and the progression of the rotation and sliding movements. Hence, the leg and arm  
10 L which is connected to the leg remain on trajectories that coincide perfectly, so that in each phase of the flex/extensor movement there is a perfect correspondence between every point of contact between the leg and arm L. This prevents any kind of slipping between the mechanical device and the limb, thereby avoiding the aforementioned anomalous tensions.

15

#### A Brief Description of the Drawings

Other characteristics and advantages of the invention will be more evident with the description of some specific and preferred but not exclusive configurations of the articulated joint, indicatively illustrated in the enclosed  
20 drawings in which:

- figure 1 illustrates the position of the muscles of the thigh and the flexing and extension movements;
- figure 2 shows the articular surfaces of the knee;
- figure 3 illustrates the variation in the distance between the femoral  
25 condyle and the malleolus which occurs during the extension of the leg;
- figure 4 shows the type of weight-lifting machine that exists at present, called *leg extension* machine, where the weight is placed on the mobile arm;
- figure 5 shows a *leg extension* machine where the weight is placed on the articulated joint;
- 30 - figure 6 illustrates the movement of the mobile arm on a *leg extension*

- 25 -

- machine;
- figure 7 shows the constraints placed on the slinged leg in a *leg extension* machine;
  - figure 8 illustrates a prospective view of the articulated joint object of this patent application featuring only two plates;
  - figure 9 shows the frontal view of the first of these plates in this articulated joint;
  - figure 10 illustrates a lateral view of the same plate;
  - figure 11 shows the frontal view of the second of these plates in this articulated joint;
  - figure 12 illustrates a lateral view of the second plate;
  - figure 13 shows an exploded view of the articulated joint with multiple plates;
  - figure 14 illustrates a frontal view of the articulated joint and the mobile arm;
  - figure 15 shows a lateral view of the same articulated joint and its respective mobile arm;
  - figure 16 illustrates the lateral view of the articulated joint and makes its structuring theory explicit;
  - figure 17 illustrates a prospective view of the part of the articulated joint which is connected to the weight-lifting machine;
  - figure 18 illustrates the first plate of the mobile part of the articulated joint;
  - figure 19 shows the first semi-plate of the mobile part of the articulated joint;
  - figure 20 illustrates the second semi-plate of the mobile part of the articulated joint;
  - figure 21 shows the third semi-plate of the mobile part of the articulated joint which overlaps the one shown in figure 19;
  - figure 22 shows the fourth semi-plate of the mobile part of the articulated joint which overlaps the one shown in figure 20;

- 26 -

- figures 23, 24 and 25 show three different arrangements of the plates of the articulated joint, when the leg is in the extended, flexed at 90°, and flexed at 135° positions;
- figures 26 shows the articulated joint applied to a *leg extension* machine  
5 where the weight is placed on the mobile arm;
- figures 27 shows the articulated joint applied to a *leg extension* machine where the weight is placed on the pin of the articulated joint;
- figure 28 shows an exploded view of the articulated joint illustrated in figure 27;
- 10 - figure 29 illustrates a view of a knee tutor featuring the articulated joint which is the object of this patent application;

#### Mode for Carrying Out the Invention

More precisely, in a first, simplified configuration applied to a *leg extension*  
15 weight-lifting machine with a resistance (P) constrained to mobile arm L, the articulated joint is formed by two plates 1 and 2; plate 1 is fastened to the weight-lifting machine by means of a bar 1.1, while plate 2 is able to rotate onto plate 1 with reference to a horizontal axis which passes through the femoral condyles of the subject when seated. An arm 2.1, featuring a  
20 horizontal rod located at the farther end and connected to the weights, is fastened to plate 2.

Plate 2 features two openings 2.2 and 2.3 at a right angle to the rotation surfaces of the two plates. The first opening 2.2 is rectangular in shape and the shorter sides are rounded; this opening is made by extending an ideal  
25 hole 2.4, which is located at the centre of plate 2, towards the outside along a radius defined as "a" which constitutes the longitudinal axis of symmetry of mobile arm 2.1.

The ends of the second opening 2.3 are shaped like a circle. The centre of one of the ends of this second opening 2.3 is situated on a point located at a  
30 distance "l" from the centre of the aforementioned hole 2.4, and lying on

- 27 -

radius "b", at a right angle to radius "a", which passes through the centre of the aforementioned hole 2.4 and on the same plane. The centre of the other end is located at  $135^\circ$  with reference to the above mentioned right angled radius "b". The second opening 2.3 has specific shape: initially, for the first  
5  $20^\circ$  (angle  $\alpha$ ) with reference to the aforementioned right angled radius "b", it is a circumference whose centre coincides with that of the centre of ideal hole 2.4 and whose radius is equal to "l"; subsequently, for the remaining  $115^\circ$  (angle  $\beta$ ), it is a spiral which returns towards the centre of ideal hole 2.4. The sequence of points forming the longitudinal axis of this spiral is  
10 derived from the sequence of points of one end of a section of length "l", whose other end moves along the longitudinal axis of the first opening 2.2 (from ideal hole 2.4 radially towards the outside along radius "a").

Plate 1 features two pins 1.2 and 1.3, whose longitudinal axis is at a right angle to the rotation surfaces of plates 1 and 2. These pins are located at a  
15 distance equal to "l". Pins 1.2 and 1.3 are cross-through pins and feature distally stop plates 1.4 and 1.5 which prevent plates 1 and 2 from separating.

The subject sits with the flexed leg on a *leg extension* weight-lifting machine built like the machines currently on the market. The thighs are fastened to  
20 the seat by belts or other constraints. The subject begins to extend the lower part of the leg, thereby compelling mobile load arm 2.1 to rise.

This compels plate 2 to move. The particular shape of openings 2.2 and 2.3 gives rise to different movements depending on the position of mobile load arm 2.1. Indeed, in the first phase of the extension (the first  $115^\circ$ : angle  $\beta$ ),  
25 since opening 2.3 is shaped like a spiral that returns towards the centre of plate 2, and the distance between pins 1.2 and 1.3 is still "l", plate 2 will be compelled to endure a twofold movement: rotation and sliding upwards. As mobile load arm (2.1) is fastened to plate 2, it follows the movements of plate 2, and therefore translates upwards and rotates at the same time. This  
30 movement follows perfectly the movement of the leg fastened to mobile arm

- 28 -

2.1 as the latter makes a spiralling trajectory, like the physiological one of the knee. At each point of the extension, each point of contact between the leg and mobile arm 2.1 corresponds perfectly, thereby avoiding anomalous tensions in the knee.

5 Subsequently (for the remaining 15-20° of the extension: angle  $\alpha$ ), as opening 2.3 is a circumference whose centre coincides with the centre of pin 1.2 or that of hole 2.4, plate 2 will simply rotate onto plate 1.

In the return movement the same motions occur but reversed: when the leg flexes there is at first a rotation of plate 2 on plate 1, succeeded by a rotation  
10 with a translation towards the bottom and, lastly, only a translation towards the bottom.

For the articulated joint to be personalised, and thus suitable for each subject, without having to make changes in plate 2, it is necessary to use a multiple plate articulated joint.

15 Indeed, in a second configuration applied to a *leg extension* weight-lifting machine with a resistance (P) constrained to mobile arm L, plate 2 is replaced by five plates 3, 4, 5, 6, 7, shaped like a disc or like a fraction of a disc and overlapping. These plates or semi-plates are connected to one another and are free to rotate onto plate 1 and onto the last plate 8 (which acts like a  
20 cover), with reference to a horizontal axis "c", which passes through the femoral condyles of the subject when seated.

Semi-plates 4, 5, 6, 7, in overlapping couples, are fastened to plate 3, which is the farthest from plate 1 of all. Plate 3 features a threaded hole 3.1 in correspondence with the point of rotation of semi-plate 4, onto which a pin  
25 4.1 is screwed, allowing the rotation of semi-plate 4 with reference to semi-plate 3. Furthermore, two threaded holes 3.2 are made on plate 3 towards semi-arm 3.3, which lock semi-plate 5 and semi-plate 6 onto plate 3 by means of adequate screws.

Semi-plates 4, 5, 6, 7 are shaped in a particular manner. An examination of  
30 the latter two reveals that semi-plate 6 features an opening 9 which is similar

- 29 -

to the aforementioned opening 2.2. This opening 9 is also obtained by extending an ideal hole 9.1, which is located at the centre of the semi disc that forms semi-plate 6, towards the outside, along a radius defined as "a", which constitutes the longitudinal axis of symmetry of the mobile arm 6.1  
5 featured by semi-plate 6. This mobile arm 6.1 is connected to the weights.

When the two semi-plates 6 and 7 are side by side they feature a second opening 10, similar to the previously described opening 2.3.

In opening 10 considerable importance is played by radius "d", which divides opening 10 into two parts: one, 10.1, containing the circle arc of semi-plate 6  
10 and the other, 10.2, containing the spiral of semi-plate 7. Radius "d" is inclined by  $20^\circ$  (on the same plate) with reference to radius "b". A point 11 is located on radius "d" at a distance "l" from the ideal hole 7.1.

Semi-plates 4, 5, 6, 7 are cut according to an axis "e" which goes from point 11 to the point of intersection of radius "f" with the outer edge (of semi-plates  
15 4, 5, 6, 7); radius "f" is in a position which is diametrically opposite to radius "b".

Getting back to the details of the various components, it will appear that semi-plate 5 is fastened, as previously described, in the proximal part of semi-arm 3.3 of plate 3. It features two holes 5.1 where as many screws,  
20 having the same interaxis as holes 3.2, pass through. The side which faces semi-plate 4 features indentation 5.2 which is slightly shorter than half the circumference and whose centre is in point 11.

Semi-plate 4 is fastened onto plate 3, next to semi-plate 5. From the side overlooking semi-plate 5 a half circumference 4.2 (whose centre is in point  
25 11) protrudes, whose diameter is lesser than indentation 5.2 of semi-plate 5, so as to allow it to be inserted in the latter and thus permit the rotation between the mechanical members around point 11. Pin 4.1 is inserted inside hole 4.3, located at the centre of the half circumference 4.2 (endowed with a countersink on the side overlooking semi-plate 7) placed in correspondence  
30 with point 11, around which semi-plate 4 rotates. This rotating pin 4.1 is

- 30 -

screwed into hole 3.1 of plate 3. It consists in three parts: head (which is inserted in indentation 4.4 of the half circumference 4.2), body (which is smooth and occupies hole 4.3) and thread (which is to be engaged in hole 3.1).

5 Semi-plate 4 also features a threaded hole 4.5, located in the centre, where a screw fastening semi-plate 7 to semi-plate 4 itself can be inserted.

Semi-plate 6 is fastened to semi-plate 5 and to plate 3 by means of screws that cross holes 6.2, 5.1 and 3.2. At the centre of semi-plate 6 opening 9 opens up, while in the farther end (distal) from mobile arm 6.1 in the  
10 direction of point 11, part 10.1 of opening 10 opens up; the latter originates from radius "b" at a distance "l" from hole 9.1, and develops with a constant radius along a circle arc until it intersects with radius "d".

Pin 1.2 is inserted in opening 9; the former can be locked in correspondence with ideal hole 9.1. In the channel formed by opening 9 spring 12 is inserted;  
15 the latter is withheld by a distal spring-lock 13 (which is crossed lengthwise by hole) and by proximal spring-lock 14. The latter acts on a bushing 15, within which pin 1.2 is lodged. The latter's internal diameter corresponds to the outer diameter of pin 1.2 and the outer diameter to the size of opening 9. The mechanical finishing of bushing 15 must enable it to rotate freely on pin  
20 1.2, and to slide freely into opening 9. Proximal spring-lock 14 can be pushed by a peg 16, which is lodged in mobile arm 6.1 within an indentation 17 that features two locked positions: when one end of peg 16 is inserted in the proximal locked position 17.1 bushing 15, pushed from the other end by peg 16 itself (after crossing distal spring-lock 13), is compelled to place itself  
25 on ideal hole 9.1; on the other hand, when peg 16 is inserted in the distal locked position 17.2 bushing 15 is free to move within opening 9.

Semi-plate 7 is fastened onto semi-plate 4 by means of a screw which crosses a countersunk hole 7.1 which is to be engaged in hole 4.5.

Section 10.2 of opening 10 is carved onto semi-plate 7; the former extends  
30 from radius "d" until the complete development of opening 10 itself.

- 31 -

Semi-plates 5 and 6 feature an edge overlooking semi-plates 4 and 7 which is not, however, cut exactly along axis "e" but rather, considering point 11 to be the starting point of the edge, diverges by a few degrees from axis "e" in the direction of mobile arm 6.1. Semi-plates 4 and 7 also feature an edge  
5 overlooking semi-plates 5 and 6 which is not cut exactly along axis "e" but, unlike the latter plates, and, again, considering point 11 to be the starting point of the edge, rather diverges by a few degrees from axis "e" in the opposite direction from mobile arm 6.1.

As the edge of semi-plates 4 and 7 and that of semi-plates 5 and 6 share  
10 the same centre but have sides that open in the opposite direction, a distance is formed where axis "e" intersects with the external edge which permits semi-plates 4 and 7 to rotate on semi-plates 5 and 6; point 11 is the centre of this rotation movement.

A wing 6.3 and 7.2 is fastened onto semi-plates 6 and 7, in proximity to the  
15 outer edge. A threaded, cross-through hole 6.4 is featured by wing 6.3, while wing 7.2 features a non threaded cross-through hole (with the same interaxis). A screw 18 is inserted through the latter hole; screw 18 is endowed with a bolt 18.1 which is to be engaged in hole 6.4. By acting on this screw 18 it is therefore possible to adjust the distance between plates 6  
20 and 7 (and, consequently, also between plates 4 and 5); it is possible to adjust this distance to the micrometer.

A pin 1.3, which crosses threaded hole 1.4 (which is on plate 1) is inserted in opening 10. It is made of three sectors: a handwheel with a knurled edge, which makes it easier to lock it manually on plate 1, a threaded sector which  
25 is screwed inside hole 1.4, and a non threaded cylinder section which slides inside opening 10 and protrudes from the side opposite the one featuring the handwheel.

Furthermore, plate 1 also features a second hole 1.5, located centrally, with a longitudinal axis at a right angle to the rotation surfaces of plates 1, 3, 4, 5,  
30 6, 7, and located at a distance equal to "l" with reference to hole 1.4, within

- 32 -

which pin 1.2 is inserted. The latter is cross-through and its distal end is lodged inside bushing 15, thereby crossing opening 9. Pin 1.2 also consists in three parts: a handwheel with a knurled edge, a threaded sector which is screwed inside hole 1.5, and a non threaded cylinder section which slides  
5 inside opening 9.

In the section closer to mobile arm 6.1 lies an opening 19 which is rectangular in shape (and which follows the direction of axis "a"), inside which a mechanical system 20 with screws is inserted, allowing this system to move longitudinally along opening 19.

10 A small, semi rigid belt 21 is fastened onto mechanical system 20 to be tied around the distal part of the belt, approximately below the knee; the possibility to move mechanical system 20 makes it possible to identify the exact point in which this constraint is to be fastened according to the anthropometric dimensions of the user of the invention.

15 Mobile arm 6.1 also features another opening 22, located distally, which is also rectangular in shape (possibly with rounded sides) which follows the direction of axis "a".

A feather key 23 is lodged inside opening 22; the former is externally wider than opening 22 and it is thicker than mobile arm 6.1; however, it is allowed  
20 to slide freely along axis "a" of mobile arm 6.1. The foot rest is fastened to feather key 23 by means of screws; a pin 24 fastens feather key 23 to mobile arm 6.1.

The aforementioned foot rest consists in two blades 25 fastened to one another at 90°. The vertical blade allows the connection to mobile arm 6.1 by  
25 means of screws which engage in feather key 23; the horizontal blade allows the foot to rest by coming into contact with a large portion of the bottom of the foot.

The foot resting in this location is fastened to blade 25 by means of a small belt 26, so as to maintain the position it is in at the start throughout the  
30 flex/extension movement.

- 33 -

A degree angular scale 1.6 is drawn at the periphery of plate 1. The 0 position is located in correspondence with radius "a" in the position in which mobile arm 6.1 constitutes the extension of bar 1.1; the scale develops in the opposite direction compared to the direction in which pin 1.3 is located.

5 A verification linear millimetre scale is located parallel to opening 22. A 0 reference point is drawn on the outer edge of feather key 23.

The 0 of this millimetre scale 27 is located on ideal hole 9.1 and, consequently, the scale only shows values that are higher than a certain level, for instance 30 centimetres. The distance between the centre of ideal  
10 hole 9.1 and the fiducial mark of the millimetre scale 27 is called radius "R".

The above mentioned plate 8 acts as a cover; it is connected to plate 1 by means of three screws 28; these screws 28 are inserted inside specific spacing bar 29 which prevent plates 1 and 8 from getting excessively close to one another. These two plates are tightly fastened to semi-plates 3, 4, 5,  
15 6, 7, (by means of screws 28), preventing them from being drawn apart from plate 1. Semi-plates 3, 4, 5, 6, 7 are allowed to slide onto plates 1, 8 thanks to the use of self-lubricating substances for contacting surfaces.

As previously described, the length of the knee's **crossed ligaments** and their point of insertion are individual anthropometric characteristics which  
20 shape the knee's articular surfaces and which therefore differ from one individual to the next. In order to analyse these characteristics and to personalise the articulated joint a functional assessment is the common approach.

In order to carry out a correct assessment it is first of all indispensable for  
25 the knee to be placed on the machine in a precise position; that is to say, the axis which crosses the knee, around which the first 15-20° of the flex/extension take place (axis "c") correspond perfectly to axis "c" of the device, which crosses the centre of ideal hole 9.1.

This alignment of the centre of both the knee and the machine, called self-  
30 centring, must be performed before any other step and must be performed

- 34 -

again every time that the same subject places him/herself on the machine and need to return to the same working conditions.

The subject is made to sit down with his leg on the *leg extension* machine.

The thigh belts and belts 21, 26 on the distal part of the leg are fastened.

5 Mechanical system 20 and pin 24 are released, so that the former may be free to slide into opening 19 and feather key 23 into opening 22.

After having removed pin 1.3 from plate 1 and having locked pin 1.2 in the central position (by means of peg 16 which is located in the proximal locked position 17.1 which locks bushing 15 onto ideal hole 9.1), mobile arm 6.1 is  
10 used as an arm rotating around a fixed centre (whose centre is ideal hole 9.1 and which is coaxial to axis "c" of the device).

The subject, with the leg outstretched, performs some small flex/extension movements of approximately 30°, readable in the degree angular scale 1.6.

If when the subject is seated with his limb outstretched the measure of  
15 radius R differs from the measure taken when the limb is slightly flexed, the knee is not centred and the latter's axis "c" will not coincide with the axis "c" of the device. For instance, if the measure of radius R increases, the knee will be in a forward position with reference to axis "c" crossing the centre of ideal hole 9.1. If the measure decreases, the knee will be behind or below  
20 axis "c".

Once the perfect correspondence between axis "c" of the knee and that of the device has been found, it is possible to trace the articular route of the tibia as it rolls and slides onto the femur. Starting from an outstretched position a few readings are taken, particularly in the last 90° of the  
25 movement, i.e. as the leg flexes between 45 and 135°.

The measurements to be taken are the flexing angle (to be read on degree scale 1.6) and the corresponding variation of radius R (to be read on linear millimetre scale 27).

Having taken a number of such coupled readings, it is possible to compute  
30 mathematically the curve interpolating the points read at the maximum

- 35 -

flexing and thus identify the opening 10.2 which best suits the subject being examined.

The subsequent personalisation of curve 10.2 is performed on millimetric screw 18 which is hinged to wings 6.3 and 7.2 of semi-plates 6 and 7. By  
5 adjusting this screw 18, the distance between plates 6, 7, (and 4, 5) can be adjusted, as a consequence of which the position of opening 10.2 with reference to opening 10.1 will also be adjusted. Pin 4.1 is the fulcrum of the rotation of opening 10.2.

When opening 10.2 has been adjusted to suit the characteristics of the  
10 subject being examined, peg 16 is placed in the distal locked position 17.2, thereby releasing bushing 15. Pin 1.3 is then screwed into hole 1.4 of plate 1, feather key 23 is locked (by means of pin 24) into opening 22 in correspondence with the reference spot of the foot, and mechanical system 20 is locked in opening 19, thereby definitively fastening the distal part of the  
15 leg to mobile arm 6.1.

At this stage, having personalised opening 10.2, the subject may start performing normal flex/extension exercises. The movements of the multiple plate articulated joint will be similar to those of the two plate articulated joint. The subject starts from a flexed position to perform and extension of the leg  
20 from the thigh, thereby compelling mobile load arm 6.1 to rise.

This compels plates 3, 4, 5, 6, 7 to move. The particular shape of openings 9 and 10 gives rise to different movements depending on the position of mobile load arm 6.1. Indeed, in the first phase of the extension (the first 115°: angle  $\beta$ ), since opening 10.2 is shaped like a spiral that returns  
25 towards the centre of plate 6, and the distance between the two pins is still "l", plates 3, 4, 5, 6, 7 will be compelled to translate upwards and, at the same time, rotate onto plates 1,8. Arm 6.1, which is fastened to semi-plate 6, logically follows these movements.

Subsequently (for the remaining 15-20° of the extension: angle  $\alpha$ ), as  
30 opening 10.1 is a circumference whose centre coincides with the centre of

- 36 -

hole 9.1, plates 3, 4, 5, 6, 7 will simply rotate onto plate 1, 8, the fulcrum being ideal hole 9.1.

On the other hand, the following description concerns a configuration of an articulated joint with multiple plates and the resistance of the machine on the  
5 rotating device.

In this case, central pin 1.2 constitutes the end of a shaft having a longitudinal axis placed on the extension of the knee's axis "c". Plates 3, 4, 5, 6, and 7 maintain the same function (compared to the previous multiple plate configuration), even though their position is changed. Plates 3, 5, 6 are  
10 fastened to the machine; plates 4, 7, being fastened to plate 3 by means of pin 4.1 and by the screw crossing holes 4.5 and 7.1, also remain fastened to the machine, but may rotate partially onto plates 3, 5, 6, thanks to the aforementioned pin 4.1 located on the ideal point of rotation.

Plate 1 constitutes the proximal part of mobile arm 1.1 which replaces the  
15 mobile arm 6.1 of the previous multiple plate version; it features central, rectangular opening 9, formerly featured by plate 6. Plate 1/arm 1.1 is free to rotate onto plates 3, 4, 5, 6 and 7.

As previously described, central pin 1.2 here constitutes one end of the propeller shaft, which features on the other end a feather key 30 which is  
20 lodged in the central, rectangular opening 9 of plate 1. In order to prevent pin 1.2/shaft from slipping out of plates 3, 4, 5, 6, 7, the latter is endowed with a threaded area, in proximity to feather key 30, onto which plate 8 is screwed, thereby acting as a cover for the entire system.

Central opening 9 remains unchanged in its engineering, compared to the  
25 description made in the first case for plate 6, with the ideal hole 9.1 as the main locating spot. However, the length of this opening is increased vertically according to the size of feather key 30, whose point of symmetry (where the transverse and longitudinal axes meet) must coincide with the ideal hole.

30 Plates 3, 5, 6 are crossed by a cross-through hole 31 whose centre

- 37 -

corresponds to the centre of ideal hole 9.1, where the central pin 1.2/propeller shaft is be lodged and allowed to rotate freely.

The motion of the pin 1.2/propeller shaft does not affect plate 3, 5, 6, which are fastened to the machine; rather, it transmits this motion to plate 1 by  
5 means of feather key 30 which is located in opening 9. The latter, in turn, will follow the motion suggested by the second opening on plates 6,7, compelled to do so by the presence of the second pin 1.3 that is fastened to plate 1 and lodged in peripheral opening 10.

The invention thus made is subject to several modifications and variations,  
10 all of which pertain to the inventive concept. Furthermore, all details may be replaced with other technically equivalent ones.

**CLAIMS:**

1. An adjustable rotation radius articulated joint for a gym machine and knee tutor situated in correspondence of the knee of a user, comprising:
  - a first plate;
  - a second plate; and
  - a group composed of a third plate; first and second plate segments forming a fourth plate; third and fourth plate segments forming a fifth plate;
  - the first plate and the third plate segment each having an arm;
  - the third plate segment and the second plate segment are fixed to the third plate;
  - the first plate segment and the fourth plate segment are rotatably fixed to the third plate;
  - the fourth plate segment having a first slot which continues into the third plate segment;
  - a center pin fixed on the first plate;
  - the first plate has a peripheral pin slidably engaged in the first slot; and
  - an adjustment screw engaged between the third plate segment and the fourth plate segment to personalize the joint for use on a knee of a user.
2. The articulated joint according to claim 1, wherein the fourth plate segment and the first plate segment rotate together on a pin fixed to the third plate around a fulcrum on the first plate segment.
3. The articulated joint according to claim 1, further comprising:
  - a second slot provided on the third plate segment extending from a center of the third plate segment along a longitudinal axis of the arm of the third plate segment.
4. The articulated joint according to claim 1, further comprising:
  - a second slot provided on the first plate extending from a center along a longitudinal axis of the arm of the first plate.

- 39 -

5. The articulated joint according to claim 3, wherein the center pin is rotatably engaged in a bushing located in the second slot and wherein spring-lock means are provided having a spring engaged in the second slot against the bushing for fixing the bushing at the center of the third plate segment when fixed at a first position and permitting the bushing to slide in the second slot against the spring when fixed at a second position.

6. The articulated joint according to claim 5, wherein the spring-lock means comprises the spring, a first end portion, a second end portion and a peg, the spring engaged against the first end portion and the second end portion and the peg;

the peg slidably extending through the first end portion to press the second end portion against bushing in the first position when the peg is secured in a first notch on the third plate segment, and

wherein, when the peg is secured in a second notch on the third plate segment in the second position the bushing is slidable in the second slot.

7. The articulated joint according to claim 1, wherein the adjustment screw is inserted through a through hole in a first wing on the fourth plate segment and held in the through hole by a bolt, wherein when the adjustment screw is threaded in a threaded hole on a second wing on the third plate segment a distance between the first and second wings is adjusted.

8. The articulated joint according to claim 1, wherein the third plate segment, the second plate segment and the third plate are formed as a single unit.

9. The articulated joint according to claim 1, wherein the first and fourth plate segments are formed as a single unit.

10. The articulated joint according to claim 3, wherein the first slot has a specific shape; initially for the first  $15^{\circ}$ - $45^{\circ}$  has a circular form, whose center coincides with the center point with a radius equal to "1"; subsequently, for

- 40 -

the remaining 90°-120°, it forms a spiral which develops towards the center point; one end of the first slot lies on a radius "b"; that is at a right angle to radius "a"; the center point is one end of the second slot; the other end of the first slot is located at a distance "l" from the other end of the second slot.

11. The articulated joint according to claim 10, wherein a radius "d" – that is inclined by 15°-45° with reference to radius "b" divides the first slot in two parts; a circular part located on the third plate segment and a spiral part located on the fourth plate segment; and a fulcrum is located on radius "d".

12. The articulated joint according to claim 10, wherein the above-mentioned pins are located at a distance equal to "l".

13. The articulated joint according to claim 10, wherein the first plate segment, the second plate segment, the third plate segment and the fourth plate segment each have a periphery; the first plate segment is spaced from the second plate segment, and the third plate segment is spaced from the fourth plate segment along an axis "e" which goes from a fulcrum to a point where a radius "f" intersects the peripheries of the first plate segment and the second plate segment and the peripheries of the third plate segment and the fourth plate segment; the radius "f" is diametrically opposite to radius "b"; the first plate segment, the second plate segment, the third plate segment and the fourth plate segment each has an edge that extends generally along the axis "e", but the edge of the first plate segment diverges from the edge of the second plate segment by a few degrees and the edge of the third plate segment diverges from the edge of the fourth plate segment by a few degrees, starting from the fulcrum and ending at the peripheries of the plate segments, so that a distance is created between the first plate segment and the second plate segment and between the third plate segment and the fourth plate segment adjacent the intersection of axis "e" with radius "f".

14. The articulated joint according to claim 3 or 4, wherein a belt is fixed adjustably along a longitudinal axis of the arm adapted to constrain a calf of

- 41 -

a user against the arm.

15. The articulated joint according to claim 3 or 4, wherein the arm features a rectangular opening located distally which develops along a longitudinal axis "a" inside which a feather key is lodged, fixed adjustably along the rectangular opening by means of a pin; a foot rest is blocked by the feather key; the foot rest having a belt adapted to constrain a foot of the user on the foot rest.

16. The articulated joint according to claim 15, wherein a linear scale is provided along an edge of the arm opposite an adjustment distance of the foot rest on the arm, a zero point of the linear scale corresponding to the center of the third plate segment.

17. The articulated joint according to claim 1, wherein the movement of rotation of the joint arises around axis "c", at a right angle to rotation surfaces of the joint itself.

18. The articulated joint according to claim 1, wherein the first and second plates are fixed together in spaced relationship and the first plate has a femoral arm for attachment to the gym machine or to the thigh of the user;

the arm of the third plate segment is a distal arm; the second plate segment and the third plate all fixed together to rotate between the first and second plates;

the first plate having a peripheral pin inserted in a peripheral hole slidably engaged in the first slot.

19. The articulated joint according to claim 1, wherein:

the third plate segment has a femoral arm for attachment to the gym machine or to the thigh of the user;

the second plate is fixed to one end of a center pin; the femoral arm having a longitudinal axis of symmetry;

said third and second plate segments and third plate being fixed

- 42 -

together to rotate between the second plate and an element fixed to the other end of the center pin, wherein:

the first plate has a second slot that extends along the longitudinal axis of symmetry of the arm for the calf of the user;

the third and second segments of plate and third plate are each provided with a cross-through hole, all of said cross-through holes being coaxial with one another; and

the center pin has a feather key lodged in the second slot, the center pin serving as a center of rotation on the first plate for the third and second segments of plate and third plate.

20. The articulated joint according to claim 18, wherein a degree angular scale is provided along the periphery of the first plate to indicate an angle between the longitudinal axis of the femoral arm and the longitudinal axis of the arm for the calf of the user.

21. The articulated joint according to claim 19, wherein the first plate has a central hole located at a distance equal to "l" from a peripheral hole.

22. The articulated joint according to claim 19, wherein the center pin is lodged in the cross-through holes of the third and second segments of plate and of the third plate.

23. The articulated joint according to claim 19, wherein the center pin has, in proximity to the feather key, a threaded area onto which the second plate is fastened to act as a cover for the joint.

24. The articulated joint according to claim 19, wherein the center pin constitutes a driver shaft to which a load is applied.

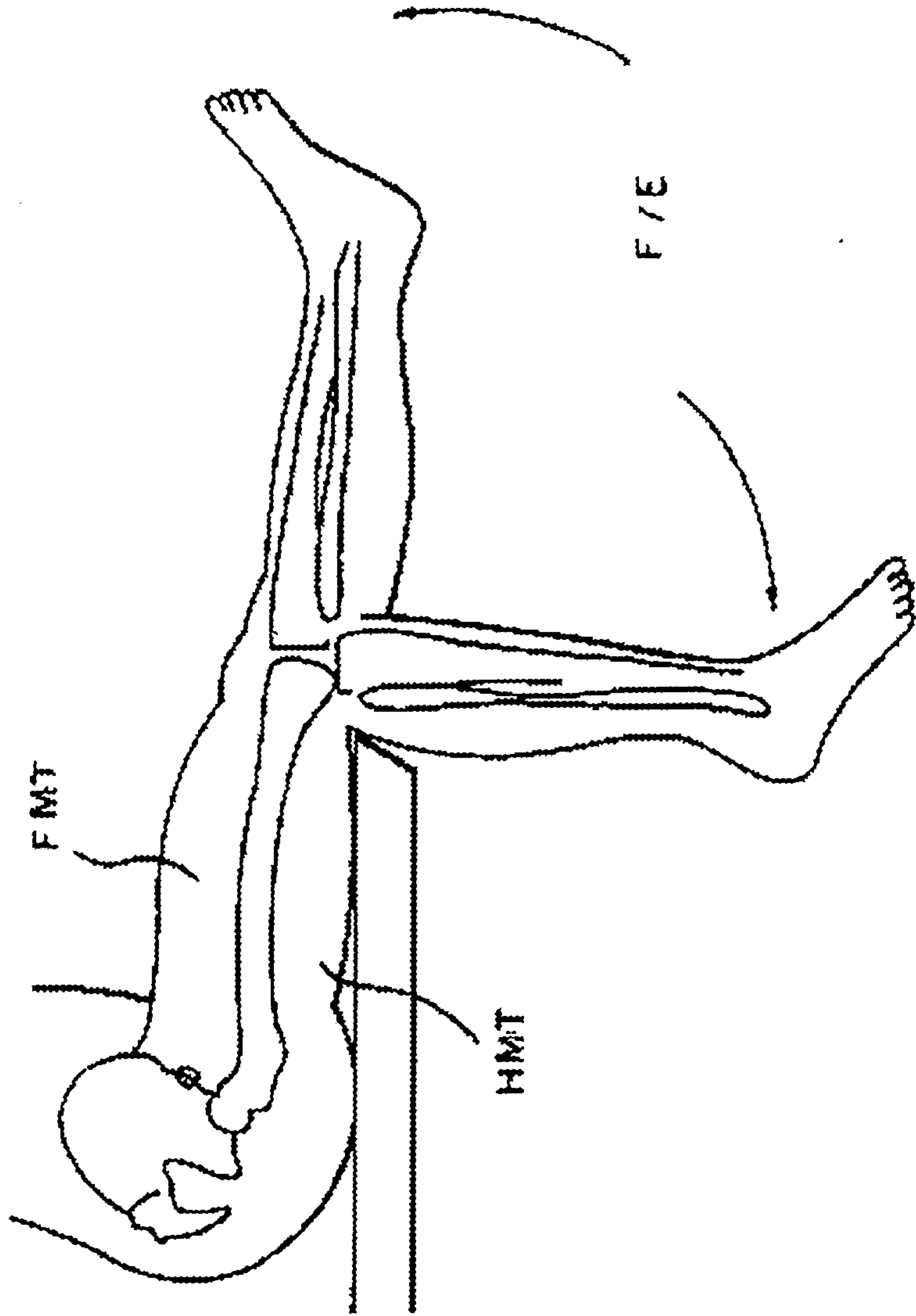
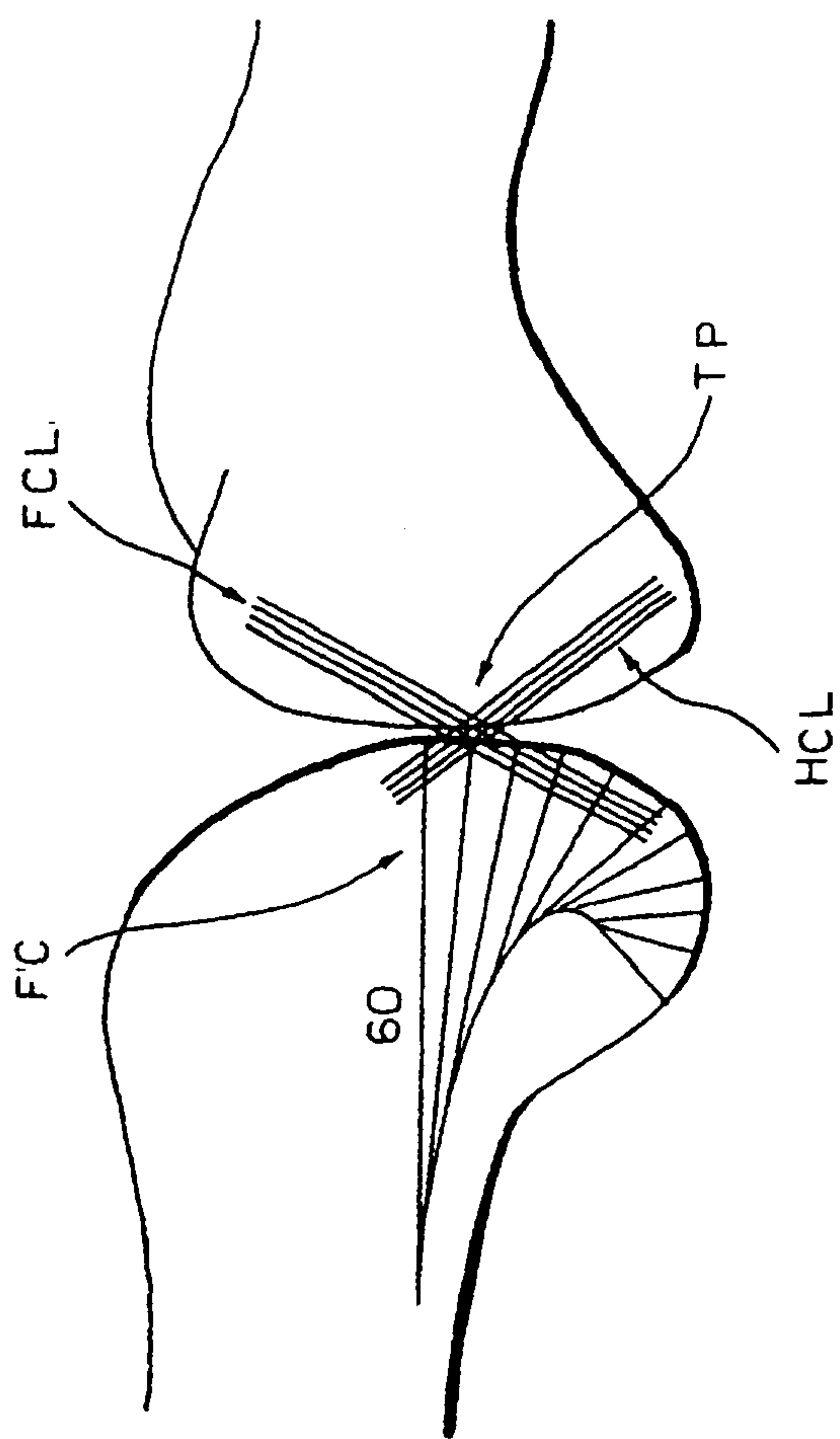


FIG. 1

FIG. 2



3/19

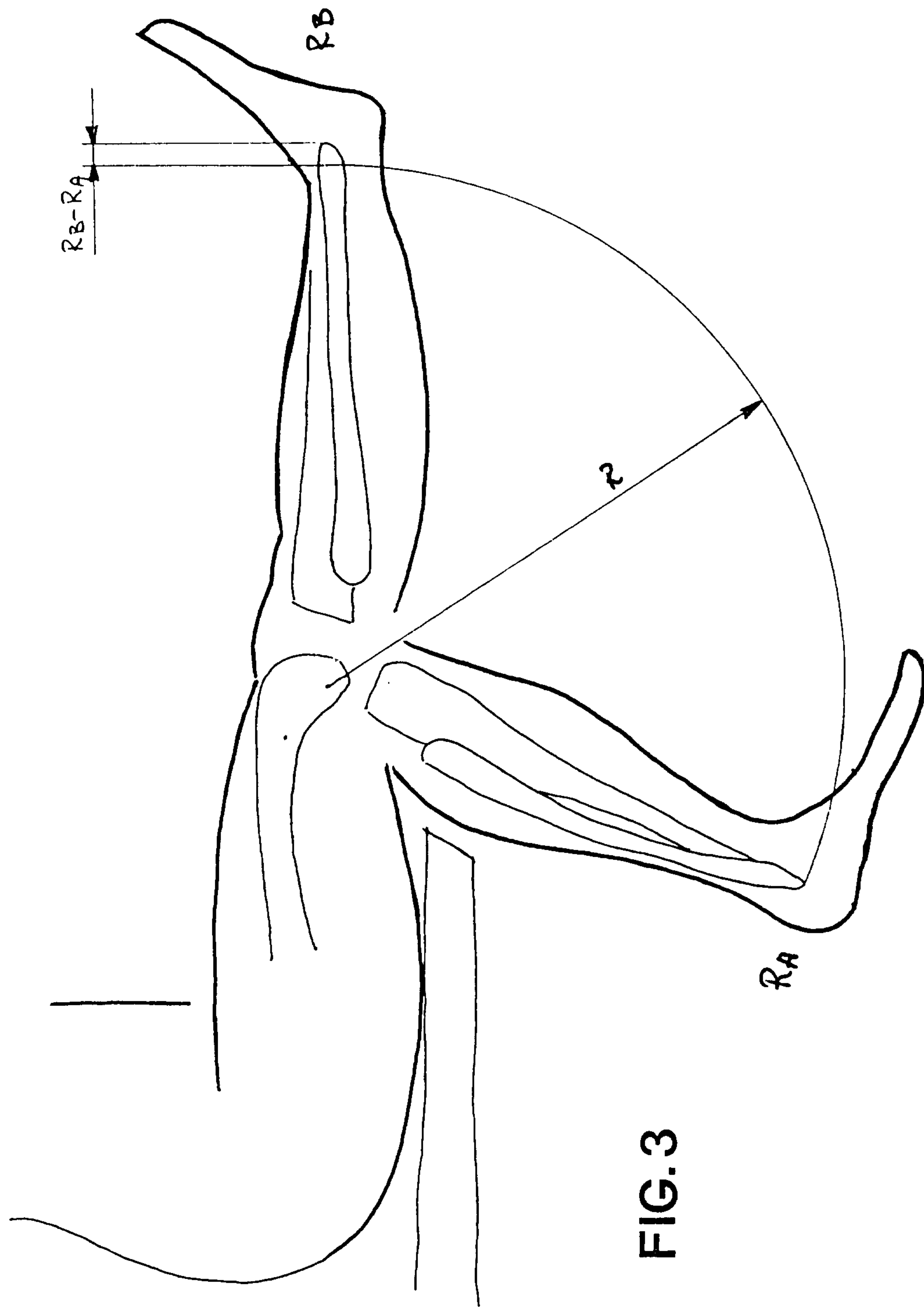


FIG. 3

4/19

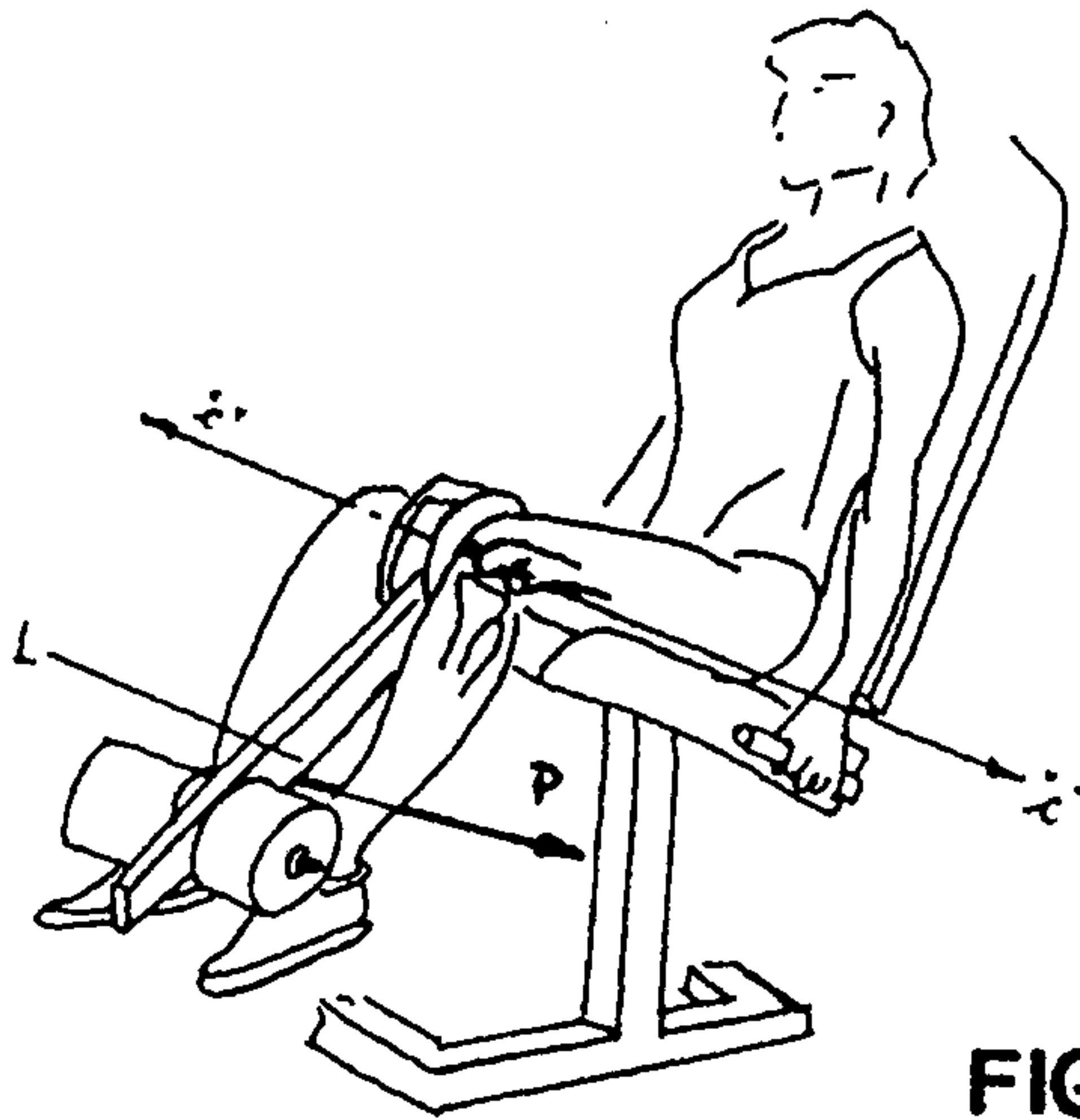


FIG. 4

PRIOR ART

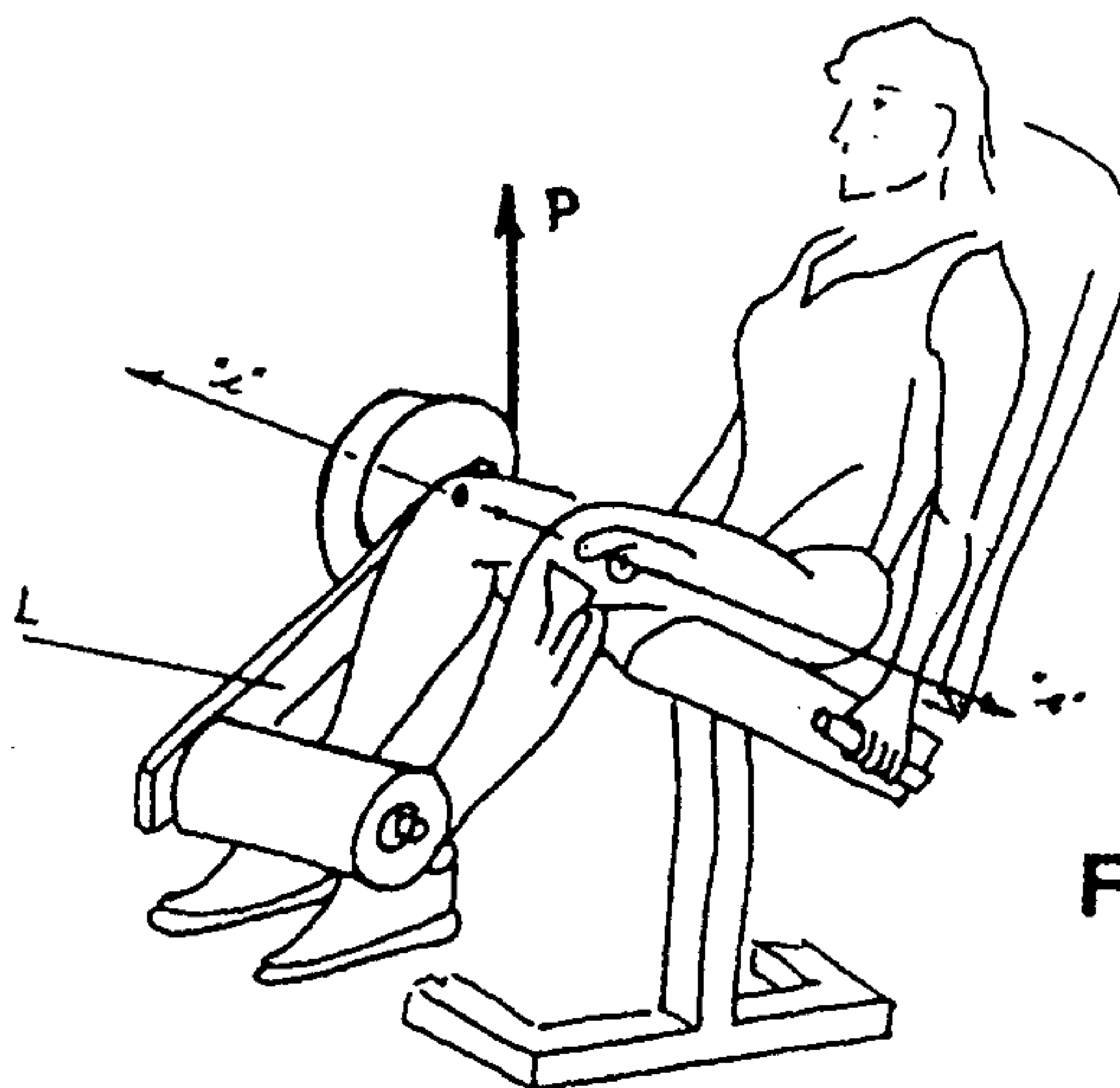
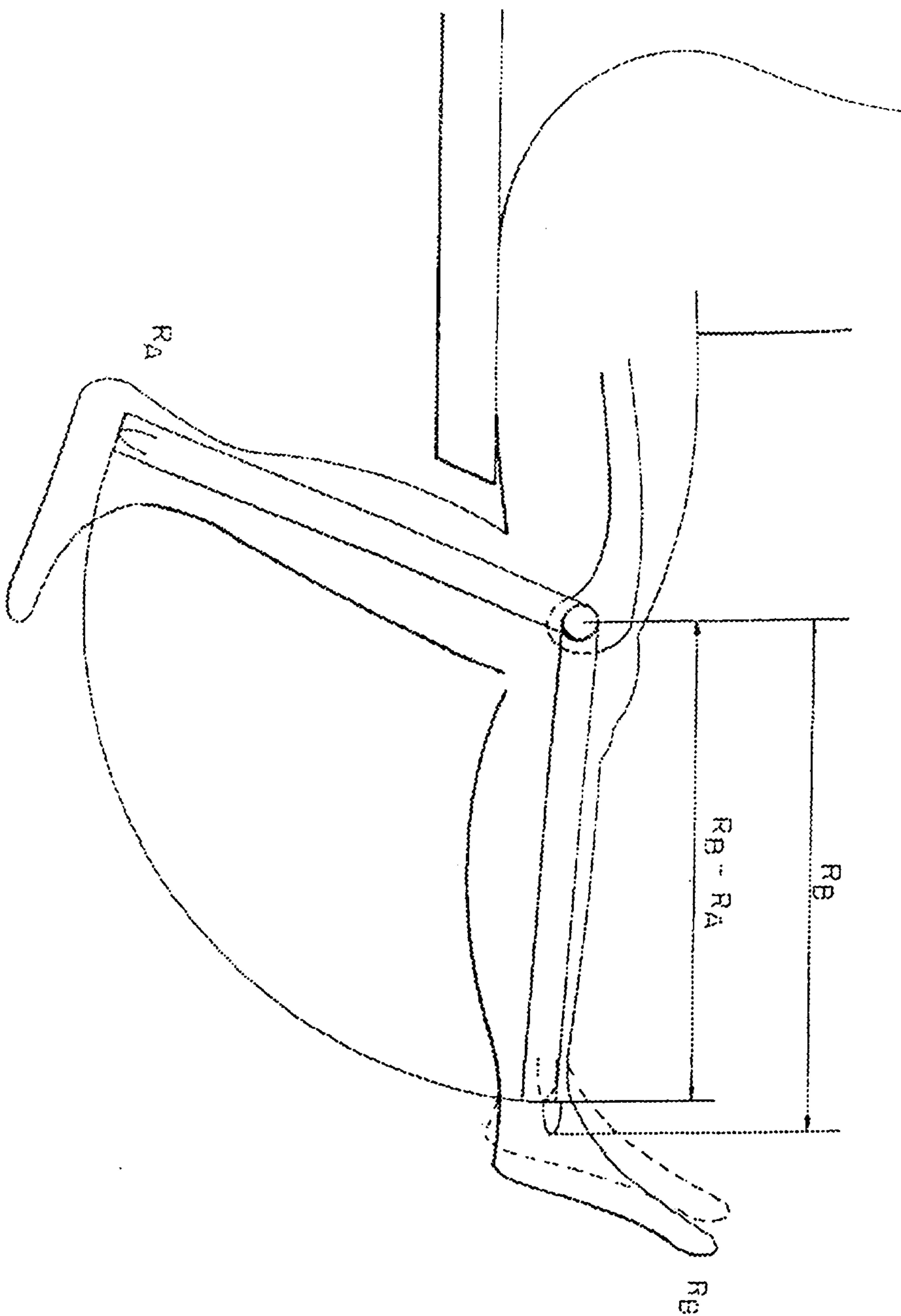


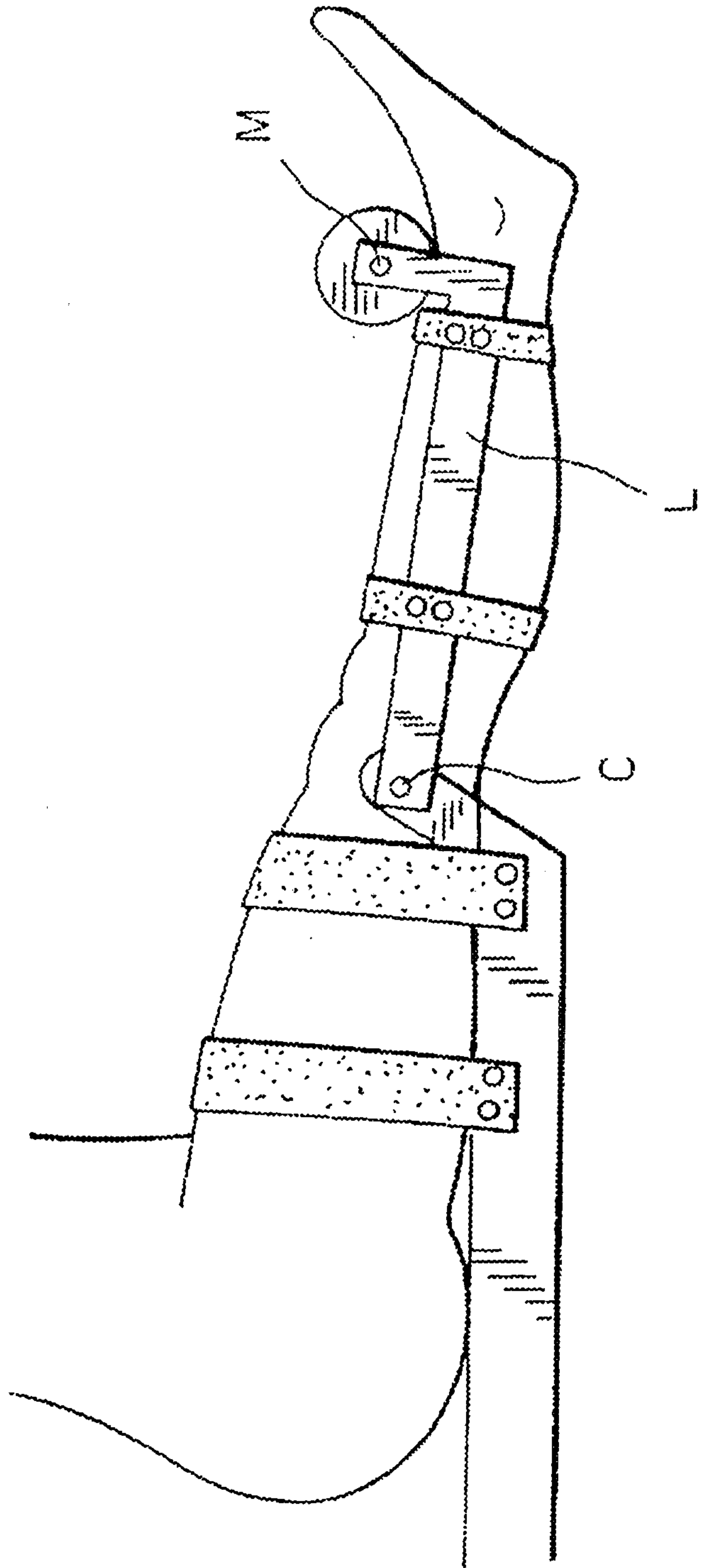
FIG. 5

PRIOR ART



**FIG. 6**  
PRIOR ART

**FIG. 7**  
PRIOR ART



7/19

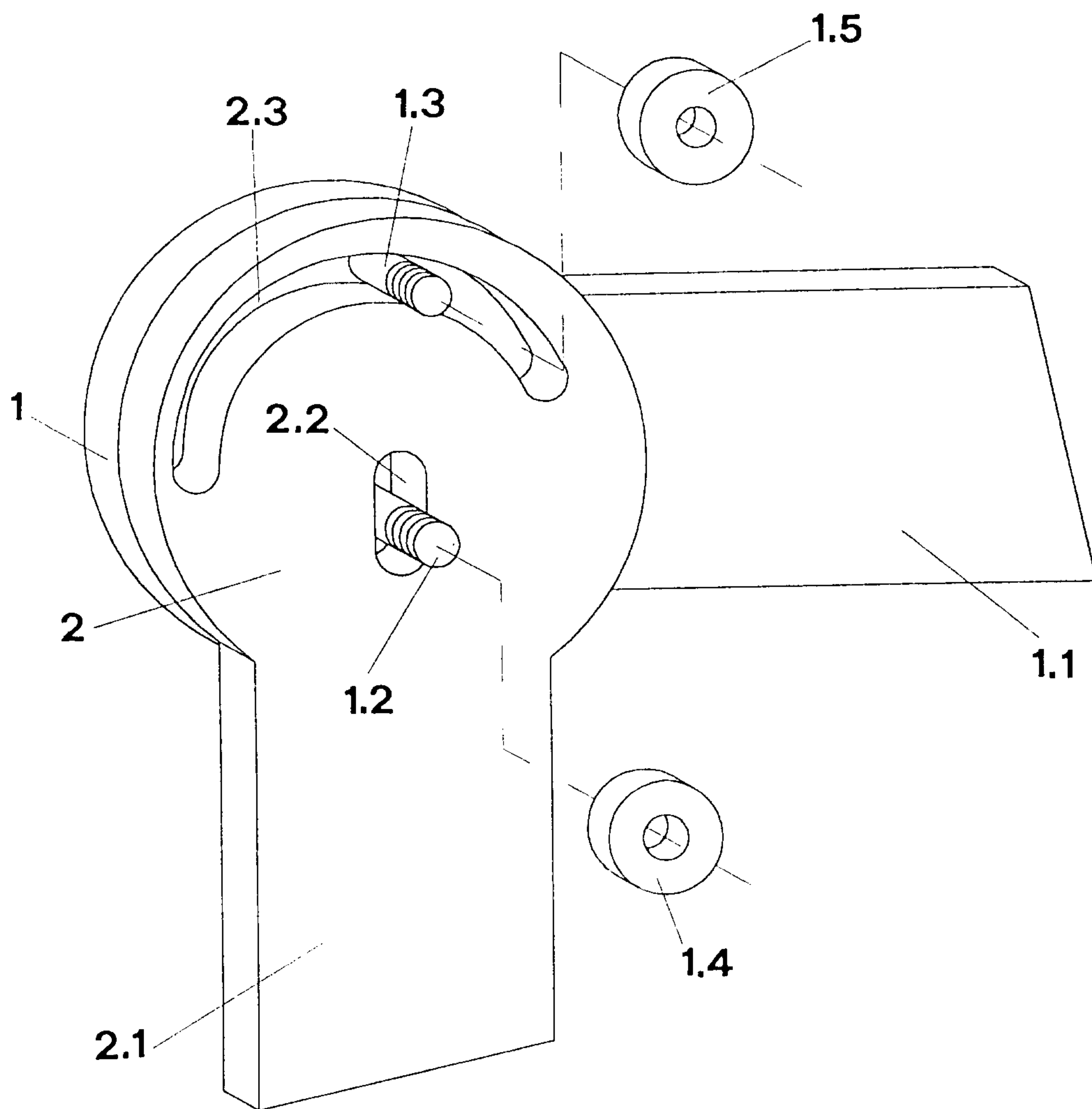


FIG. 8

8/19

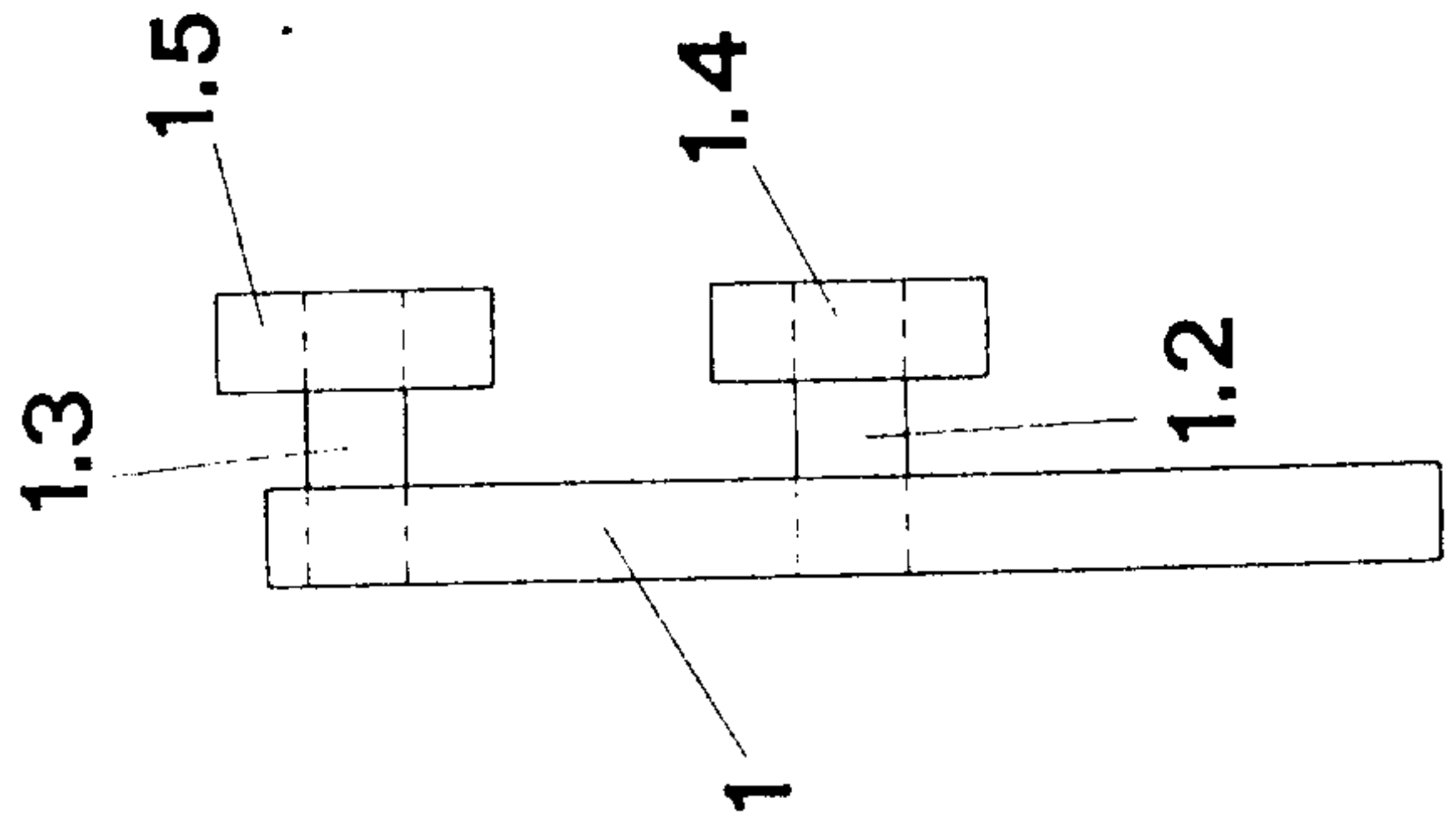


FIG. 10

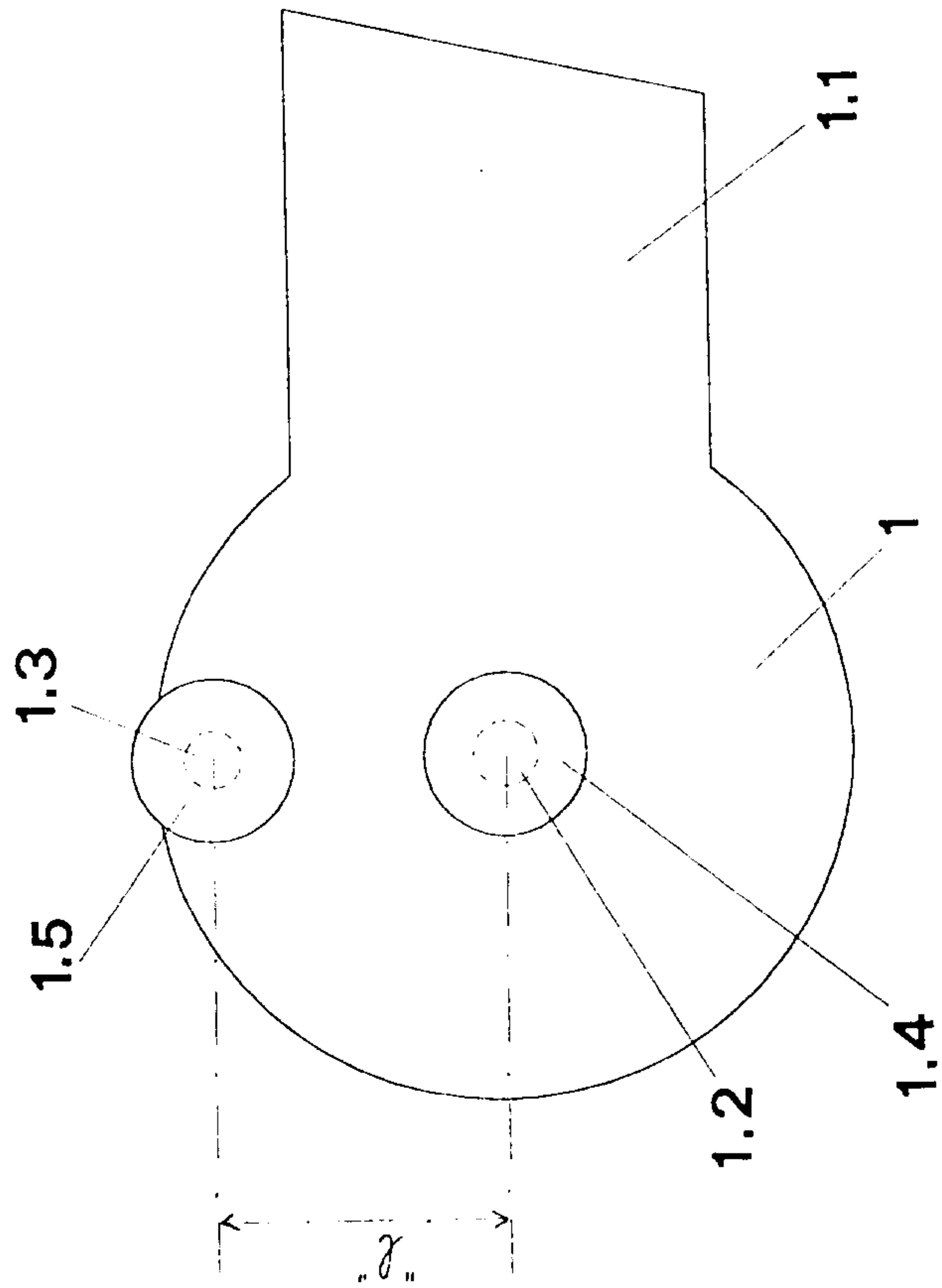


FIG. 9

9/19

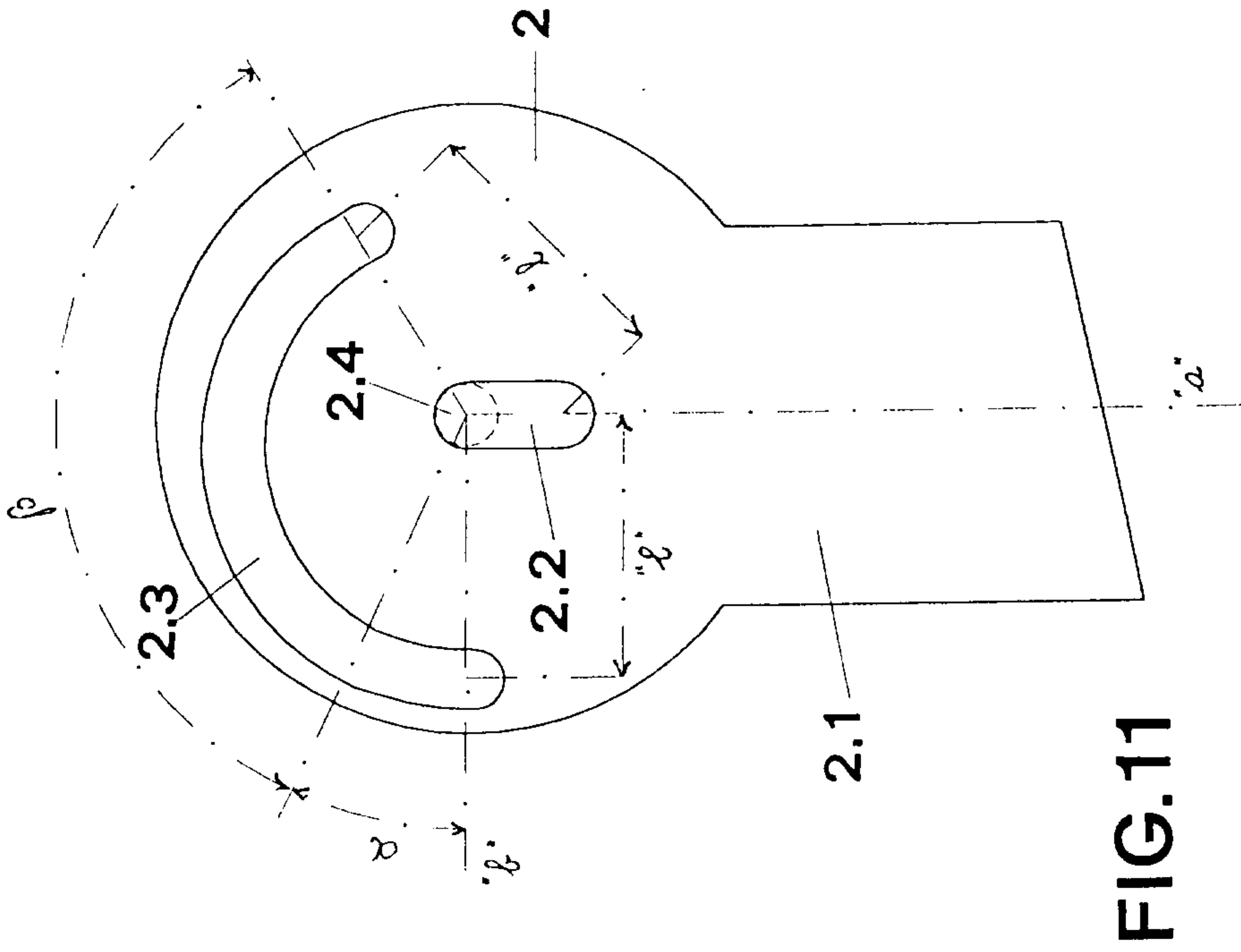


FIG. 11

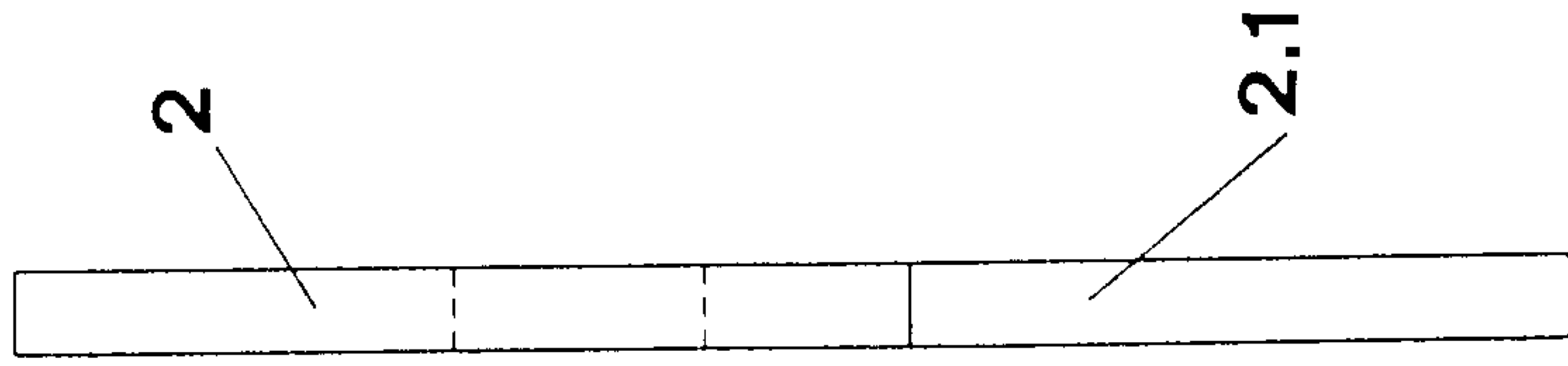
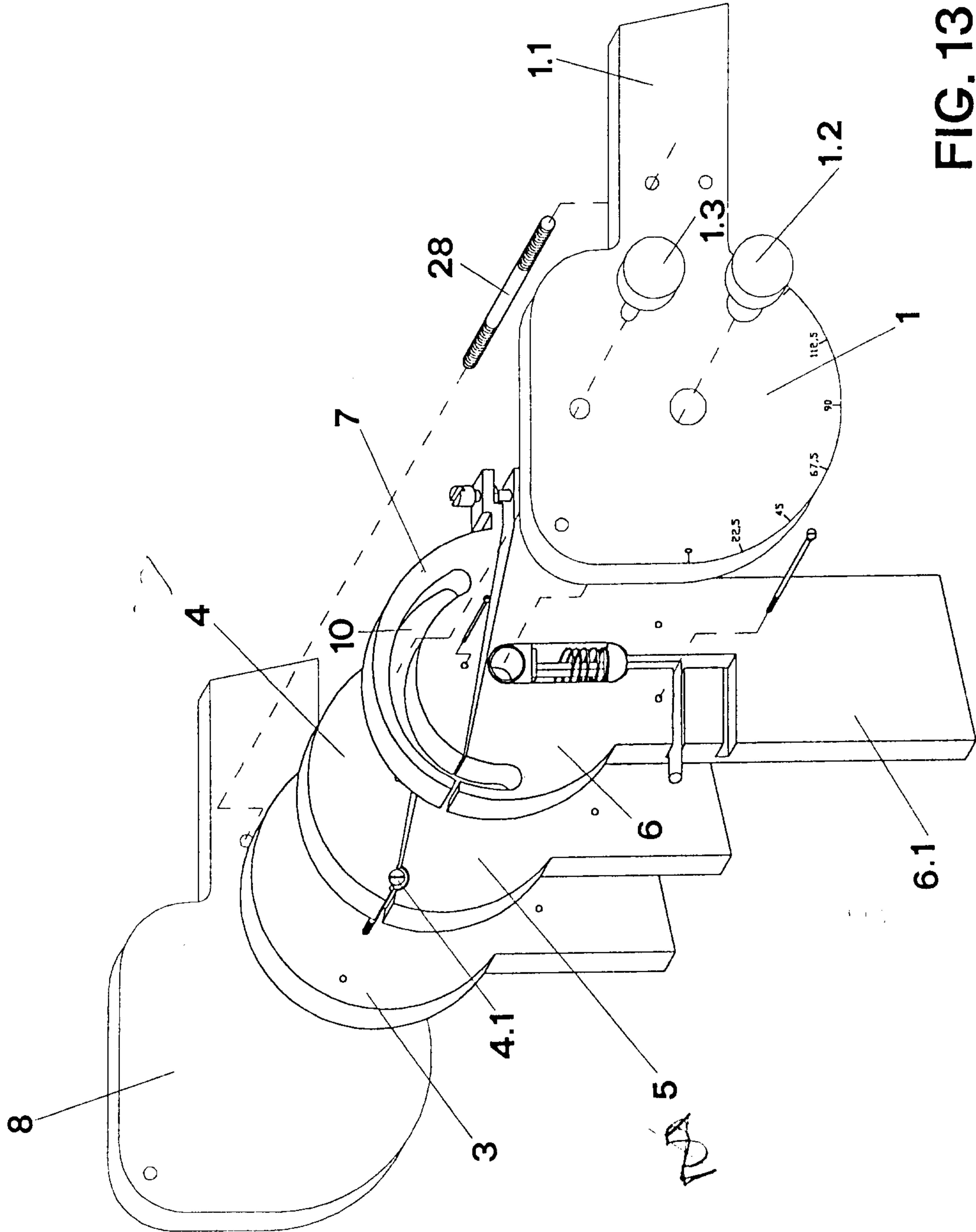


FIG. 12

10/19



11/19

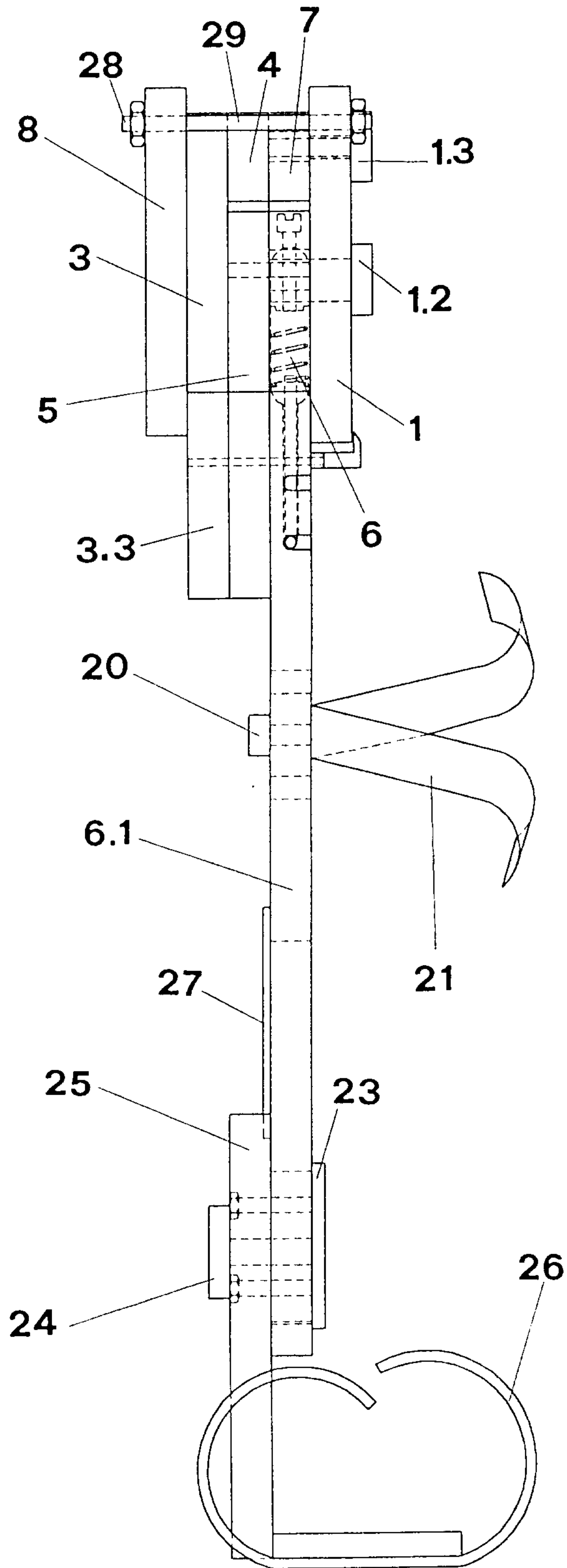


FIG.14

12/19

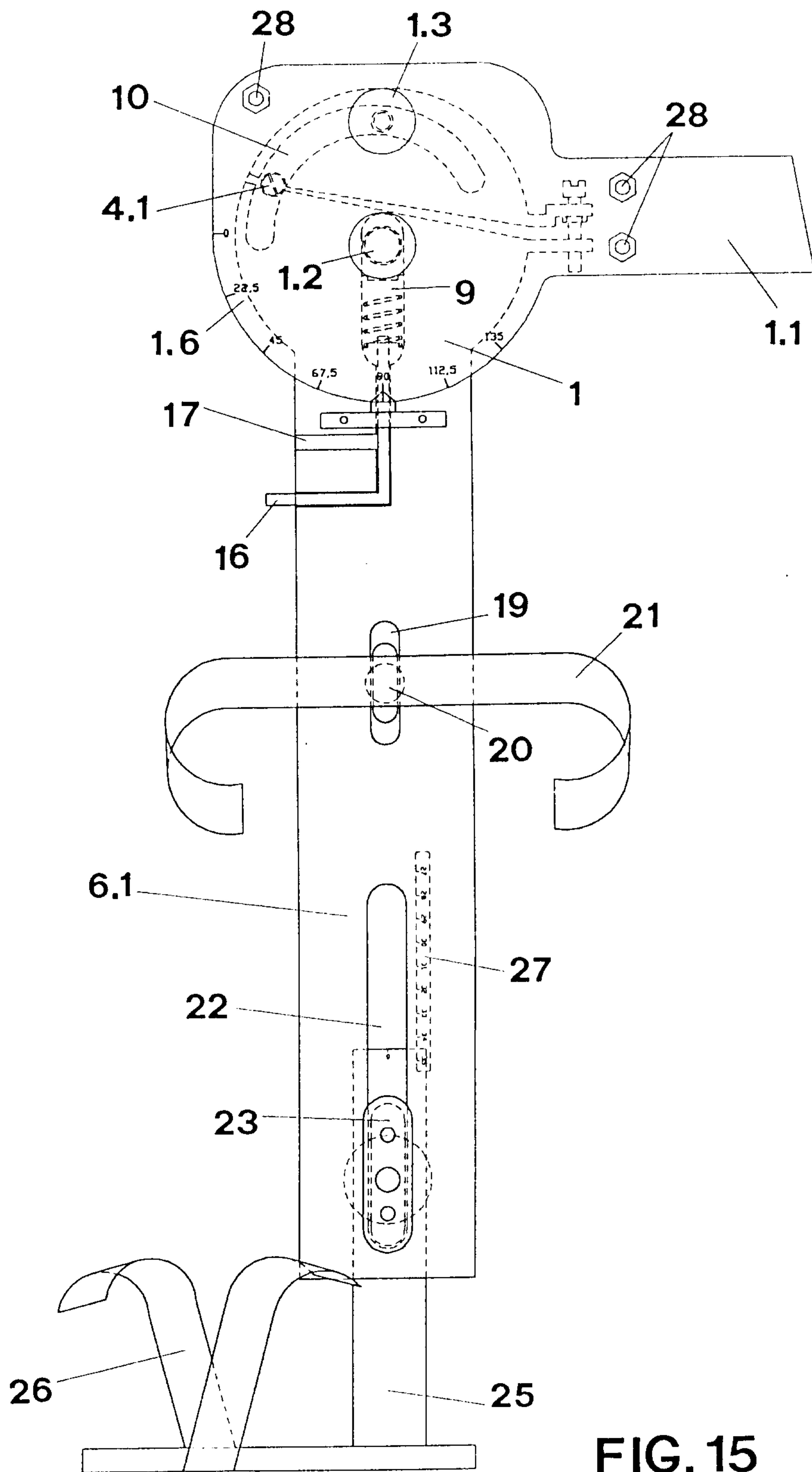


FIG. 15

13/19

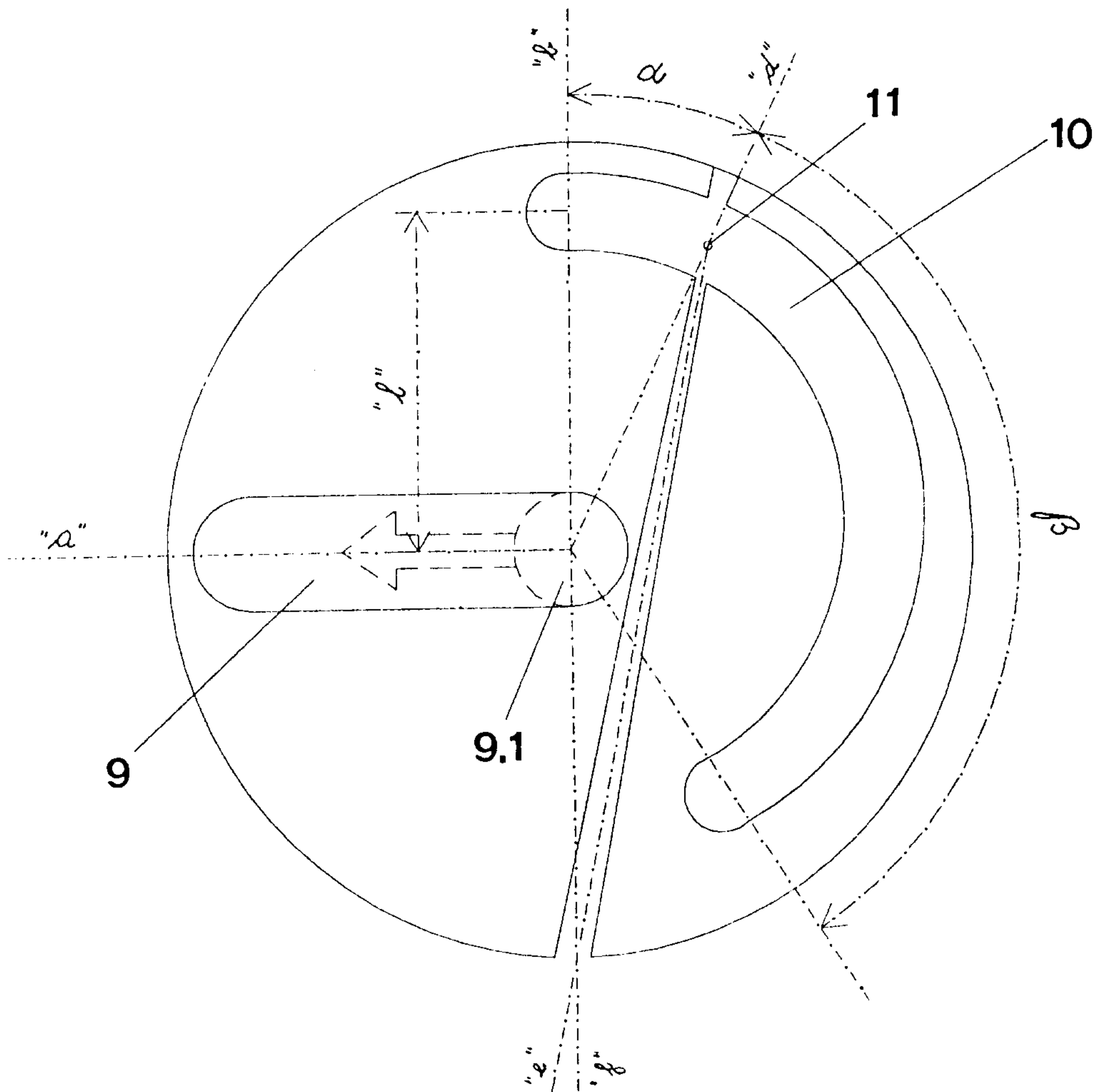


FIG. 16

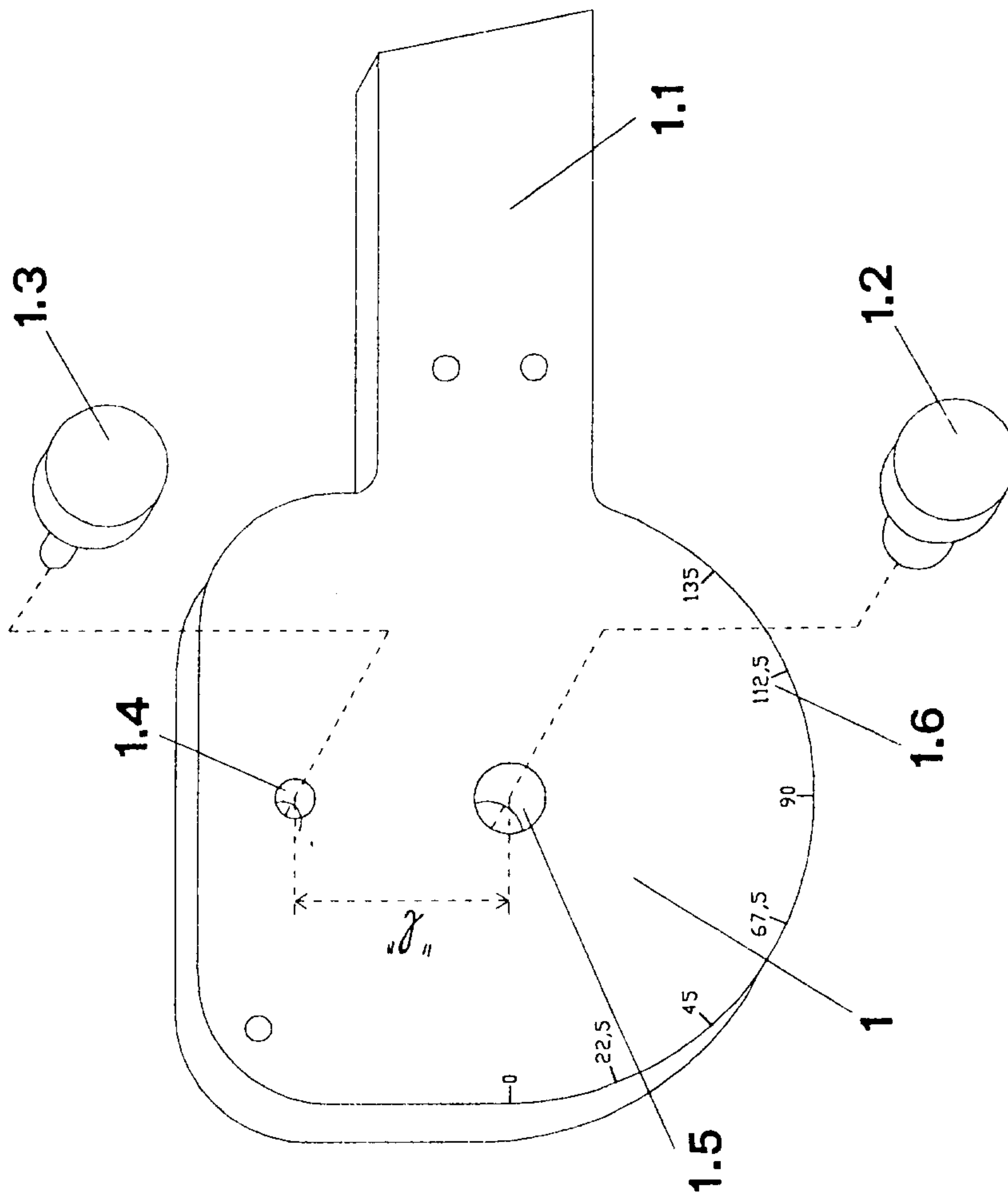


FIG. 17

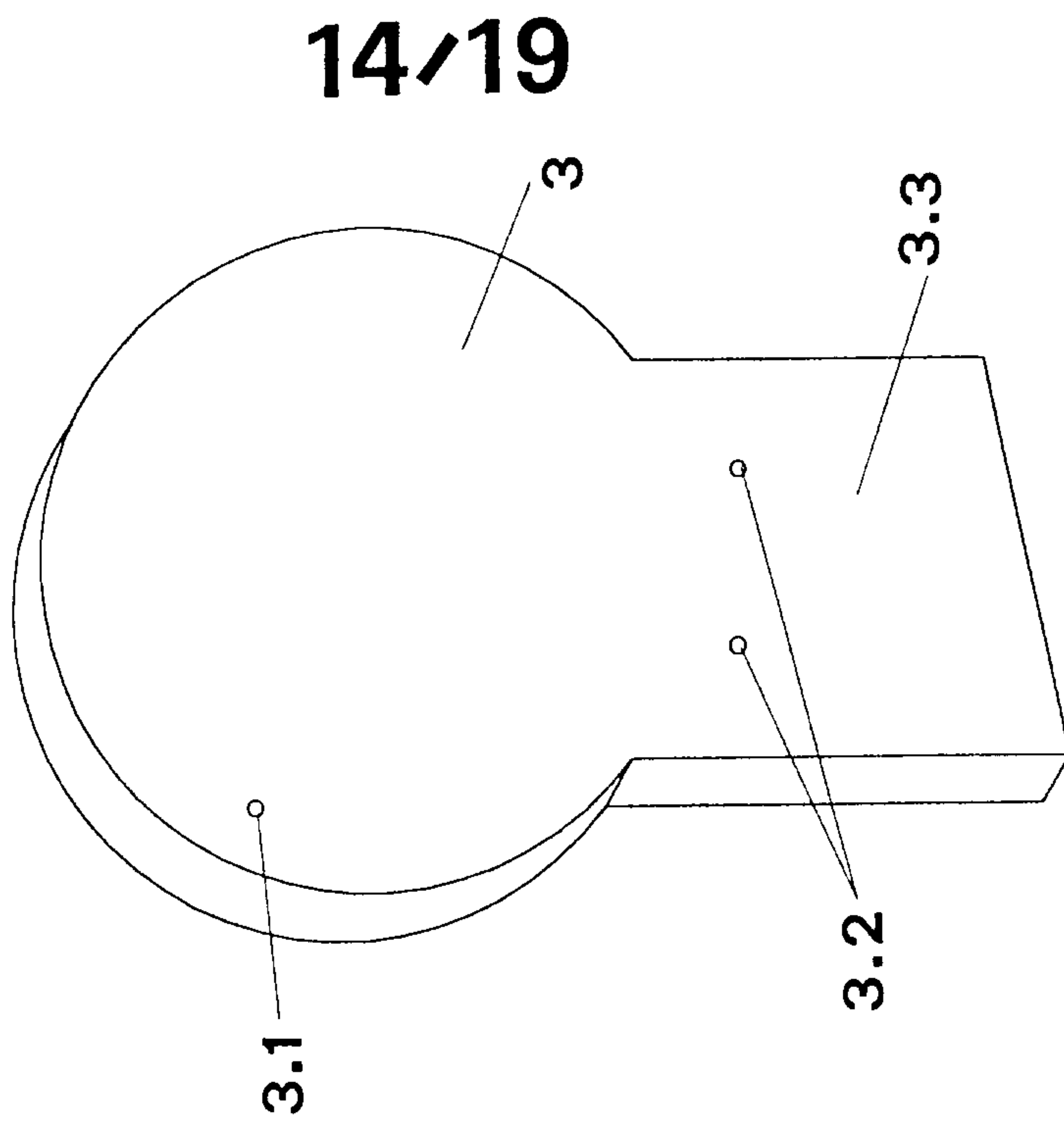
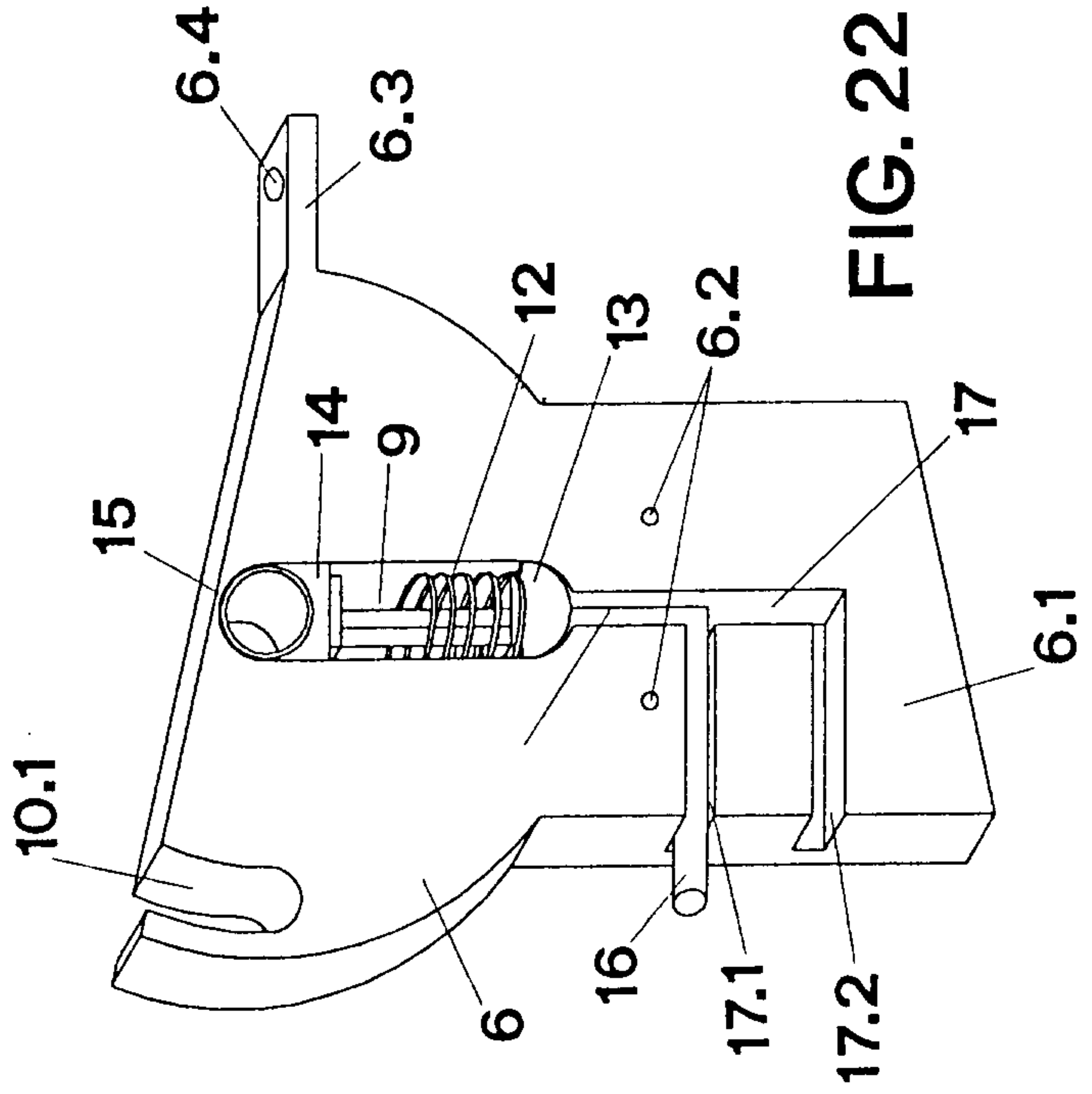
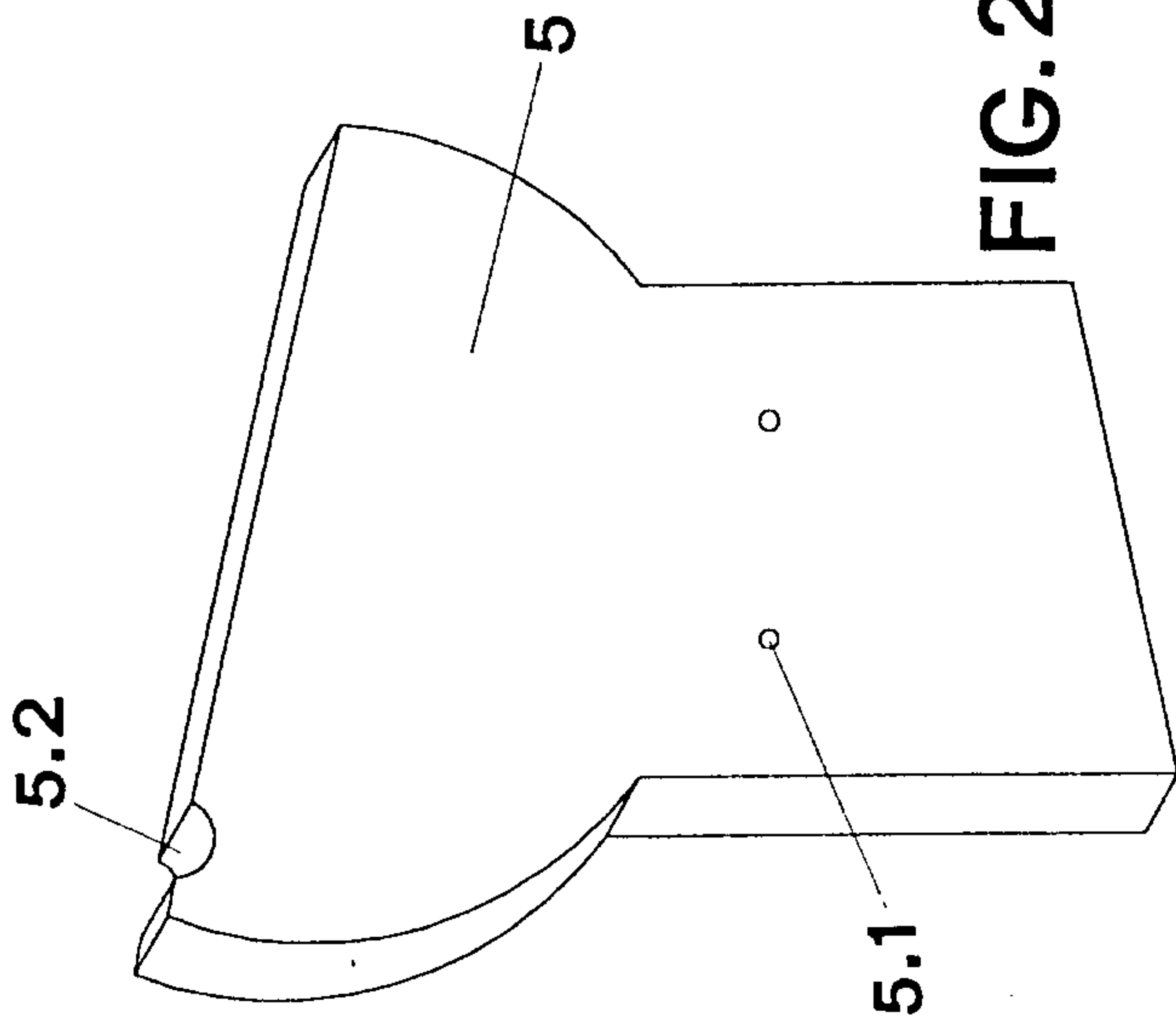
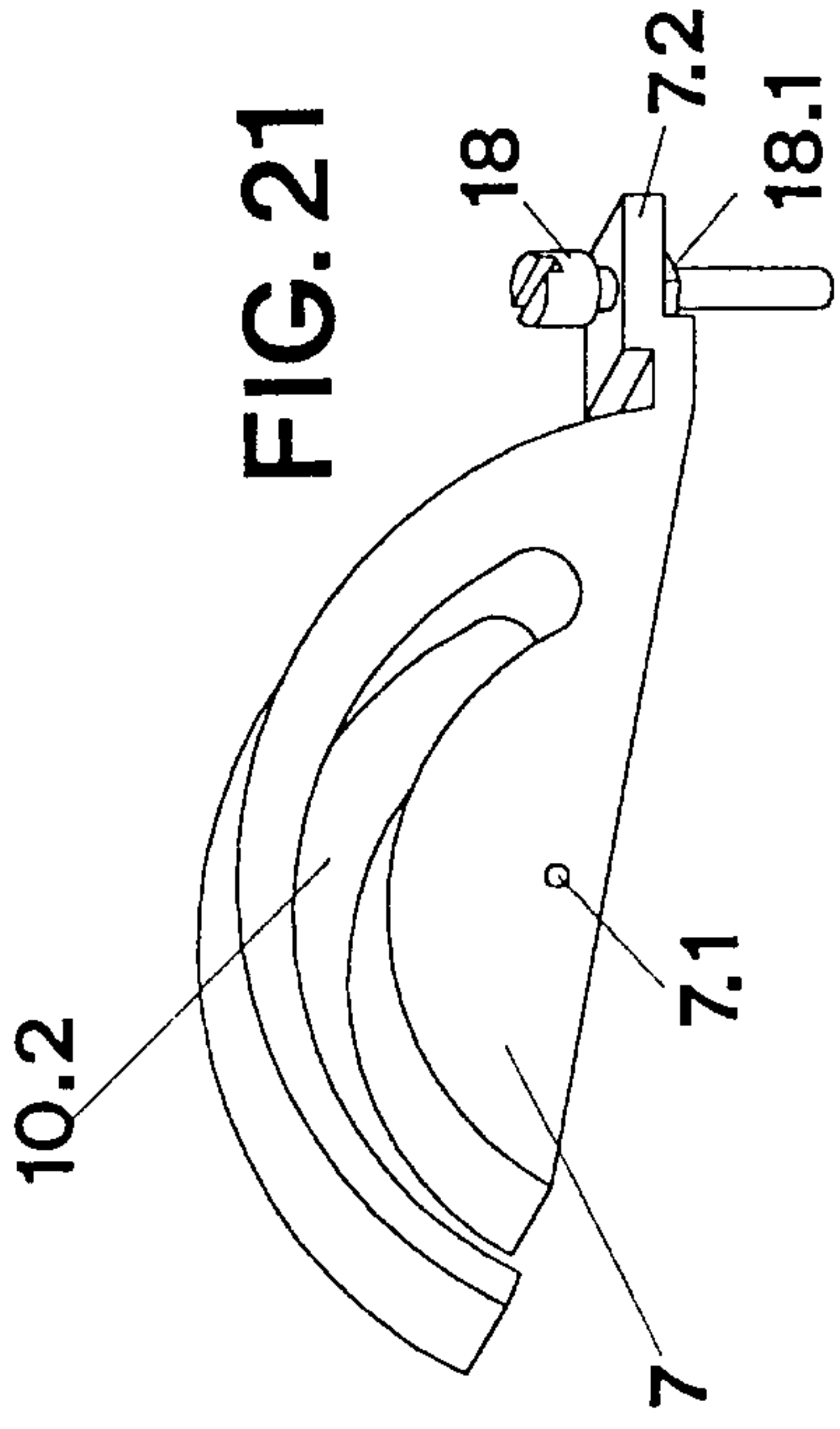
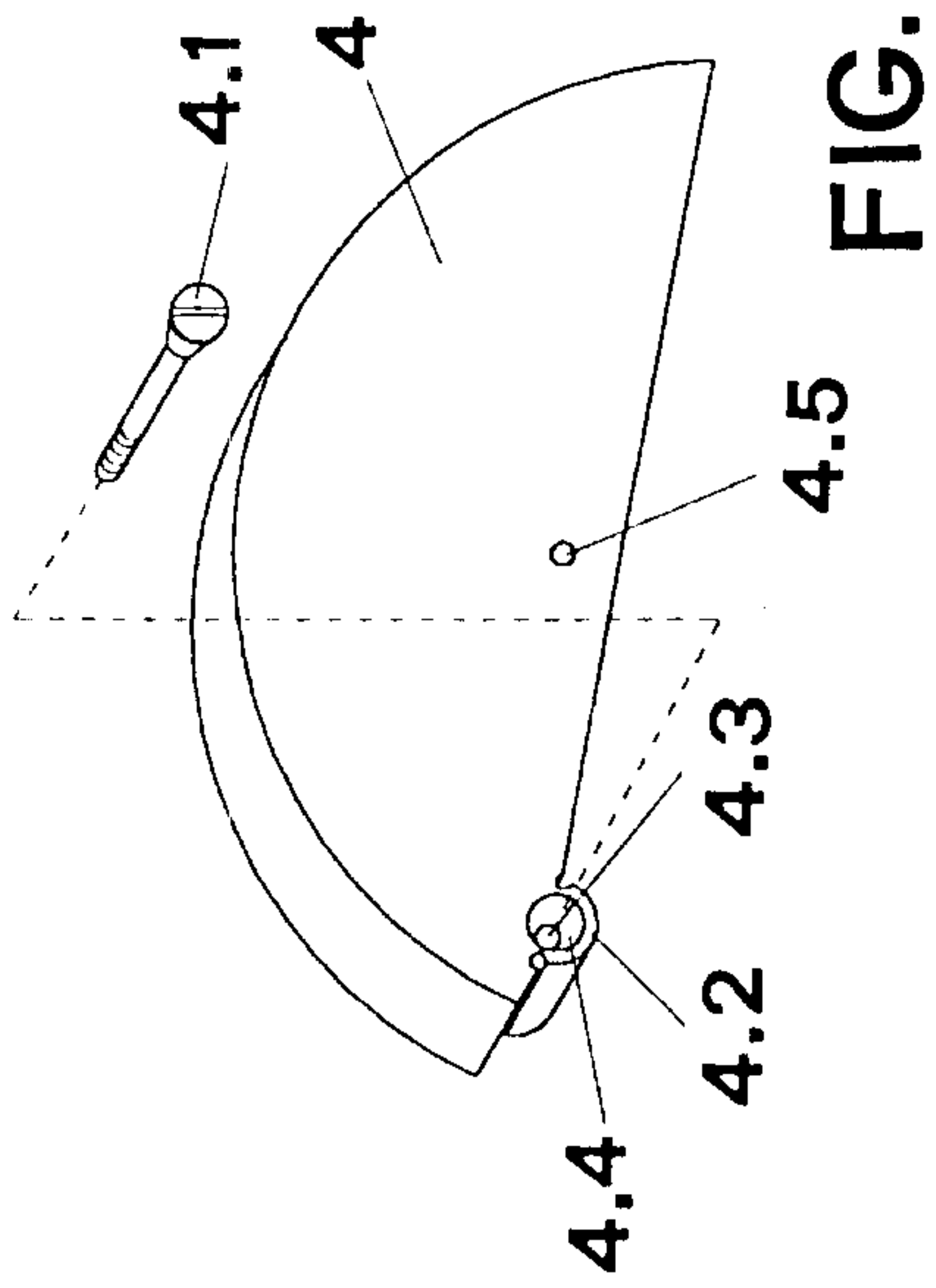


FIG. 18

15/19



16/19

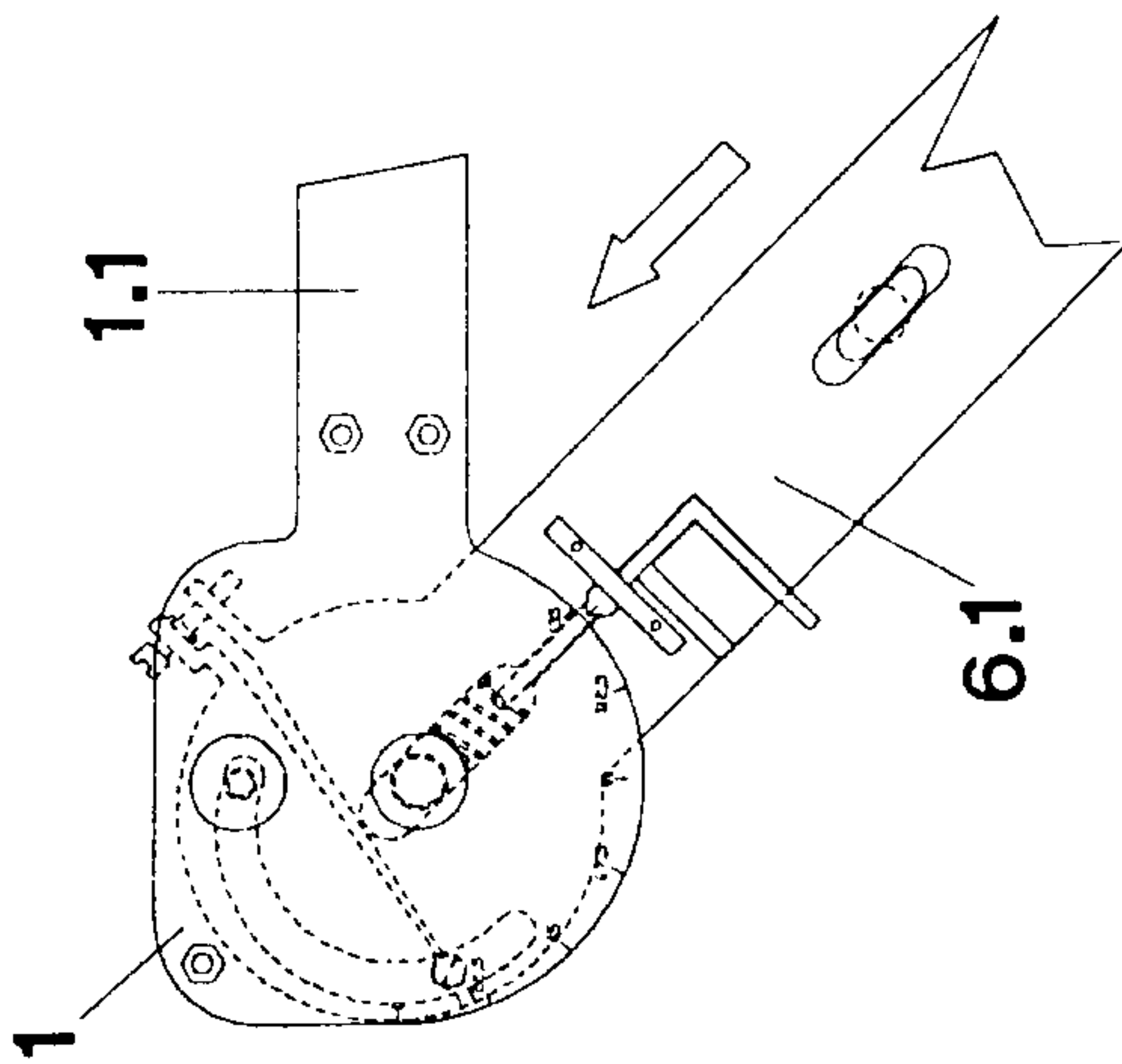


FIG. 23

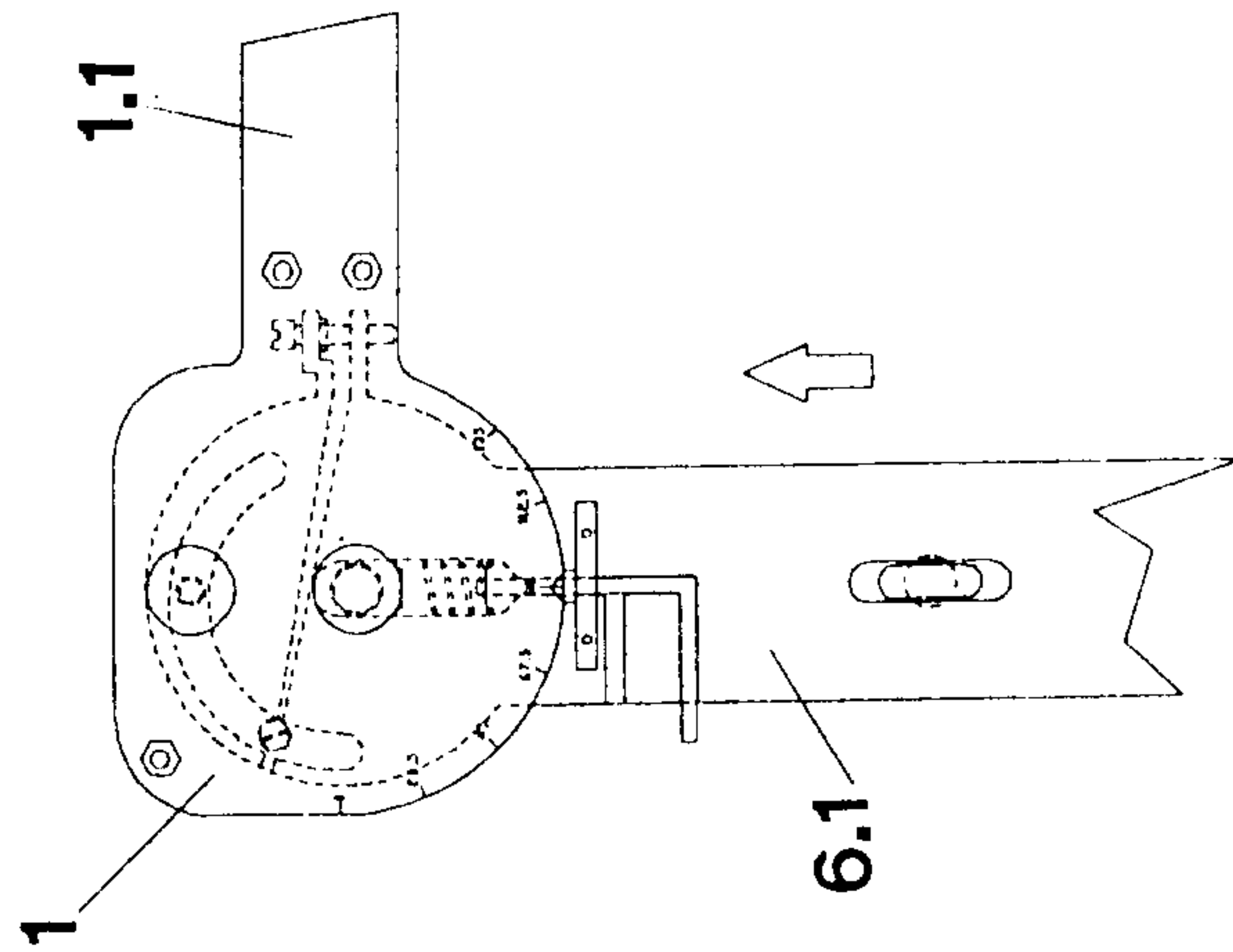
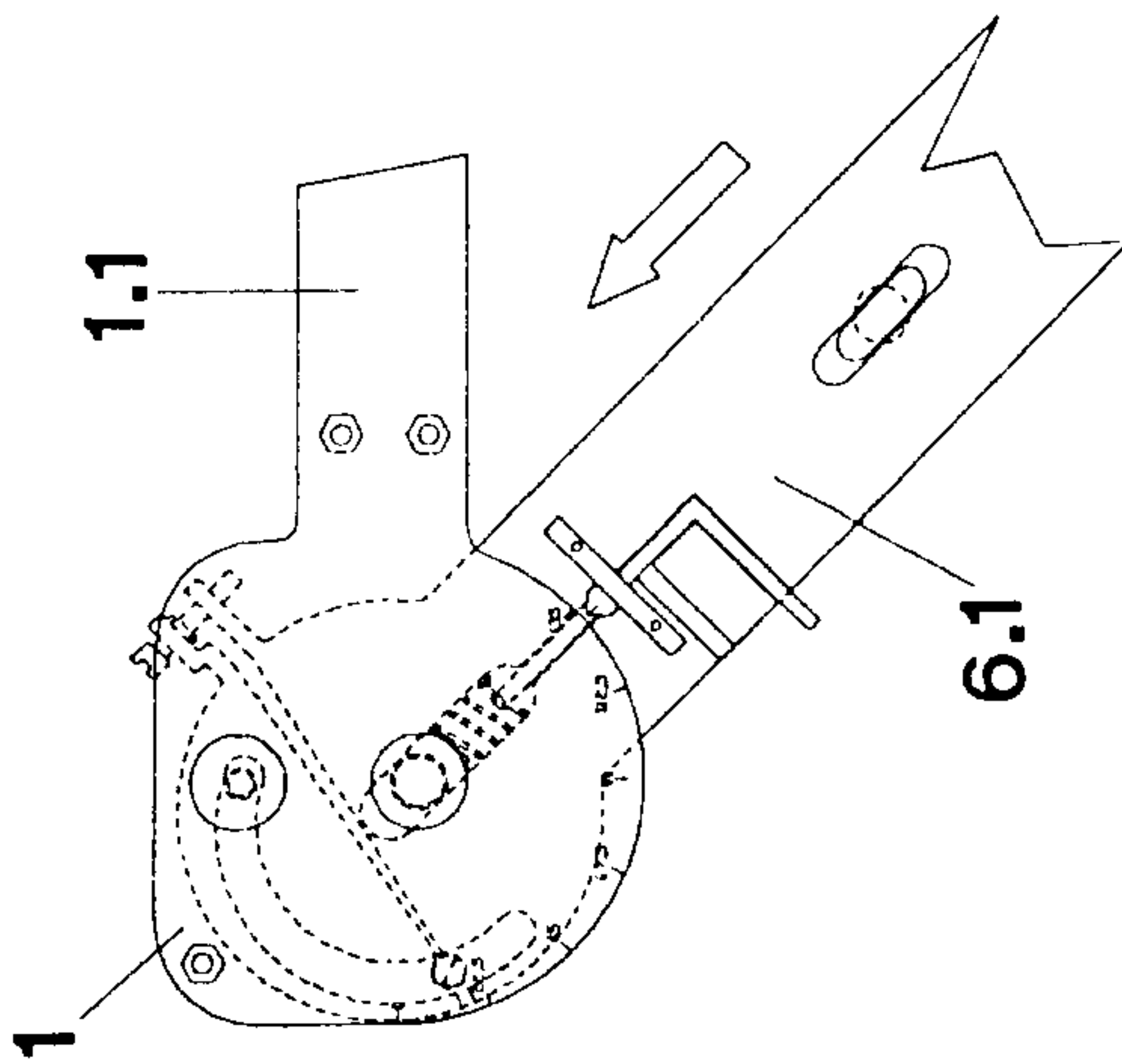
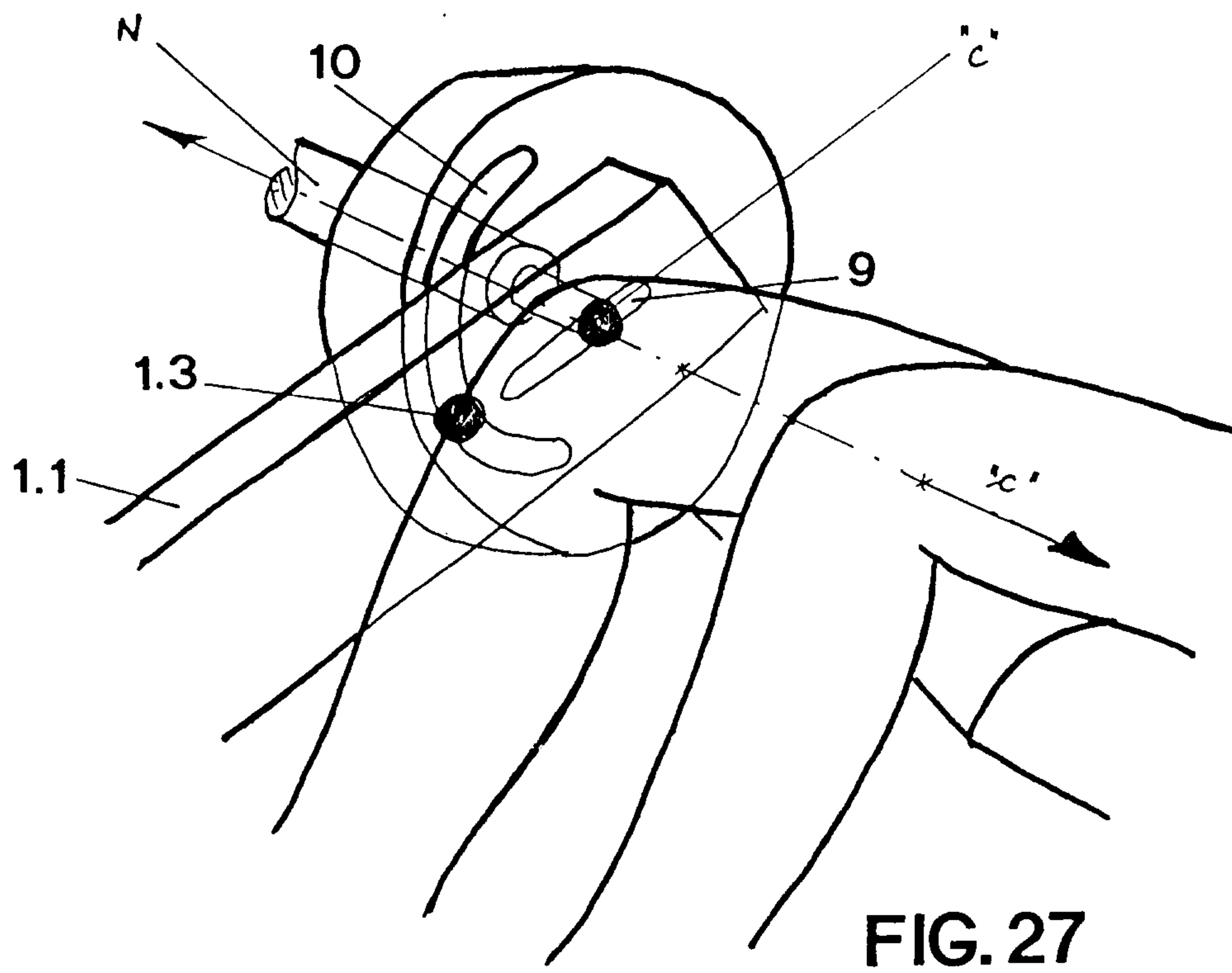
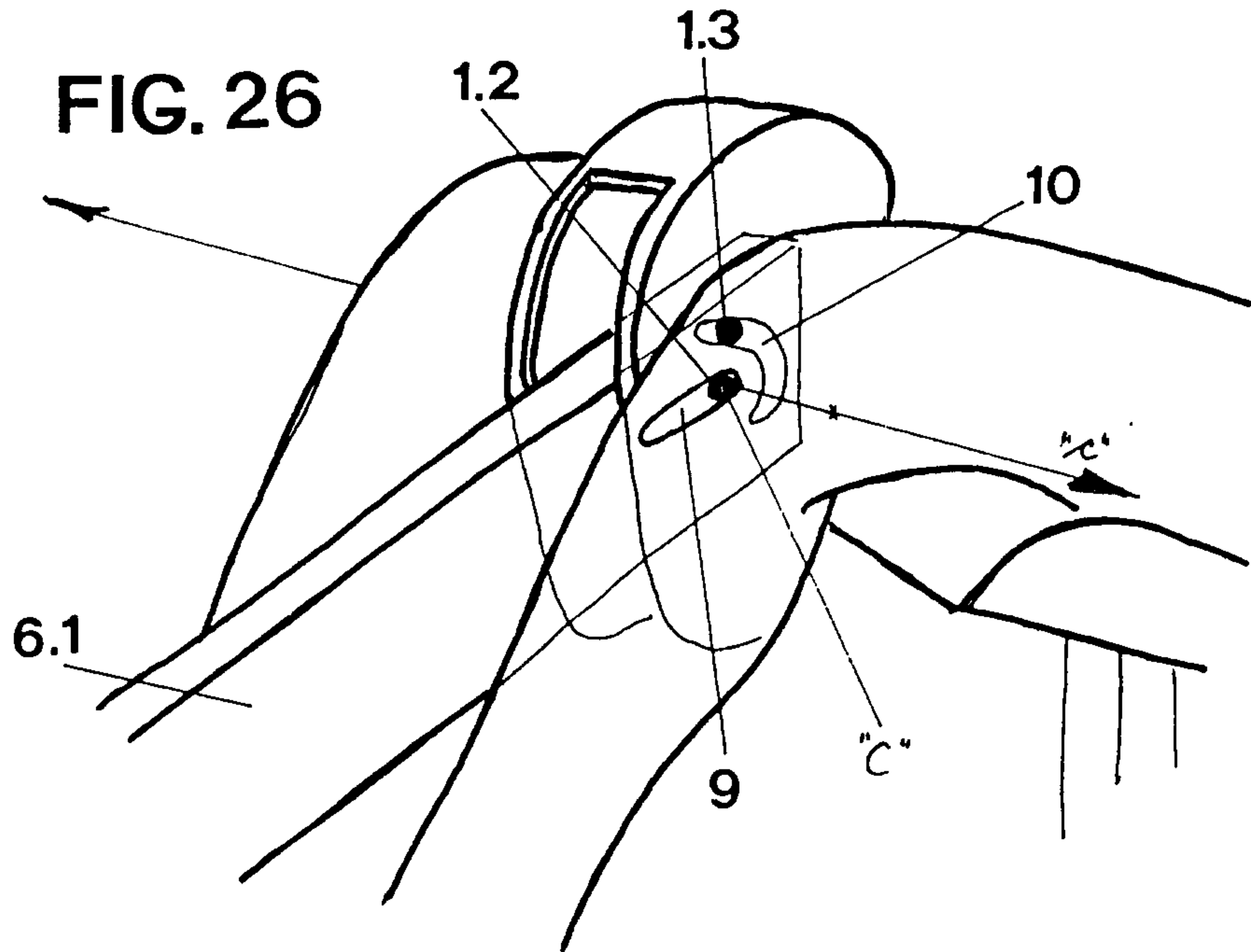


FIG. 24

FIG. 25



17/19



18/19

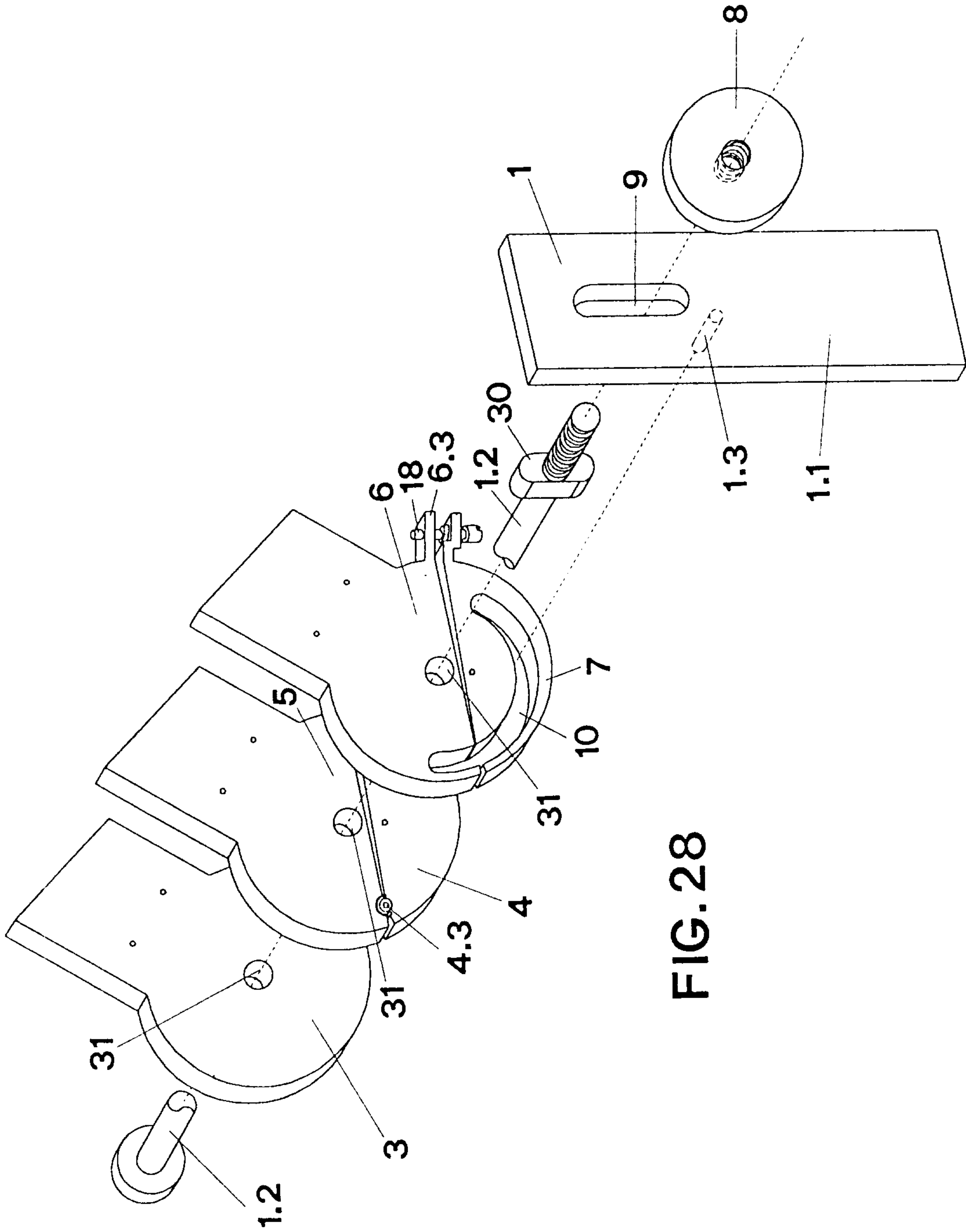


FIG. 28

19/19

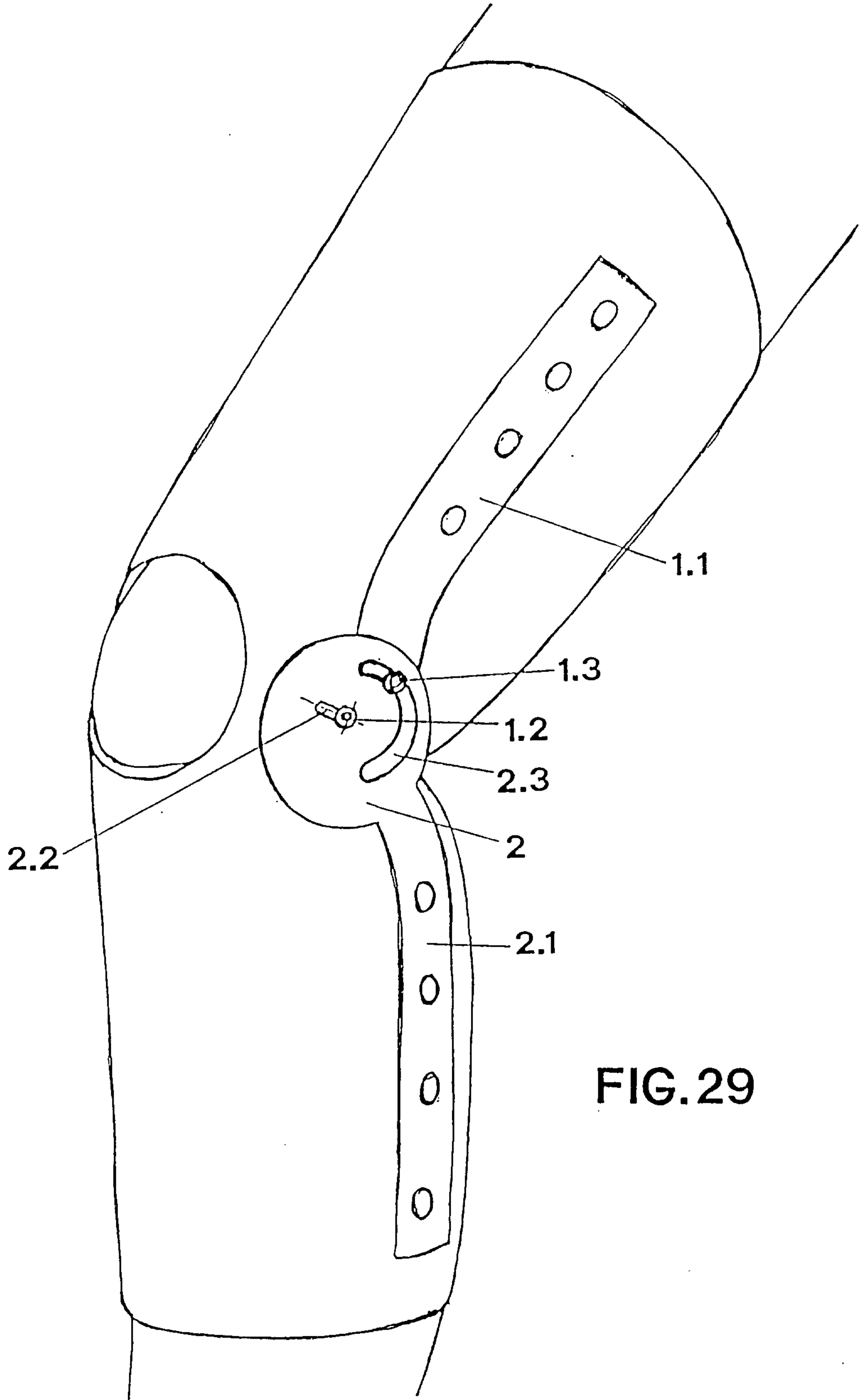
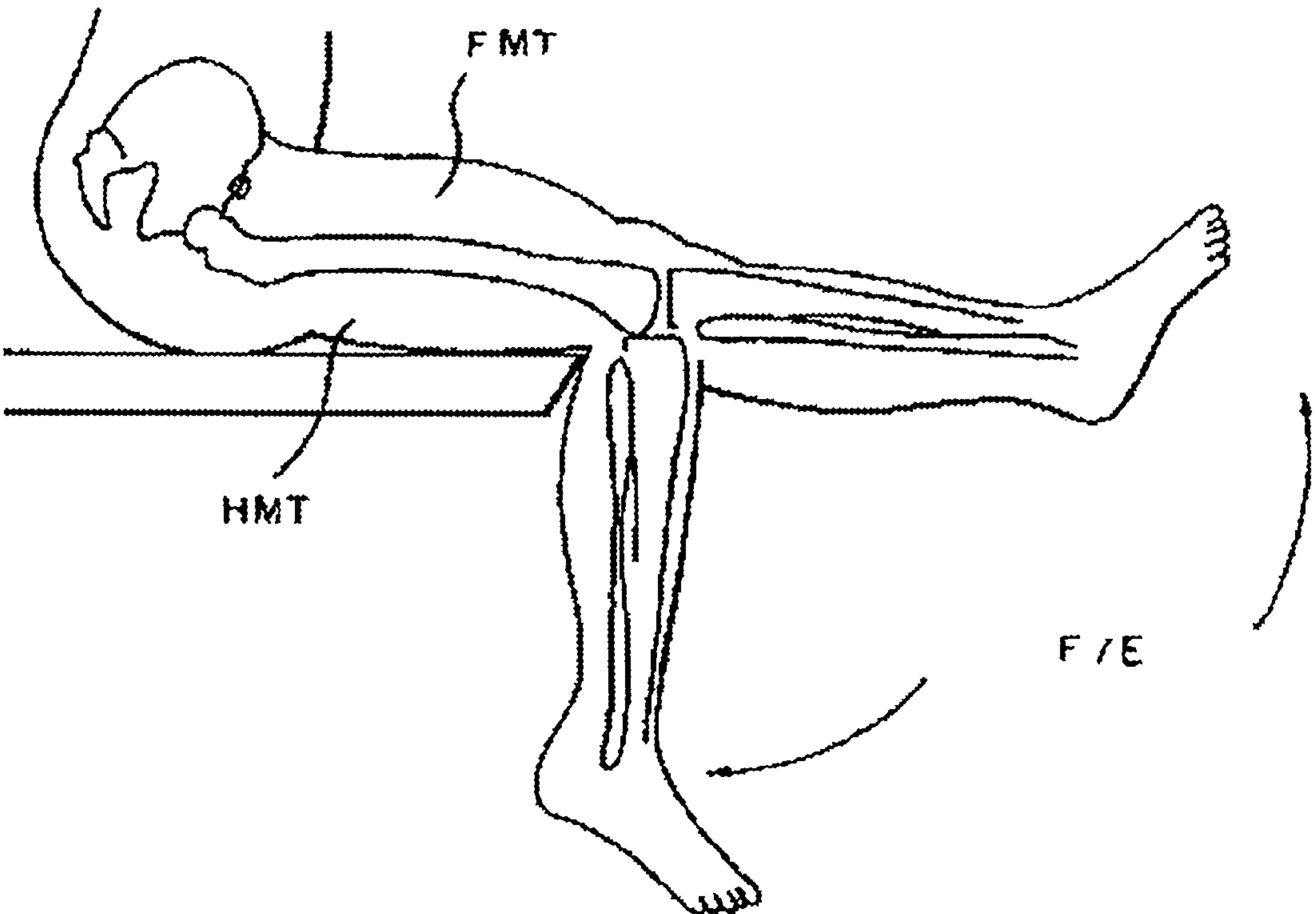


FIG. 29



FMT

HMT

F/E