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(54) CONTROL SYSTEM AND METHOD FOR EXERCISE MACHINE

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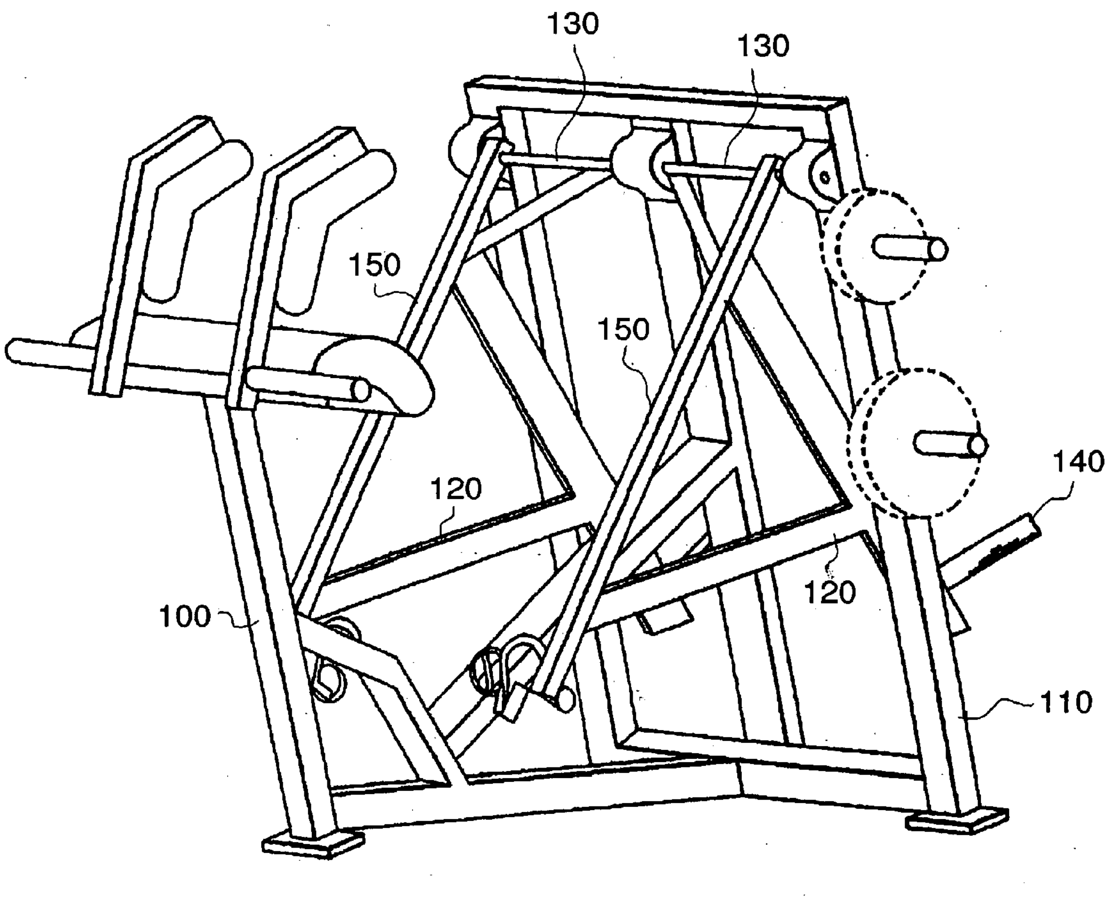
(57) **ABSTRACT**

An exercise machine for simulating running has a frame having a forward portion and a rear portion. A shoulder harness is connected to the forward portion of the frame for supporting the torso of the user and preventing the forward movement of the user's body. Two levers are pivotally connected to the rear portion of the frame, and a pedal assembly is connected to each lever, for receiving the foot of the user. In one embodiment, a passive means for generating a counter force is connected between the lever and the rear frame, such as an elastic band, spring, torsion bar or hydraulic cylinder. In another embodiment a hydraulic or pneumatic actuator is connected between each lever and the frame, and an active control system is operatively connected to each actuator; the active control system being configured to generate a counter force to the user according to a preselected program.



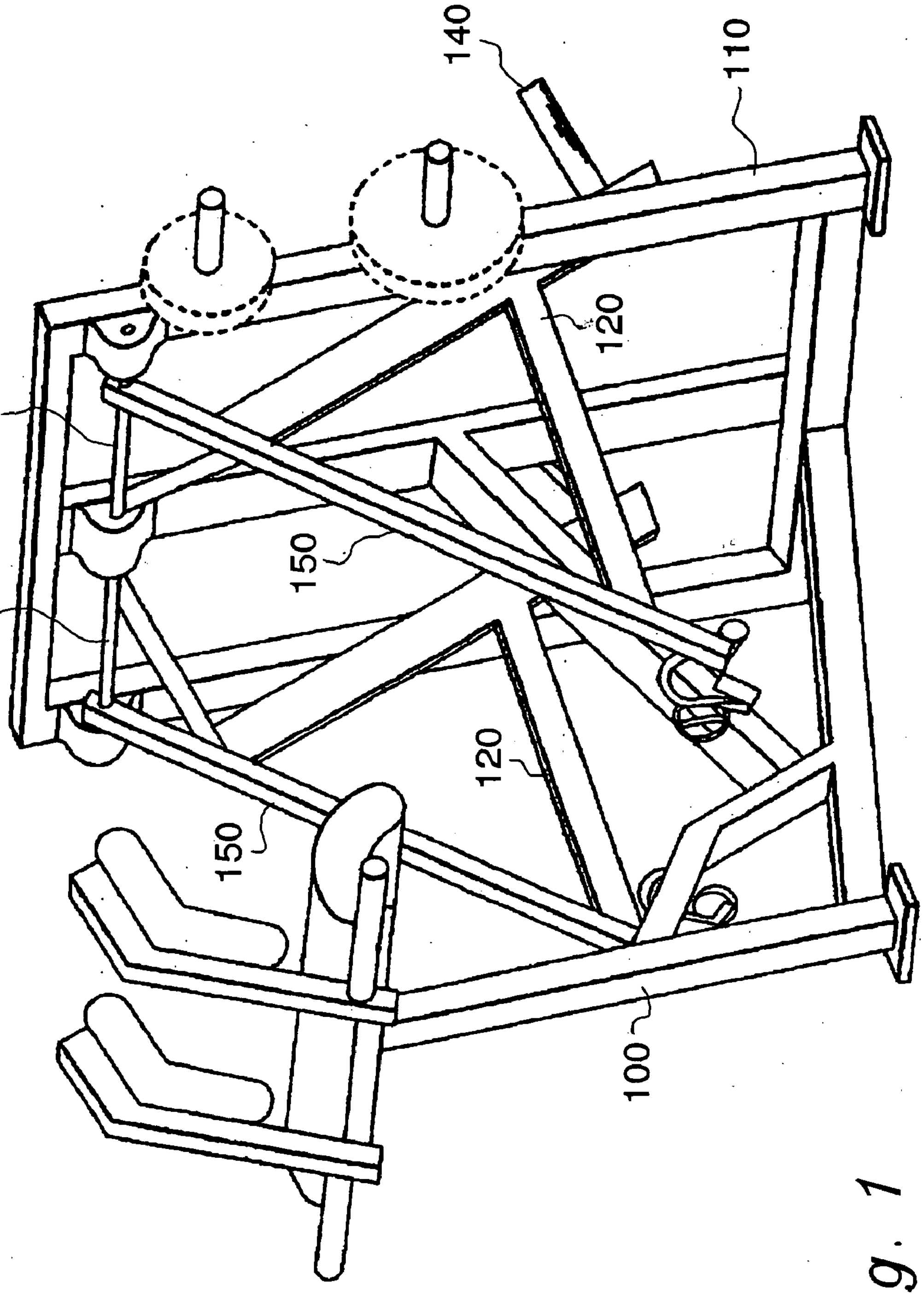
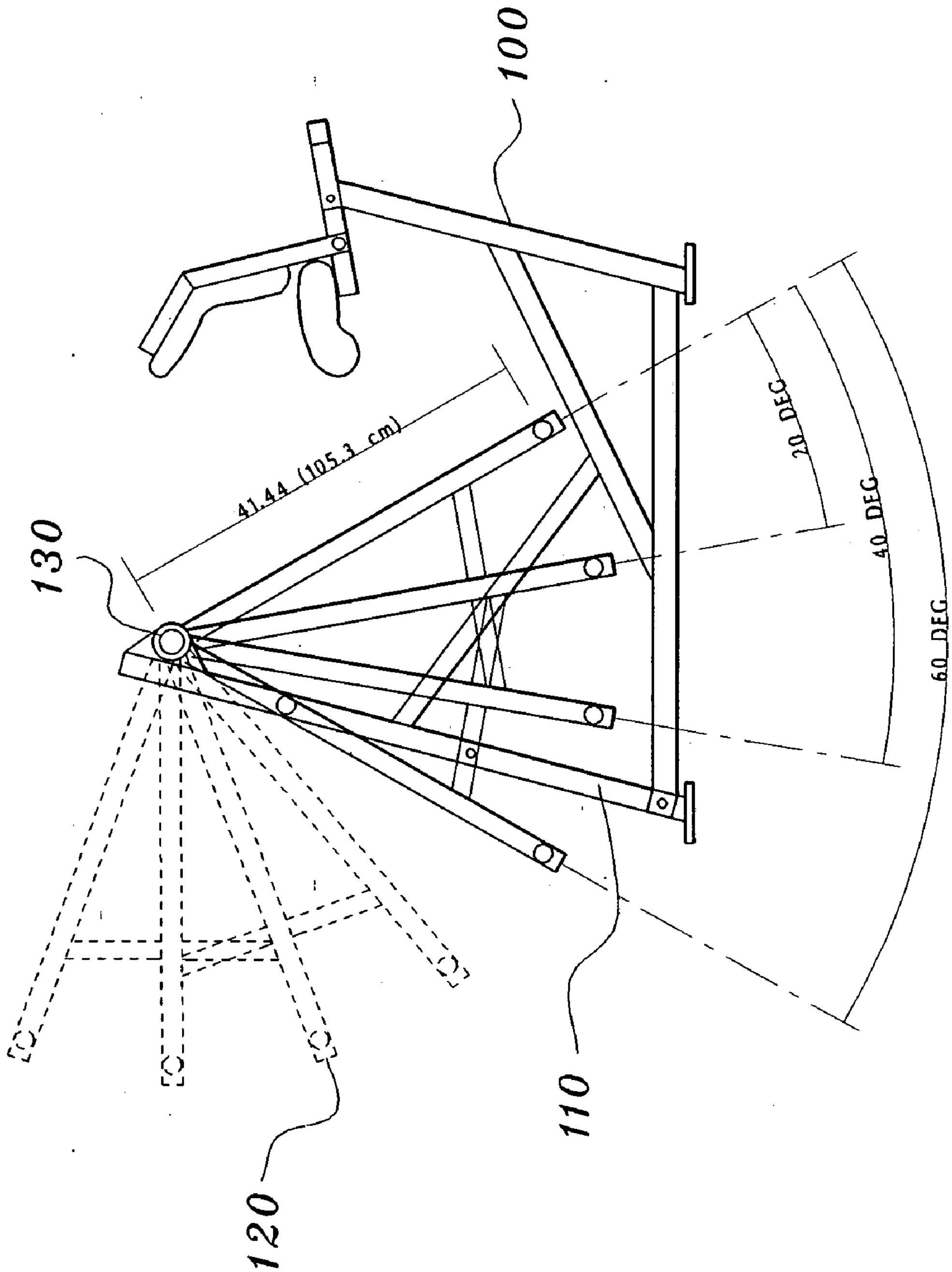


Fig. 1

Fig. 2



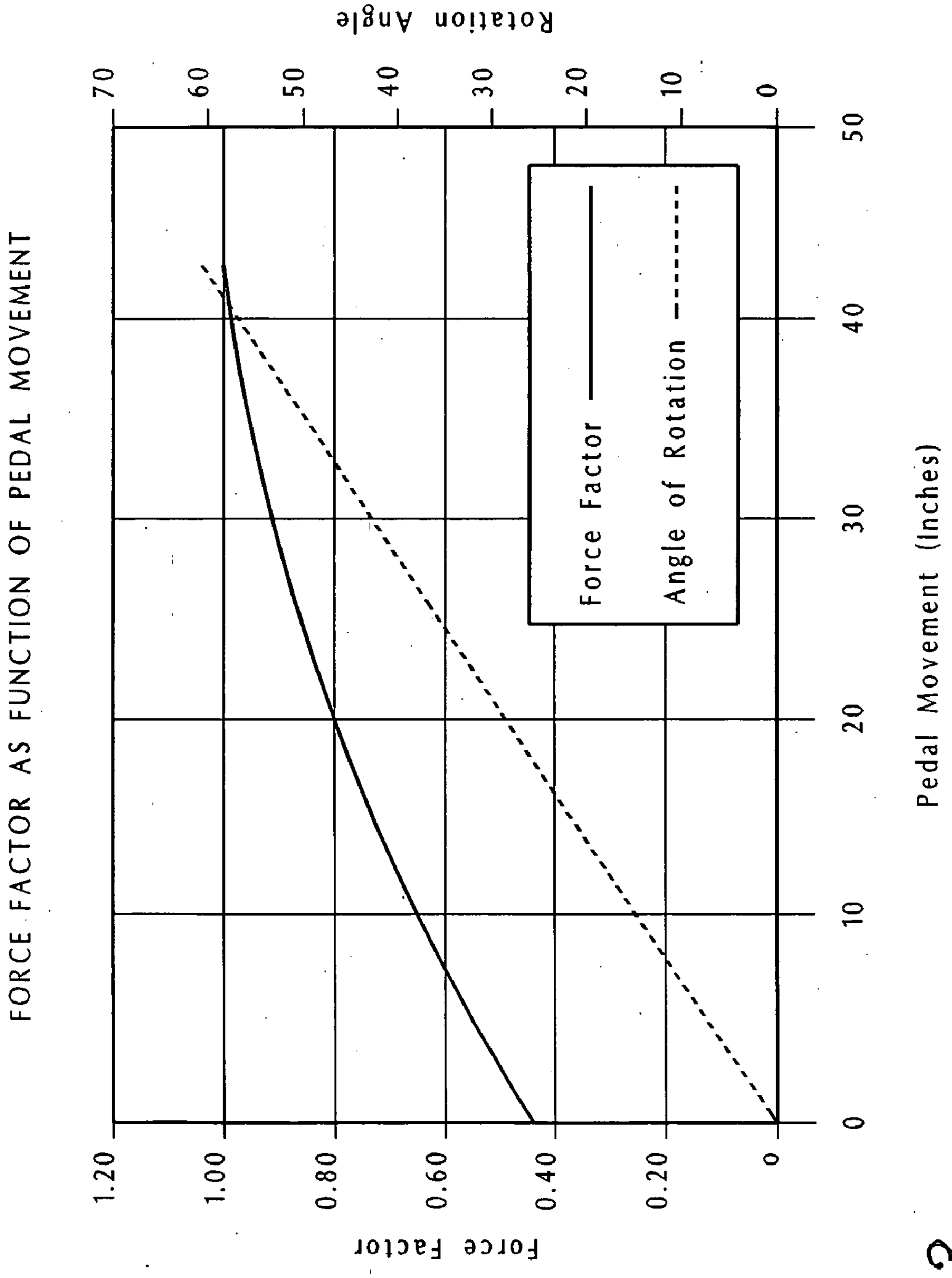

FORCE FACTOR AS FUNCTION OF PEDAL MOVEMENT
Rotation Angle
70
60
50
40
30
20
10
0
Force Factor
1.20
1.00
0.80
0.60
0.40
0.20
0
Pedal Movement (Inches)
0
10
20
30
40
50
Force Factor
Angle of Rotation

Fig. 3

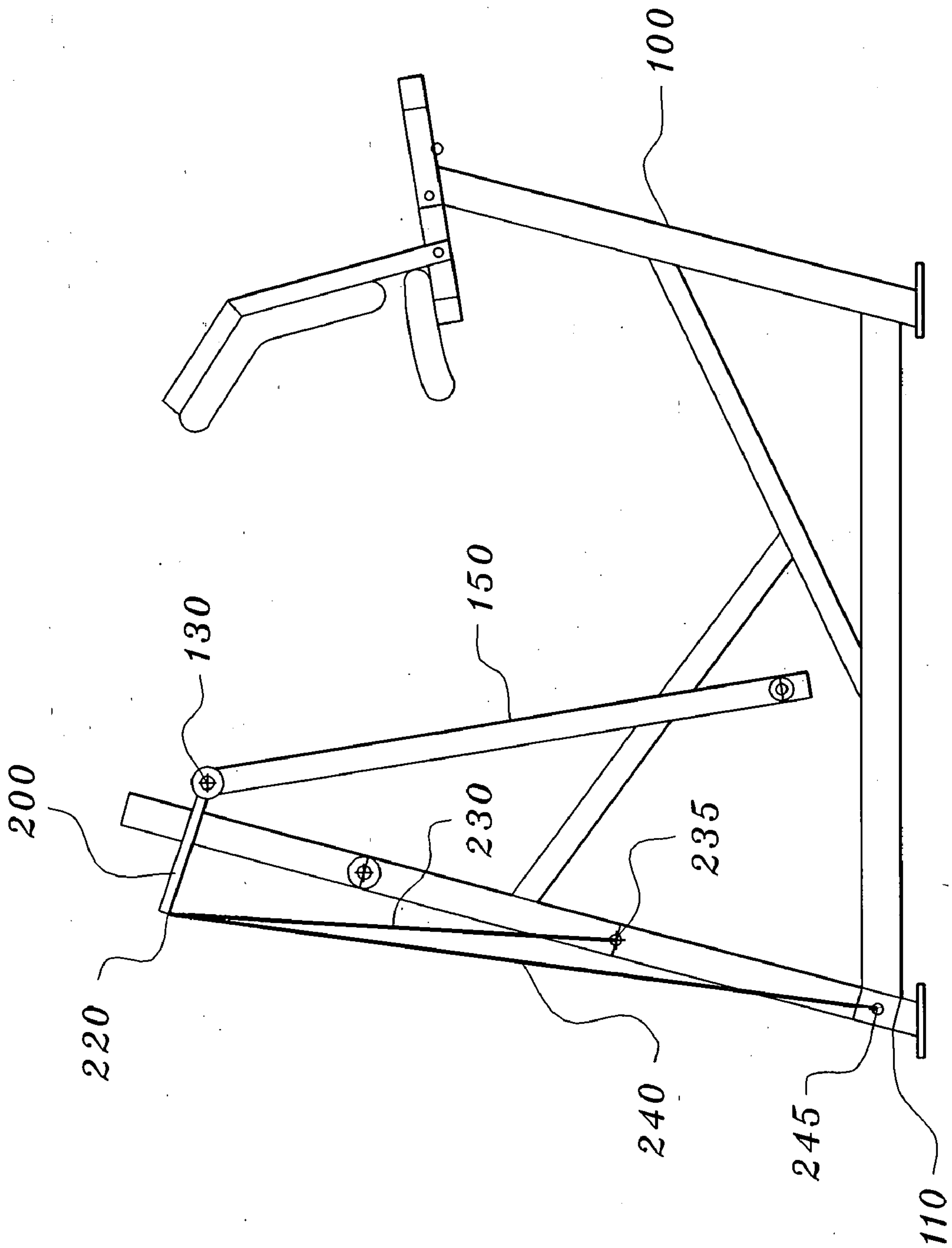


Fig. 4

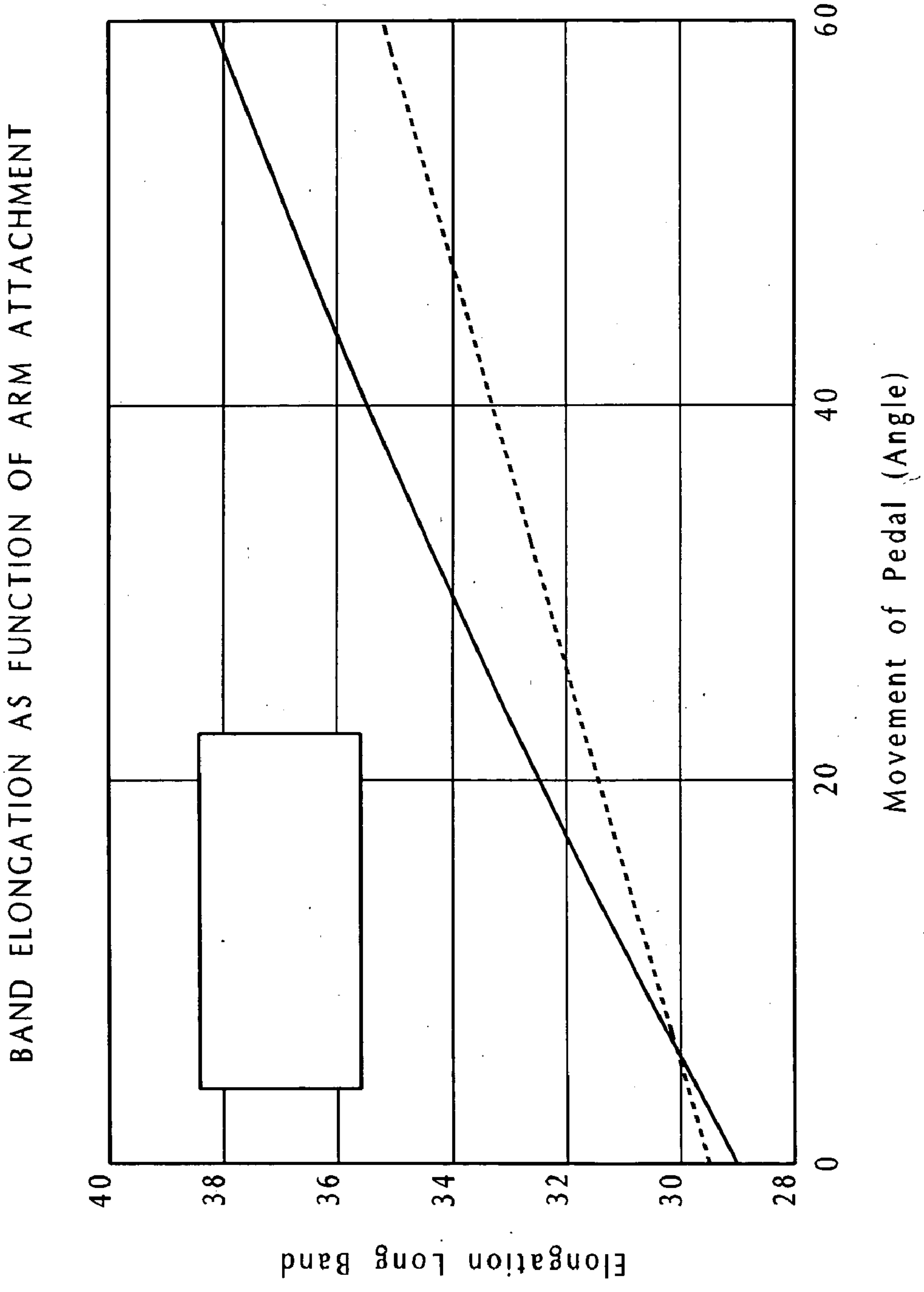

BAND ELONGATION AS FUNCTION OF ARM ATTACHMENT
Elongation Long Band
40
38
36
34
32
30
28
0
20
40
60
Movement of Pedal (Angle)

Fig. 5

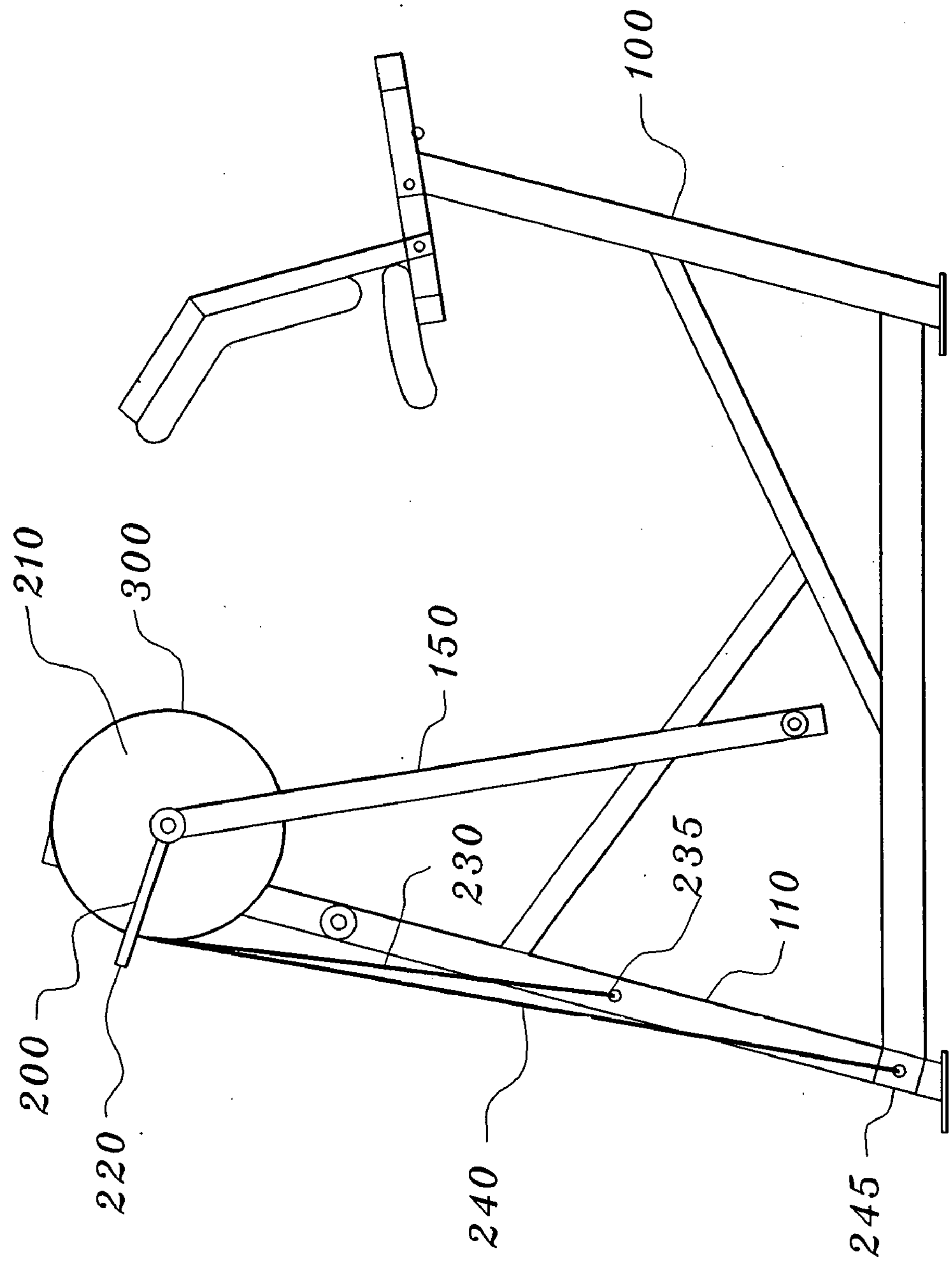


Fig. 6

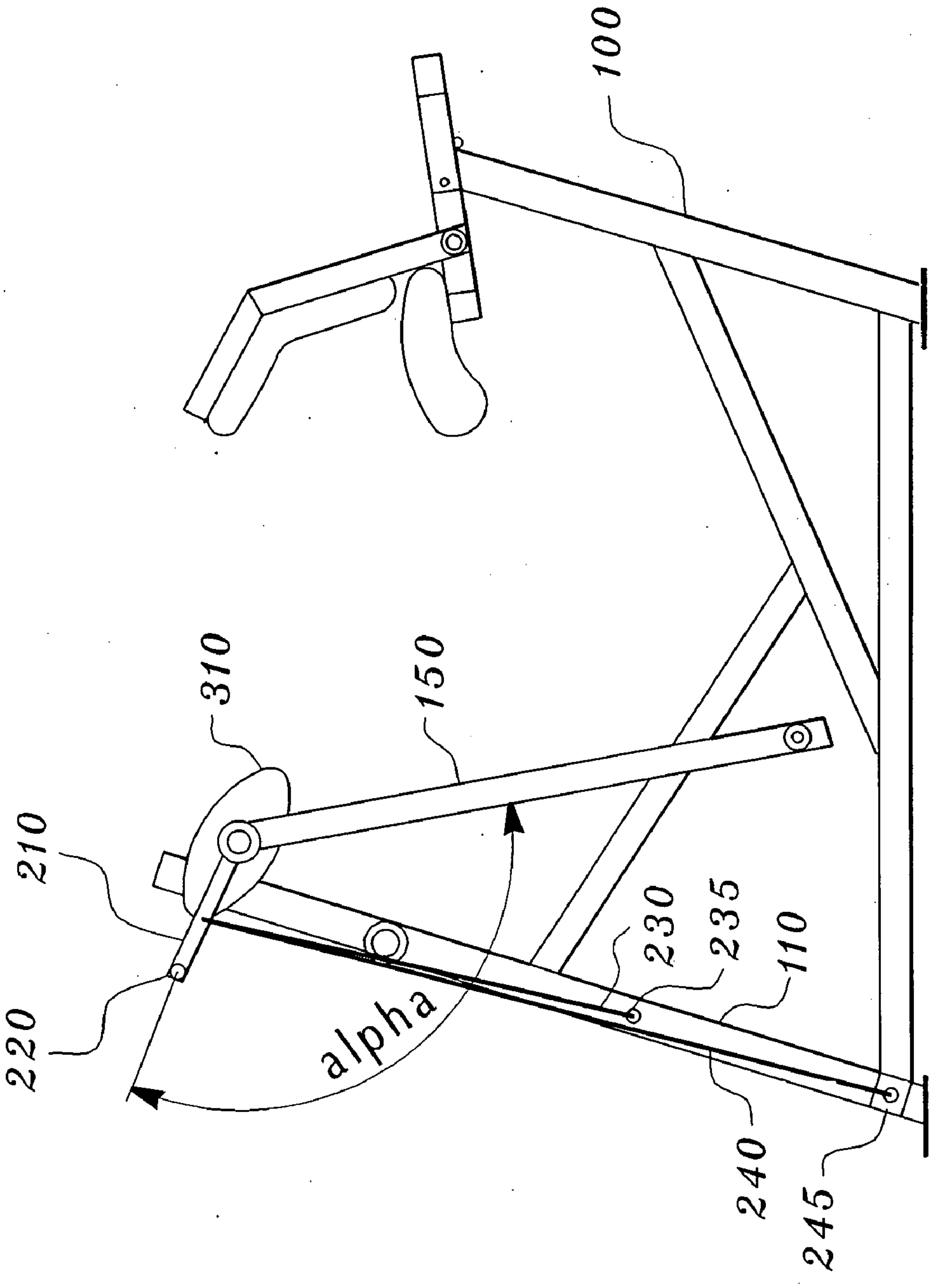


Fig. 7

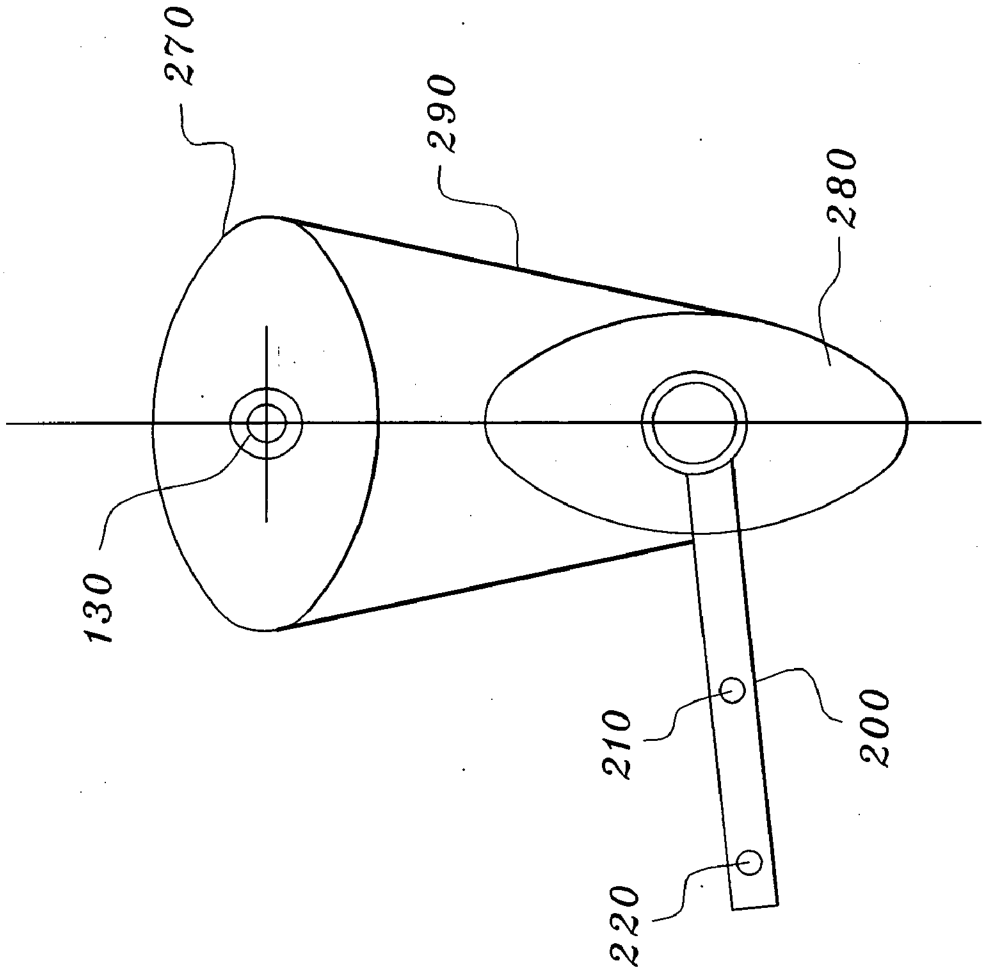


Fig. 8

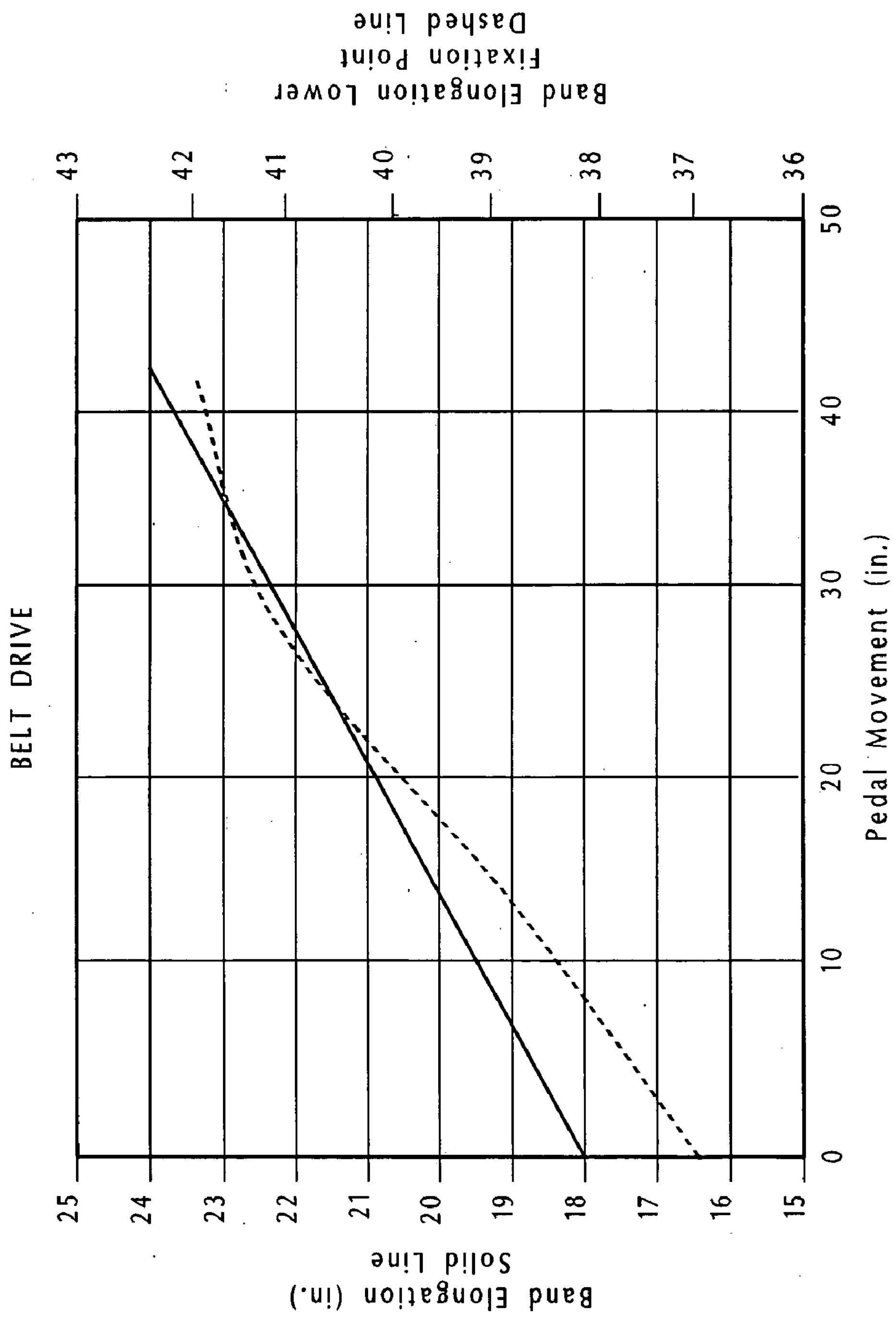

BELT DRIVE
Band Elongation Lower
Fixation Point
Dashed Line
43
42
41
40
39
38
37
36
Band Elongation (in.)
Solid Line
25
24
23
22
21
20
19
18
17
16
15
0
10
20
30
40
50
Pedal Movement (in.)

Fig. 9a

Fig. 9b

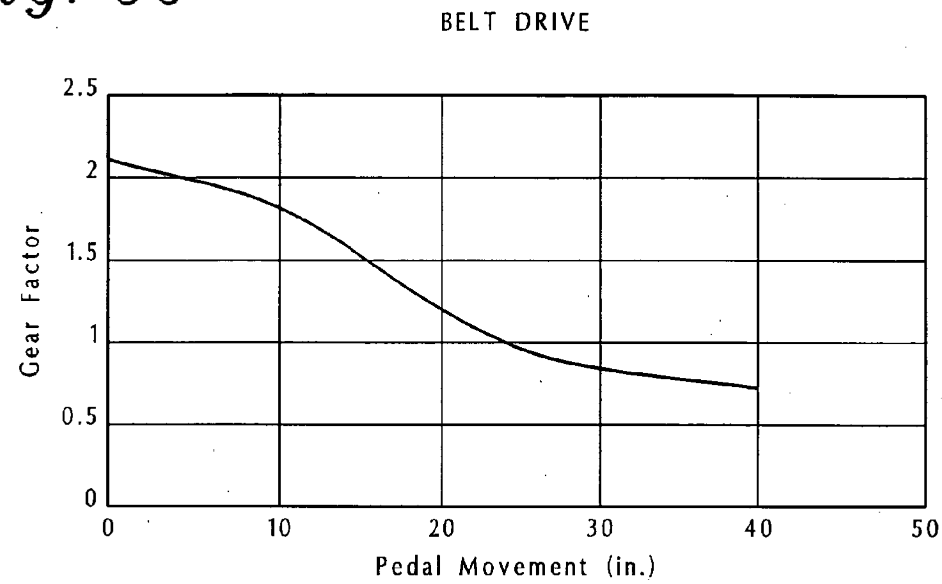
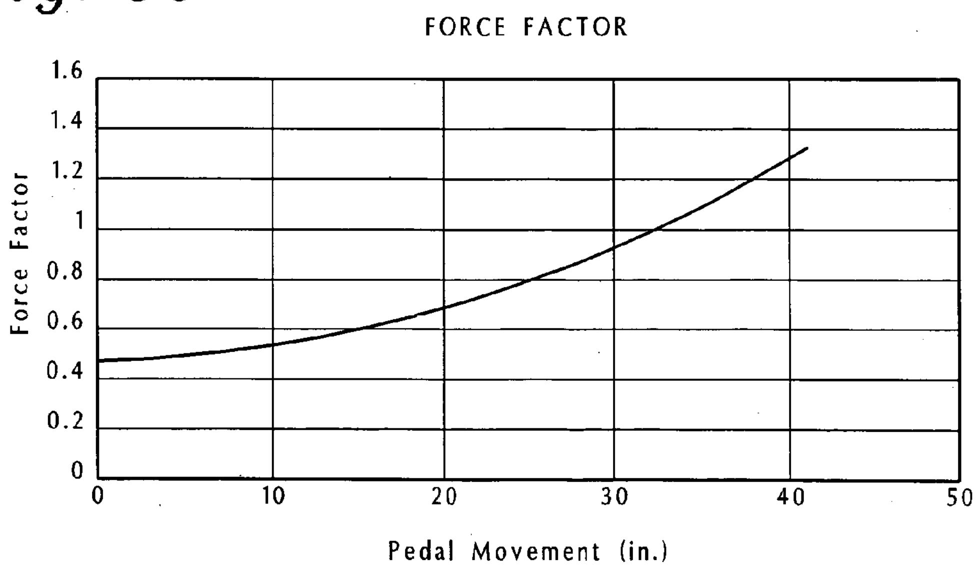

BELT DRIVE
2.5
2
1.5
1
0.5
0
Gear Factor
0
10
20
30
40
50
Pedal Movement (in.)

Fig. 9c


FORCE FACTOR
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Force Factor
0
10
20
30
40
50
Pedal Movement (in.)

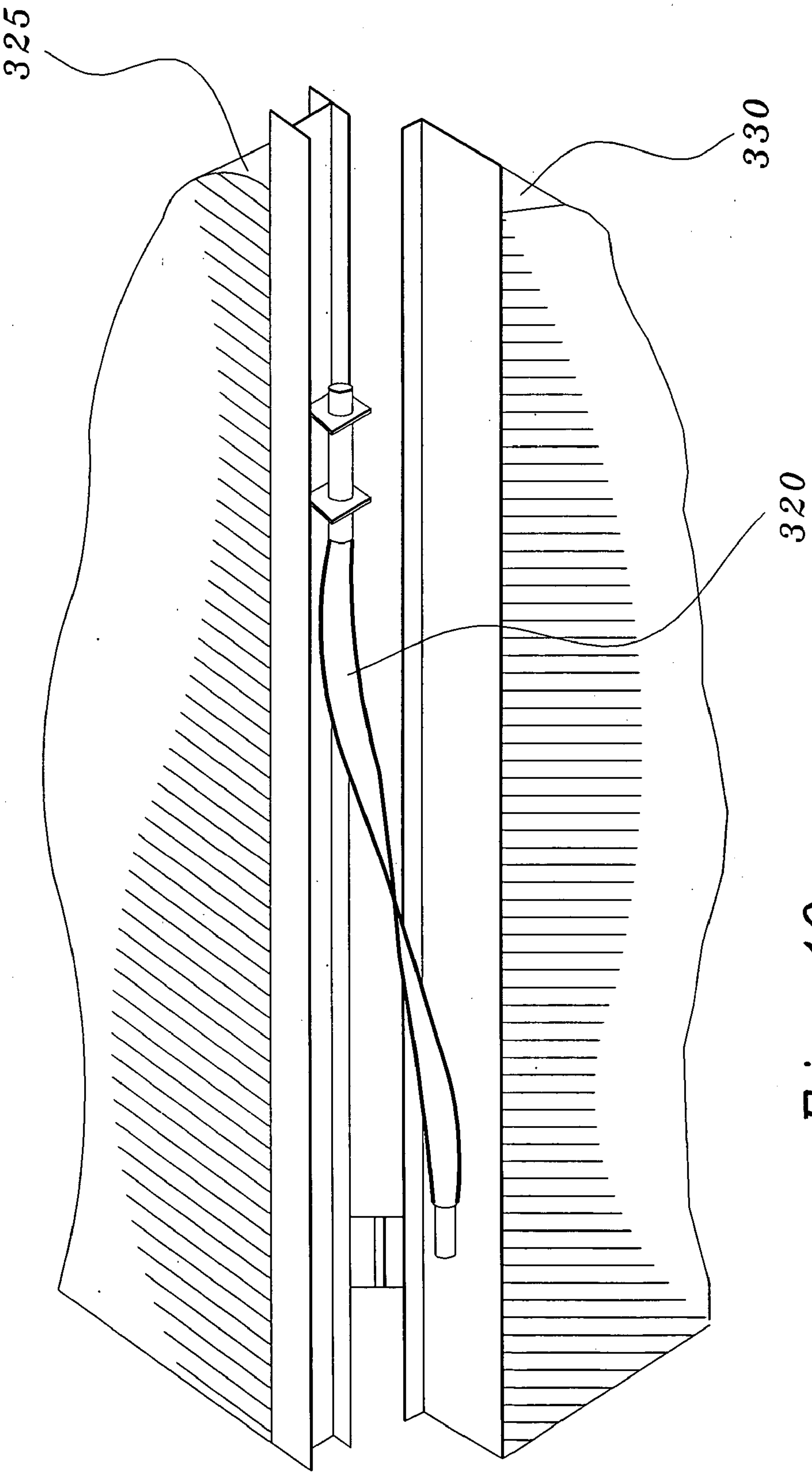


Fig. 10

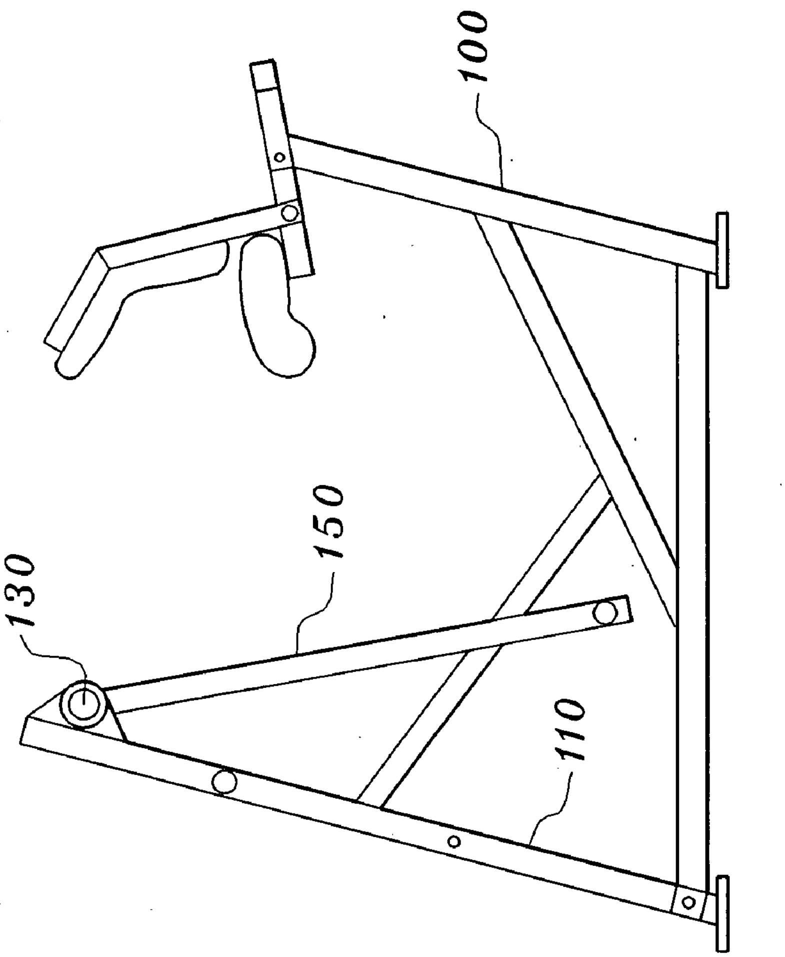


Fig. 11a

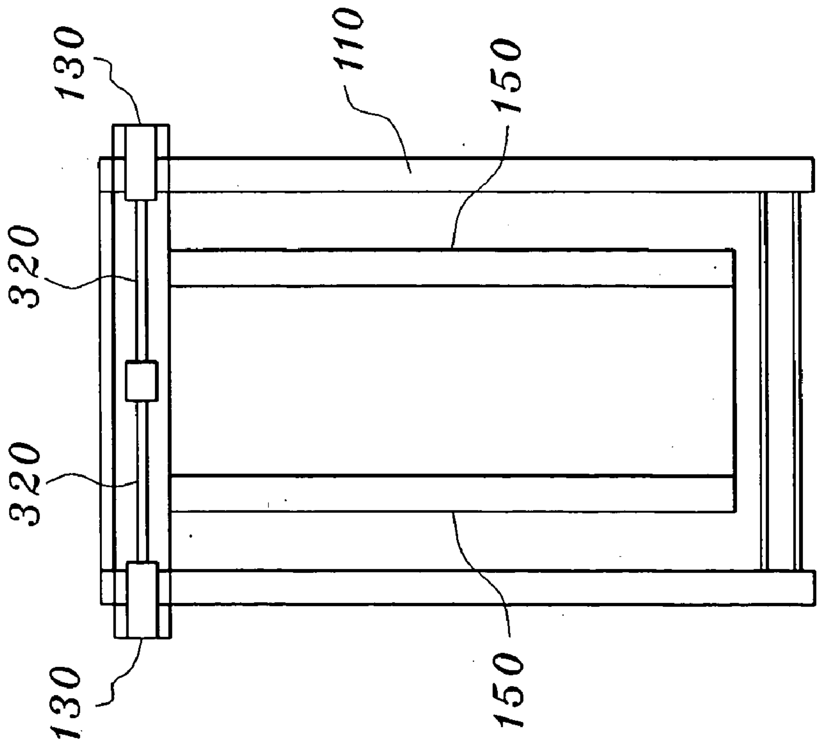


Fig. 11b

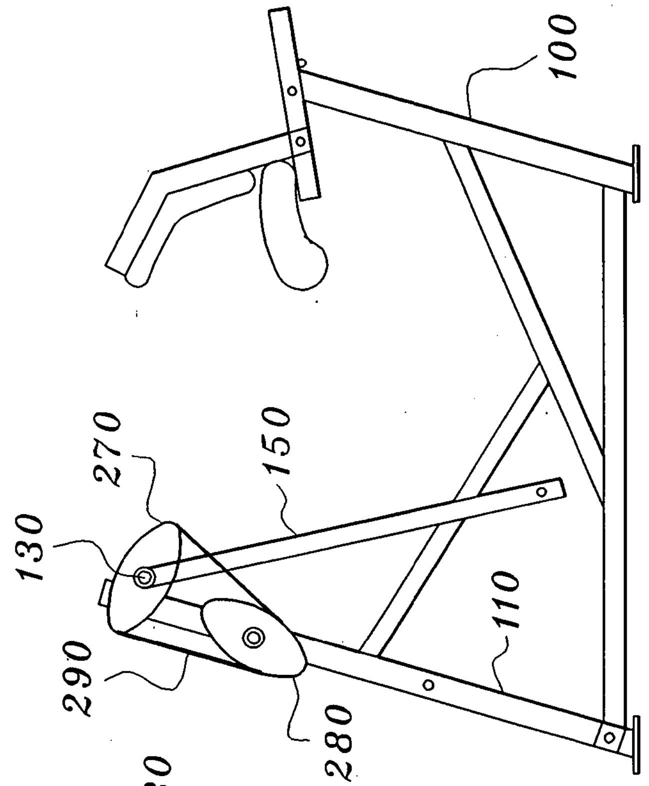


Fig. 12a

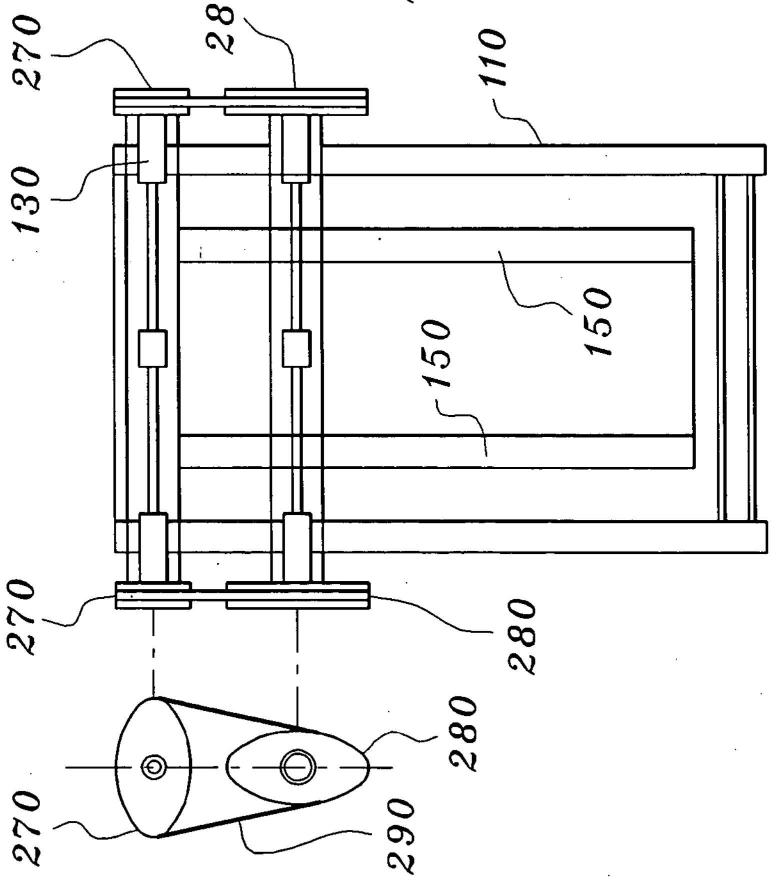


Fig. 12b

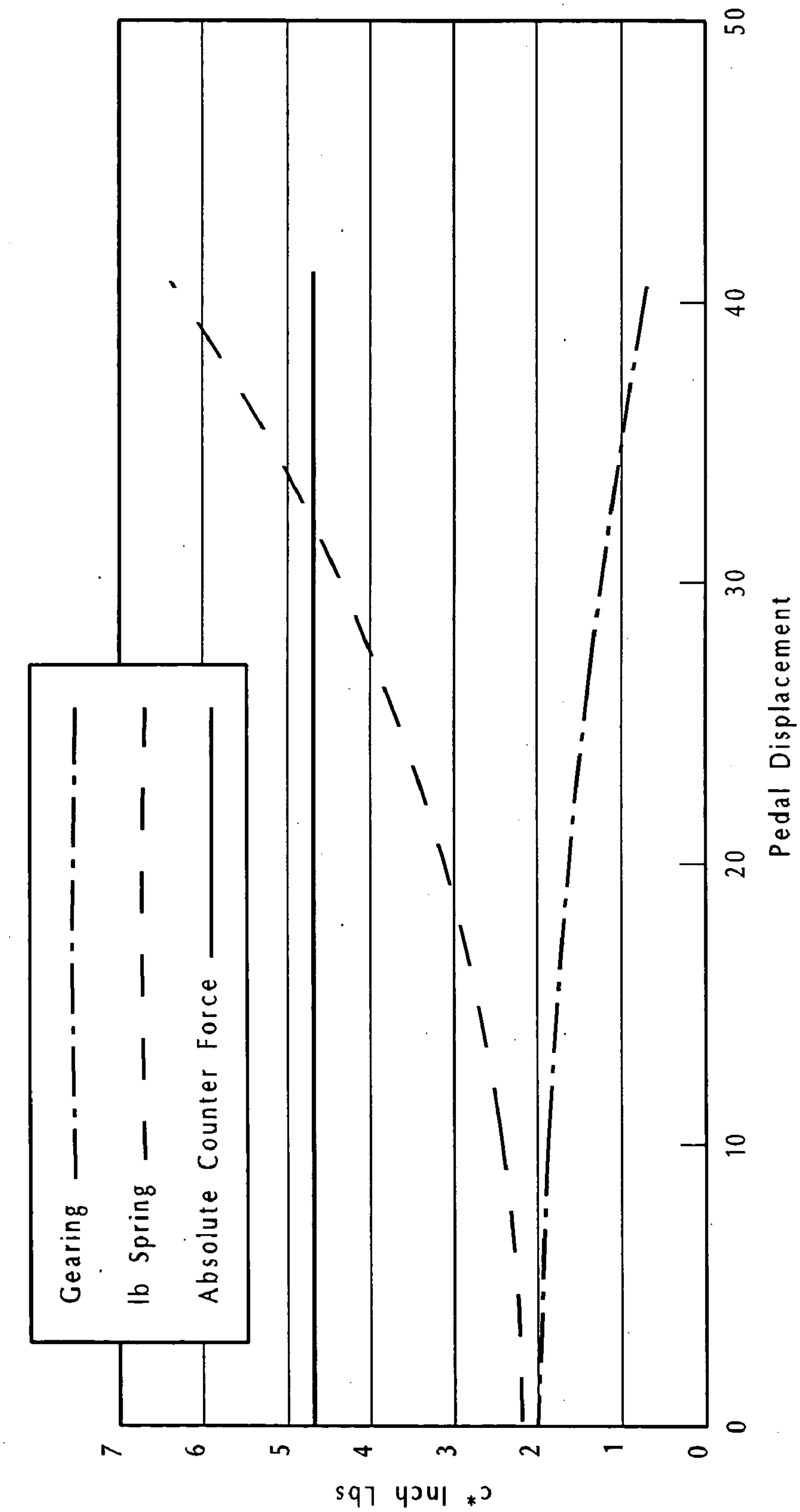

Gearing
lb Spring
Absolute Counter Force
c* inch lbs
0
1
2
3
4
5
6
7
0
10
20
30
40
50
Pedal Displacement

Fig. 13

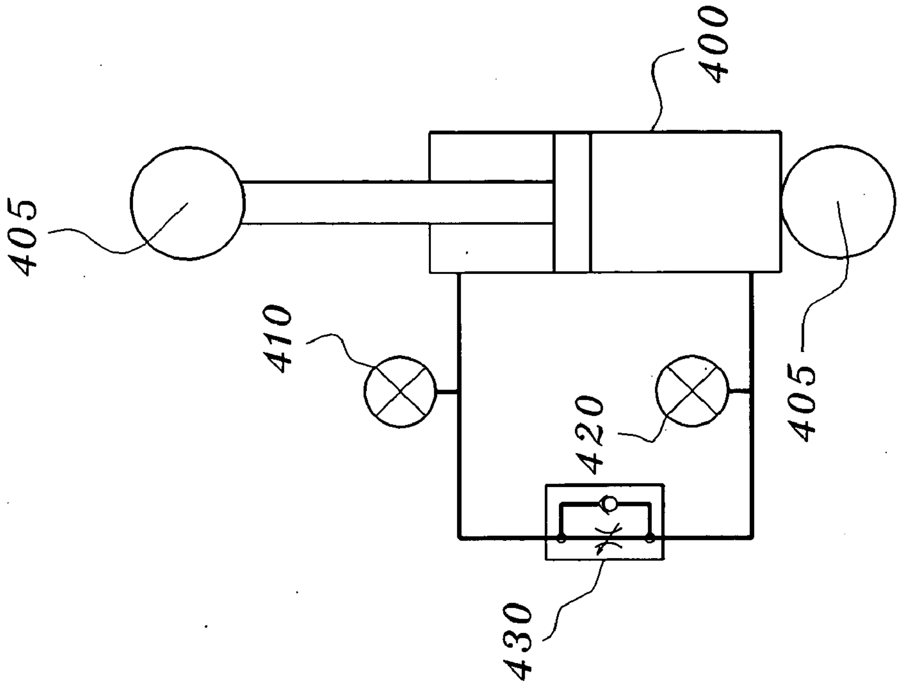


Fig. 14a

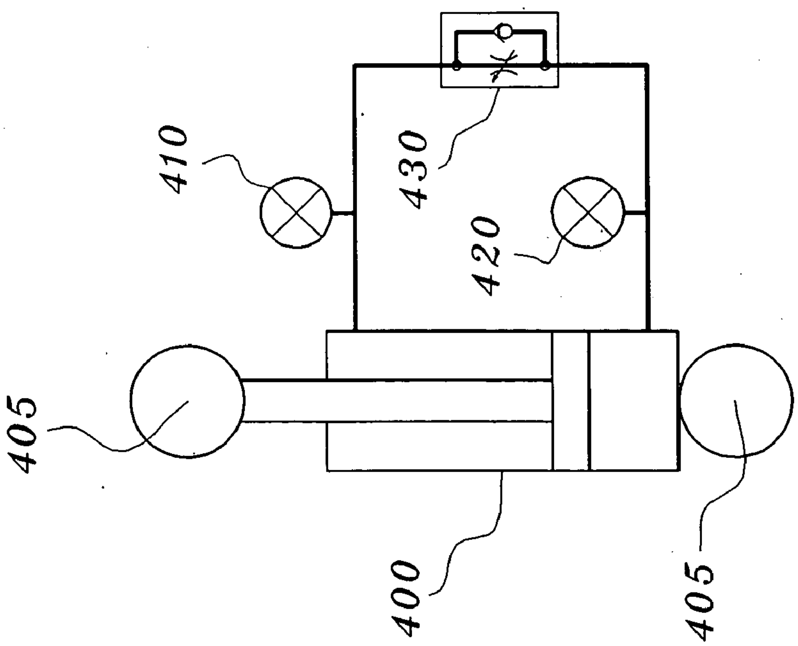


Fig. 14b

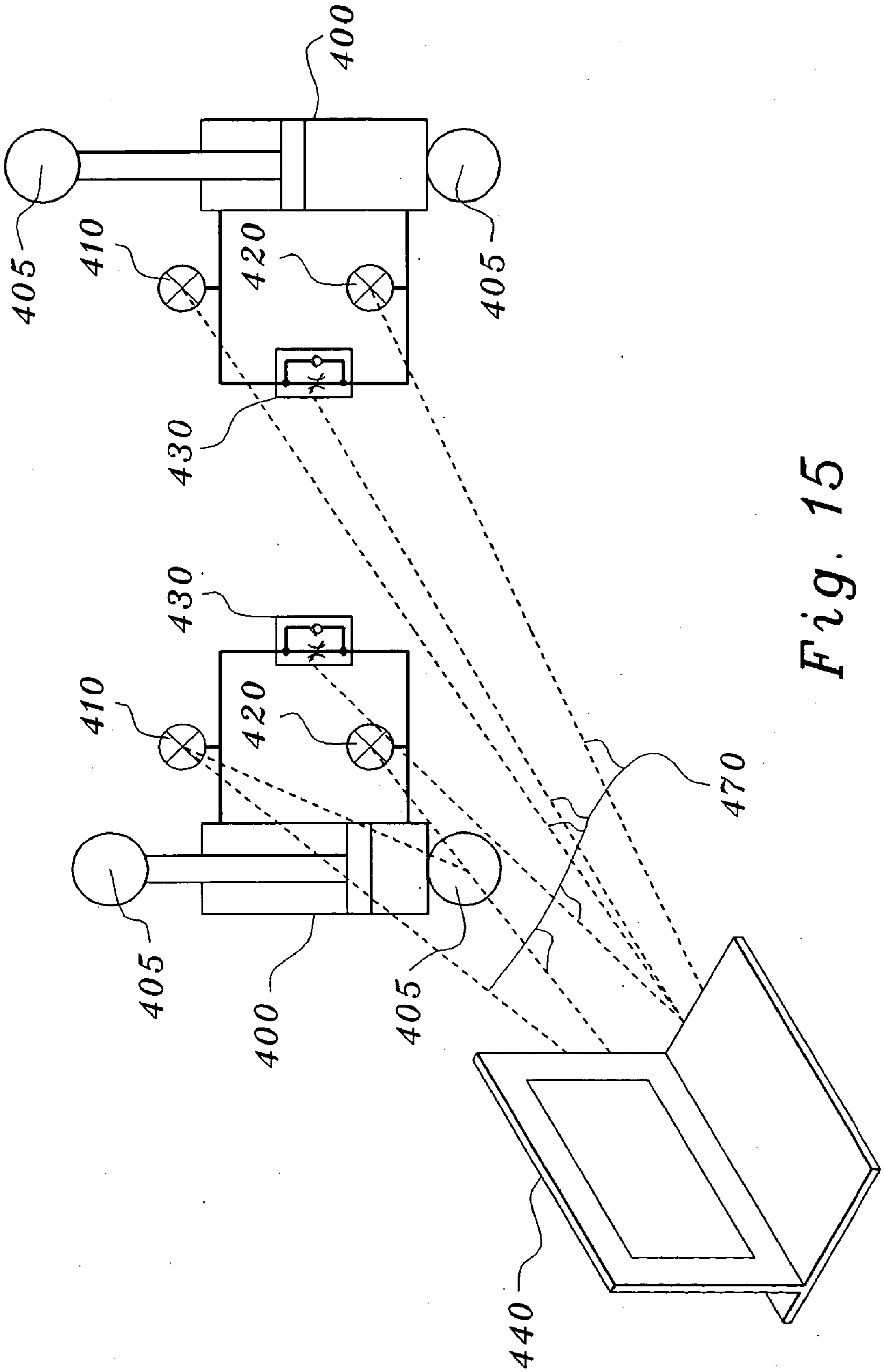


Fig. 15

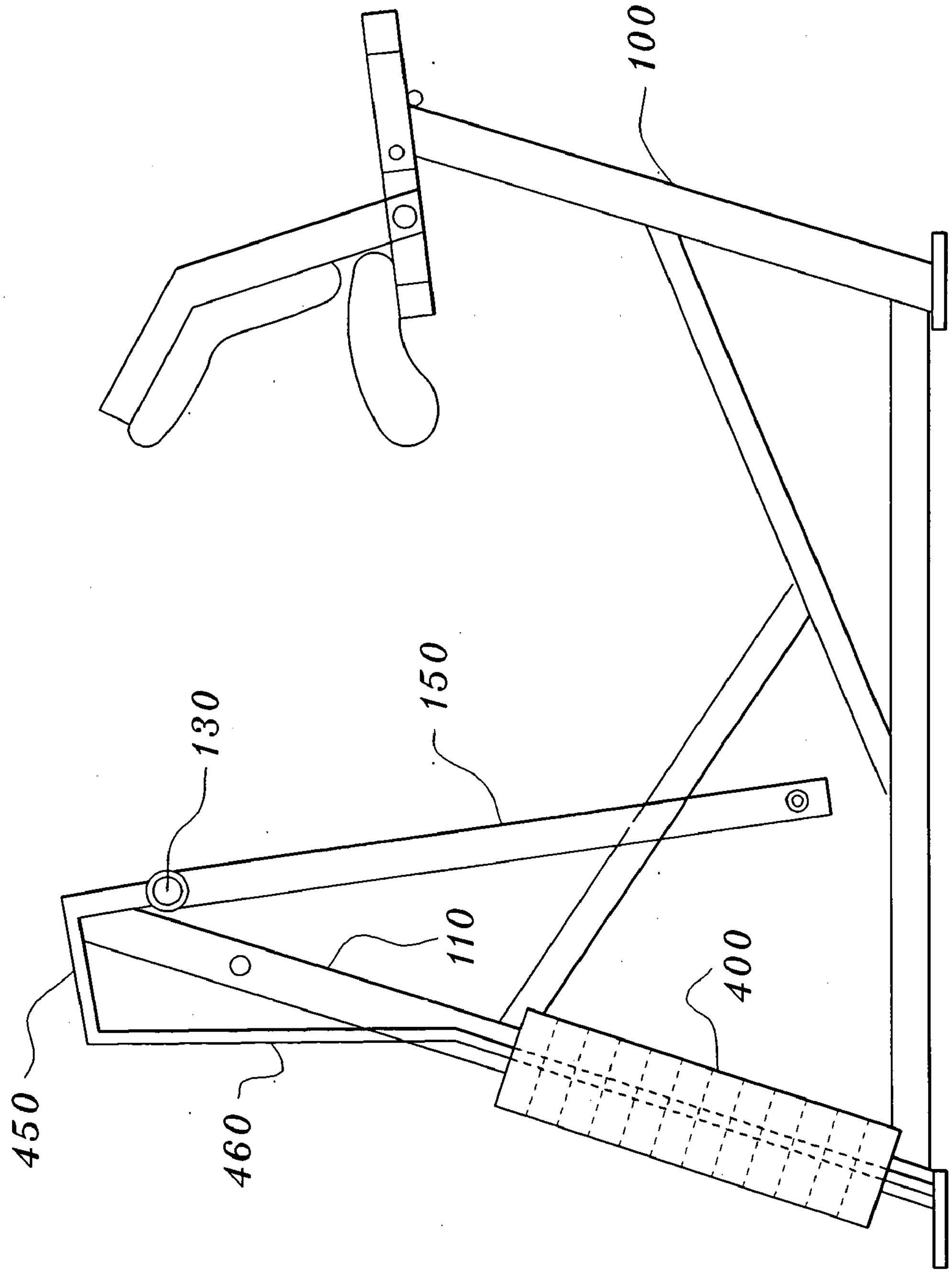


Fig. 16

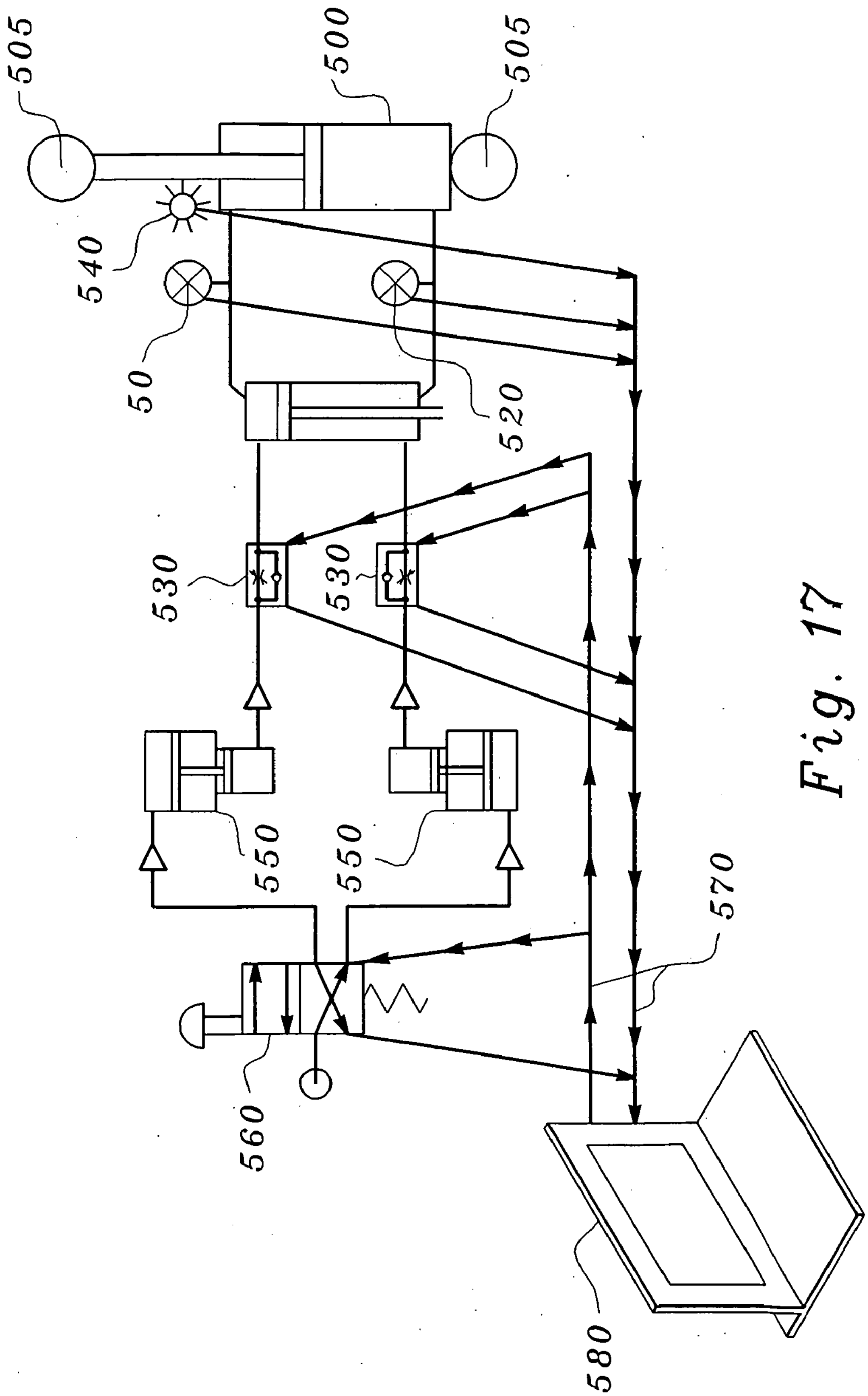


Fig. 17

CONTROL SYSTEM AND METHOD FOR EXERCISE MACHINE

TECHNICAL FIELD

[0001] This application relates to the existing strength training equipment that simulates the motions of running. The majority of strength and resistance training weights for the counter-force. This application concerns the application of passive and active systems to replace the effect of conventional weights.

BACKGROUND

[0002] Applicant Johnston is one of the inventors of U.S. Pat. No. 5,941,804, "Exercise Machine for Simulating Running," which patent is incorporated into this application by reference in its entirety. We use the device disclosed in U.S. Pat. No. 5,941,804 ("the runner") to analyze the dynamics of a running machine, since the runner has been proven to be effective in training for fast runs and fast take-offs. Nevertheless, the power curve developed by the runner using weights for counter force is not ideal for training. A desirable power curve would be linear; that is, the force remains nearly constant for a given displacement of the exercise apparatus by the user. This can be accomplished by implementing control systems that replace the effect of conventional weights. Such control systems may be passive, or, they may be made active, so that the counter-force may be varied in a controlled way during the exercise.

SUMMARY

[0003] We disclose an exercise machine for simulating running, comprising a frame, the frame having a forward portion and a rear portion. A shoulder harness is connected to the forward portion of the frame for supporting the torso of the user on its ventral side, and preventing the forward movement of the user's body. Two levers are pivotally connected to the rear portion of the frame, and a pedal assembly is connected to each lever, for receiving the foot of the user. In one embodiment, a passive means for generating a counter force is connected between the lever and the rear frame, such as an elastic band, spring, torsion bar or hydraulic cylinder. In another embodiment A hydraulic or pneumatic actuator is connected between each lever and the frame; and, an active control system is operatively connected to each actuator; the active control system being configured to generate a counter force to the user according to a preselected program.

DESCRIPTION OF DRAWINGS

[0004] FIG. **1** shows the runner desired to be improved.

[0005] FIG. **2** shows dynamic envelopes of the present runner.

[0006] FIG. **3** shows the force factor of the present runner.

[0007] FIG. **4** shows an improvement where an auxiliary arm for upper elastic band fastening points is added.

[0008] FIG. **5** is a graph of band elongation in relation to the selection of attachment points.

[0009] FIG. **6** shows an alternate embodiment where bands are attached to the pedal lever of the modified runner by a circular disk.

[0010] FIG. **7** shows an alternate embodiment where bands are attached to the pedal lever by an elliptical disk.

[0011] FIG. **8** shows schematically a combination of elliptical wheels connected by a drive belt.

[0012] FIGS. **9**A and **9**B are graphs showing band elongation for the combination of FIG. **8**, variation of pedal movement with the gear factor, and variation of the force factor with pedal movement.

[0013] FIG. **10** depicts generally the use of a torsion bar in another embodiment.

[0014] FIG. **11** shows an embodiment using a torsion bar to provide resistance.

[0015] FIG. **12** shows an embodiment where a torsion bar is combined with Alternate torsion bar configuration with a belt-driven wheel.

[0016] FIG. **13** is a graph showing a linear load distribution curve achieved by using a torsion bar with a belt drive.

[0017] FIG. **14** shows an embodiment using a passive hydraulic or pneumatic control system.

[0018] FIG. **15** shows an embodiment using a passive pneumatic or hydraulic control system where the resistance is set by a connection between control valves and a computer.

[0019] FIG. **16** shows a pneumatic or hydraulic control cylinder on a modified runner.

[0020] FIG. **17** shows an embodiment of an active pneumatic or hydraulic control system with pressure amplification and feedback.

[0021] Some of the drawings have dimensions. The dimensions are given merely to illustrate typical embodiments and do not limit the scope of the claims.

DETAILED DESCRIPTION

[0022] FIG. **1** shows the of the existing runner. The main components of the runner are: the center frame (**100**), the rear frame (**110**) which is perpendicular to the center frame (**100**), and two A-frames (**120**) which are attached to and pivot on a rotating axle or hinge (**130**) above the openings of the rear frame (**110**), through which they travel during the exercises. The A-frames (**120**) are forced to swing about the axle (**130**) by the user's foot pressure upon pedal levers (**150**), attached to the A-frames (**120**) as shown. The A-frames support weights (not shown) placed upon posts (**140**) attached to them.

Dynamics of Weight Resistance

[0023] FIG. **2** shows the pedal levers (**150**) and the A-frames (**120**) of the conventional runner in four different positions, at 0 degrees, and 20, 40 and 60 degrees of rotation.

[0024] The values of pedal movement to rotation angle can directly be retrieved. One can see that the maximum angle of 60 degrees brings the weight nearly horizontal to the axis of its rotation resulting in the maximum value for the force factor (maximum leverage).

[0025] The graph in FIG. **3** shows the result of the dynamic analysis: the force factor distribution over the movement of the athlete's foot in the pedal (solid line). It also shows the near linear relationship between pedal movement and the resulting rotation angle of the pedal-weight arm (dashed line). The plot for force is derived from the changing lever arm of the weight when it swings up from its starting position around its axis of rotation Consider a weight of 40 pounds. When the athlete starts to stretch his leg he will encounter a force of only 17 pounds. At the end of the movement when the leg is stretched, he will encounter the full force of 40 pounds. This relationship is far from the desirable linear one.

Passive Control Systems

[0026] A purely passive control system can change the displacement-load relationship in a desirable direction. The embodiments discussed below use one of the following passive means for generating a counter force. The weight may be replaced by, for example, different sets of elastic bands or cylindrical springs, torsion bars or cylindrical helical springs, or pneumatic or hydraulic actuators.

Replacement of the Weights by Elastic Bands and Cylindrical Springs.

[0027] FIG. **4** shows the first alteration of the weight system to a band system. The A-frame (**120**) of the conventional runner is gone and the new pedal lever has only an attachment arm (**200**) that is attached to it at a variable angle α. The angle α or the position of the attachment arm (**200**) will change the load curve. The same is true for the location of the elastic band attachment. The angle α can set so that in the beginning of the pedal movement the lever arm has its maximum value.

[0028] An elastic band or spring has the characteristic that the force increases as it is extended. This can be compensated for by the movement of the attachment arm (**200**). During the movement, the moment of the lever gets shorter, which causes a smaller elongation of the bands or springs, thus compensating the increasing spring or band load partially. FIG. **4** shows elastic band (**230**) attached to the rear frame (**110**) at attachment point (**235**); and a band (**240**) attached to the rear frame (**110**) at attachment point (**245**). Alternatively, the bands (**230**, **240**) can be attached at different points on the attachment arm (**200**).

[0029] FIG. **5** is a graph relating the elongation of the bands or springs (**230**, **240**) to the selection of the attachment points as shown in FIG. **4**. One can clearly see the resulting change of the control curve. The flatter it is, the more even the counter force is over the range of the movement. One can see that the location of the spring attachment point on the rear frame changes the spring characteristics. When attached to the upper attachment point (**235**) the spring (**230**) reacts in this example near linear to the movements of the athlete's pedals. The dashed line relates to the lower attachment point (**245**). In our case it is no longer a linear behavior but it follows a second order squared curve. These are factors that must be considered when elastic bands or springs are used.

[0030] FIG. **6** shows a sheave (**300**) in the shape of a circle to be used when the load (reaction force of the band or spring) should have the same characteristics as the elastic element itself. The sheave (**300**) is attached concentrically to the axle or pivot (**130**) of the lever (**150**).

[0031] FIG. **7** shows the circular sheave (**300**) of the previous FIG. **6** replaced by an elliptical sheave (**310**). This shape allows for tuning the reaction load from high at the start of the movement to low at the end and vice versa. Preferably the angular position of the elliptical sheave (**310**) is adjustable, so that the starting and ending loads can be preset.

Belt Drive

[0032] In another embodiment, a belt drive is added between two wheels, as shown in FIG. **8**. A first elliptical wheel (**270**) is connected to the pivot (**130**) of the pedal lever (**150**) and moves with it. A second elliptical wheel (**280**) is connected to the rear frame (**110**) and caused to move by a belt (**290**) engaging both wheels. The geometry of this embodiment requires that the long axes of the two elliptical wheels (**270**, **280**) are 90 degrees offset to one another.

[0033] The resulting gear ratios and resulting turn increments of the driven wheel are given in Table 1 below. One can clearly see that the second wheel (**280**) wheel turns in different increments than the first wheel (**270**), dependent on the location of the pedal lever (**150**). In Table 1, the increments have been calculated for constant turn increments of the primary wheel of 5 deg each.

TABLE 1

Primary wheel		Driven Wheel	
turn incr steps	cumulative	turn incr steps	cumulative
5	5	7.4	7.4
5	10	7.2	14.6
5	15	6.3	20.9
5	20	5.8	26.7
5	25	5.7	32.4
5	30	5.2	37.6
5	35	5	42.6
5	40	5	47.6

[0034] The bands or springs (**230**, **240**) are connected to the extension arm (**200**), now fixed to the axis of the second wheel (**280**).

[0035] FIG. **9** is a graph showing the elongation of the bands (**230**, **240**) versus the movement of the pedal lever (**150**). For the belt drive shown above the band elongations have been calculated and are shown here for two different attachment points, The solid line is related to the upper frame attachment (**235**) and the dashed line to the lower attachment point (**245**). The different inclinations indicate different force factors.

[0036] When the athlete starts to stretch his leg, the driven wheel (**280**) turns faster than the driving wheel (**270**) which is directly connected to the lever (**150**) holding the pedals.

[0037] At the end of the movement, when the athlete's leg is stretched, the driven wheel (**280**) turns slower than the driving wheel (**270**), thus exerting more force to stretch the bands or springs. The resulting force factors are shown in the next graph in FIG. **9**B.

[0038] One can clearly see that the curve is reciprocal to the gear ratio.

[0039] This shows that we have full control of the spring or exercise band (**230**, **240**) behaviors by means of the wheels (**270**, **280**) we select. The variables involved are the dimensions of the wheels (**270**, **280**), the location of the attachment points (**235**, **245**) on the frame (**110**), and the location of the attachment to the driven wheel (**280**). The latter may be made by choosing the length of the extension arm (**200**) appropriately, or by choosing different attachment points (**210**, **220**). FIG. **4** shows the various possible combinations.

Replacement of the Weights by Torsion Bar or Helical Spring

[**0040**] The load resistance may also be provided by one or more torsion bars in place of springs or elastic bands. The general connection of a torsion bar is shown in FIG. **10**. Such a bar (**320**) is connected at its ends between two hinged plates (**325**, **330**). Torsion bars are well known in the art. Often they are constructed with an internal spring that is twisted to a given tension before installation. Either this type, or the more general form of a twisting solid bar (FIG. **10**) may be used in the present embodiment. The stiffness or resistance is a nearly linear function of the angle of twist. The counter-force curve follows the same law as that for elastic bands, except that the displacement is angular.

[**0041**] FIG. **11** The FIG. **11** shows the preferred arrangement for a torsion bar control in the alternate embodiment. The torsion bar (**320**) is preferably attached between inner and outer bearings in the pivot (**130**). Equivalently, a flat helical torsion spring could be used at the pivot (**130**) of the pedal lever (**150**).

[**0042**] FIG. **12** shows an alternate embodiment using the two-wheel belt-drive system already discussed earlier in connection with elastic bands and springs. This arrangement allows for a more even distribution of the reaction force over the total range of movement of the pedal lever (**150**). It is thus possible to balance reaction force and gear sizes the amplification factor in such a way that a constant amplification factor can be achieved. Using the right torsion bar (**325**) or spring parameters and a tuned wheel (**270**, **280**) arrangement will enable the user to set up all desired resistance values and characteristics. FIG. **13** shows such a tuned system that led to a nearly constant counter force over the total range of pedal movement.

Hydraulic/Pneumatic Passive Systems

[**0043**] Another passive control system is shown in FIG. **14**. It comprises a hydraulic cylinder (**400**) which is controlled by a control valve (**430**). The control valve (**430**) itself is controlled by manual adjustment to set the level of the counter force. The cylinder (**400**) attaches to the frame (**110**) and pedal lever (**150**) at attachment points (**405**). First and second pressure sensors (**410**, **420**) measure pressure in the two cylinder (**400**) cavities. FIG. **16** shows how a cylinder (**400**) is connected by way of a linkage (**460**) to an extension arm (**450**) itself connected to the pedal lever (**150**). In this disclosure, the terms "hydraulic" and "pneumatic" may be used interchangeably.

Active Control Systems

[**0044**] All of the above systems have one in common: they are resistance training equipment and the resistance can only be pre-set before the athlete starts with the exercises. An active control system makes it possible to actively control the counter force and vary it over the total range of movement. Active control systems for exercise equipment are discussed in pending U.S. patent application, Ser. No. 10/032,993, "Exercise Recording and Training Apparatus," published on Jul. 11, 2002 under pub. No. US 2002/0091031 A1, now U.S. Pat. No. 6,659,913. patent application Ser. No. 10/032,993 is incorporated into this application by reference in its entirety.

[**0045**] FIG. **15** shows an active pneumatic control system for the runner. The microcomputer (**440**) receives the signals of the displacement (**445**) and pressure (**410**, **420**) sensors, and controls the position of the control valve (**440**) according the time and sensor inputs The computer (**440**) has a stored program to record the pressure and displacement of the cylinder (**400**), and to calculate the force exerted by the athlete and display governed based upon the pressure, displacement and time inputs of the sensors, and display these parameters on the computer display.

[**0046**] FIG. **16** shows the configuration of the pneumatic cylinder (**400**) attachment, which is basically the same for passive and active pneumatic control systems.

[**0047**] FIG. **17** shows a further embodiment of pneumatic control system with pressure amplifiers (**550**). Thus a given input pressure can be transformed into a higher force by using a two-piston system with different active areas; that is pressure amplifiers (**550**). In FIG. **17** the computer (**580**) is connected via signal connectors (**570**) to first and second pressure sensors (**510**, **520**), to a displacement sensor (**540**), first and second control valves (**530**, **535**), pressure amplifiers (**550**), and a position-limit valve (**560**). The position-limit control valve (**560**) is operated through the position limits of the pedal lever (**150**). For example, the position switches at the lower limit position to upward direction and at the upper limit to downward moving direction. The position-limit valve (**560**) is pre-set to the maximum value of the counter force. Thus the counter force can vary as a function of displacement of the pedal lever (**150**), its speed, or acceleration. The computer (**580**) has a control program stored on a computer-readable medium for controlling and measuring the various parameters of time, displacement, and pressure.

[**0048**] The pneumatic cylinders may be substituted by other equivalent active control components, such as hydraulic cylinders or linear electric motors.

We claim:

1. An exercise machine for simulating running, comprising:

a frame, the frame having a center portion and a rear portion,

two levers pivotally connected to the rear portion of the frame,

a pedal assembly connected to each lever arm, for receiving the foot of the user,

an extension arm connected to each lever at the pivotal connection of the levers to the rear portion of the frame; and,

a passive means for generating a counter force; the passive means connected between each extension arm and the rear frame.

2. The exercise machine of claim 1 where the means for generating a counter force is at least one elastic band connected between each extension arm and the rear frame.

3. The exercise machine of claim 2 where the attachment points of the elastic band to the extension arm and the rear frame are selectively variable.

4. The exercise machine of claim 1 where the means for generating a counter force is at least one elastic band connected between each extension arm and the rear frame and further comprising:

a circular sheave connected to the lever arm concentric with the pivot of the lever arm; and,

the elastic band configured to seat in the groove of the circular sheave as the circular sheave rotates.

5. The exercise machine of claim 1 where the means for generating a counter force is at least one elastic band connected between each extension arm and the rear frame and further comprising:

an eliptical sheave connected to the lever arm concentric with the pivot of the lever arm; and,

the elastic band configured to seat in the groove of the eliptical sheave as the eliptical sheave rotates.

6. The exercise machine of claim 1 where the means for generating a counter force is at least one spring connected between each extension arm and the rear frame.

7. An exercise machine for simulating running, comprising:

a frame, the frame having a center portion and a rear portion,

two levers pivotally connected to the rear portion of the frame,

a pedal assembly connected to each lever arm, for receiving the foot of the user,

a passive means for generating a counter force; the passive means connected between the levers and the rear frame.

8. The exercise machine of claim 7 where the passive means for generating a counter force is a torsion bar.

9. The exercise machine of claim 7 where the passive means for generating a counter force is a flat spring.

10. An exercise machine for simulating running, comprising:

a frame, the frame having a center portion and a rear portion,

two levers pivotally connected to the rear portion of the frame,

a pedal assembly connected to each lever arm, for receiving the foot of the user,

a first eliptical wheel connected coaxially with the pivot of the lever;

a second eliptical wheel connected rotabably to the rear frame;

the first and second eliptical wheels rotatably connected by a belt;

the first and second eliptical wheels postitioned so the their long axes are perpendicular;

a passive means for generating a counter force; the passive means connected between the first eliptical wheel and the rear frame.

11. The exercise machine of claim 10 where the a passive means for generating a counter force is a torsion bar.

12. The exercise machine of claim 10 where the passive means for generating a counter force is a flat spring.

13. The exercise machine of claim 1 where the passive means for generating a counter force is a pneumatic cylinder.

14. An exercise machine for simulating running, comprising:

a frame, the frame having a center portion and a rear portion,

two levers pivotally connected to the rear portion of the frame,

a pedal assembly connected to each lever arm, for receiving the foot of the user,

an extension arm connected to each lever at the pivotal connection of the levers to the rear portion of the frame; and,

an active means for generating a counter force; the active means connected between each extension arm and the rear frame.

15. The exercise machine of claim 14 where the active means for generating a counter force further comprises:

a pneumatic cylinder;

a pressure sensor connected to the pneumatic cylinder;

a pressure control valve connected to the pneumatic cylinder;

a displacement sensor connected to the pneumatic cylinder;

the pressure sensor, the pressure control valve and the displacement sensor connected to a computer;

the computer executing a stored program for:

measuring and displaying on the computer the displacement of the cylinder;

measuring and displaying on the computer the pressure in the pneumatic cylinder; and,

according to the stored program, computing and displaying on the computer the counter force generated when the exercise machine is operated.

16. The exercise machine of claim 15, further comprising:

a pressure amplifier connected between a source of pressure and the pressure control valve.

17. The exercise machine of claim 15, further comprising:

a position-limit valve connected between a source of pressure and the control valve.

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