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ERGOMETER

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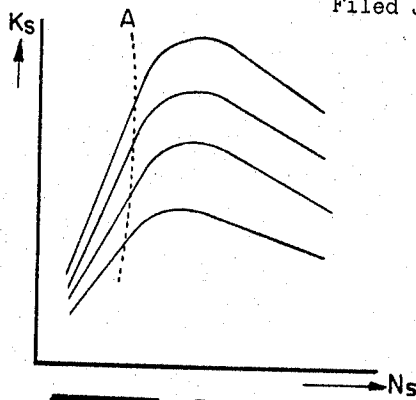


FIG. 1.

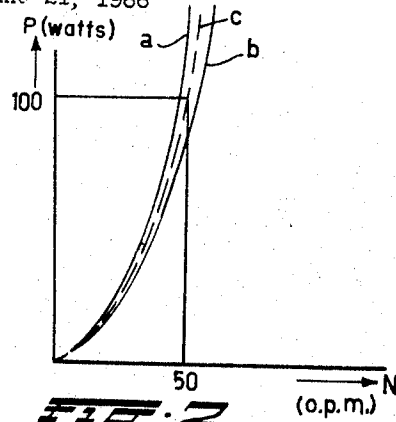


FIG. 2.

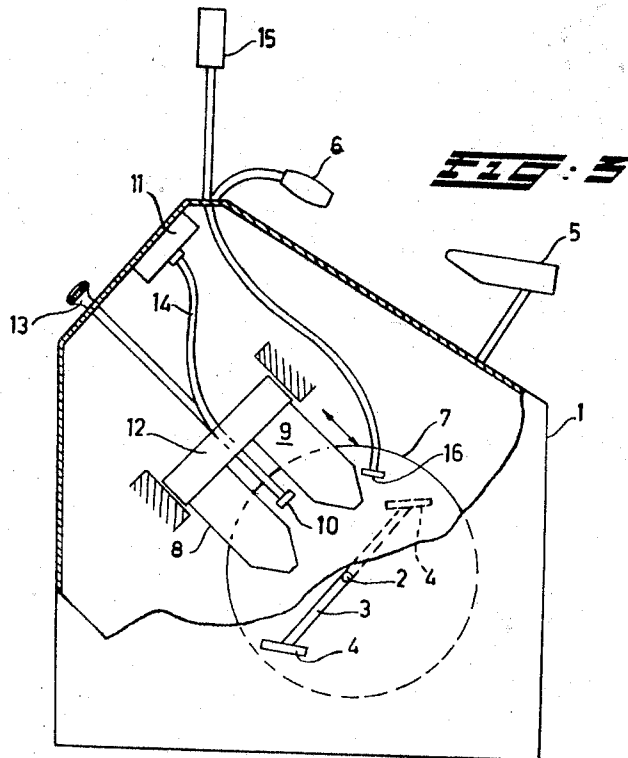


FIG. 3.

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9 Claims

ABSTRACT OF THE DISCLOSURE

A cycle ergometer for measuring human capacity, in which the resistance torque of the braking device varies in the same sense as the pedal frequency, preferably in a substantially directly proportional relationship. The braking device may be of the eddy current disc type.

This invention relates to an ergometer for measuring human physical capacity, of the type in which a person under observation should make a circular treadle movement, the treadle energy being taken up into a braking device.

A known ergometer of this type, in which the energy is absorbed by an eddy current disc, is constructed in such a way that in the range of the normal pedal frequency the braking torque is inversely proportional to the number of revolutions per unit time, consequently the energy taken up by the brake and produced by the person under observation is constant at an alternating pedal frequency. This structure is, however, disadvantageous in that the patient, in spite of the fact that the energy to be given off does not depend on pedal frequency or angular frequency, has the impression that at an increasing frequency he should produce a lesser amount of work, while at a decreasing frequency the apparatus seems to run heavier. As a result of the latter circumstance, when the tester has ordered the patient to stick to a definite number of revolutions per unit time, the patient after a slight decrease of his efforts, should not only physically exert himself in order to produce again the correct number of revolutions, but moreover exert himself psychically, because he has to achieve this from a situation which in his own mind is more difficult. This means in practice in many cases that the patent cannot make this effort, so that the test ends prematurely.

It is an object of the invention to obviate the above mentioned disadvantage of the known device, in order that the effect experienced is more natural.

It is a further object of the invention to provide an ergometer wherein for any capacity of the patient the number of revolutions of the treadle movement is such that it corresponds with the most efficient action of the patient's metabolism.

Another object of the invention is to provide an ergometer wherein said most efficient action of the metabolism is automatically obtained for any investigated patient.

Another object is to obtain a precise measurement, independent of variations of the pedal frequency during the test.

Other objects of the invention, and the manner in which it is to be performed, will appear from the following description, which is to be read in connection with the accompanying drawing. In the drawing:

FIGURE 1 represents a series of torque characteristics of eddy current discs at various magnetic field intensities;

FIGURE 2 shows experimentally determined capacity characteristics obtained by measurements on a large number of persons; and

FIGURE 3 represents in outline partially in section, an embodiment of an ergometer according to the invention.

As was stated above, in a commonly used ergometer the braking torque exerted by a braking device, which uses an eddy current disc, is inversely proportional to the number of treadle revolutions per unit time. This construction was chosen in order that the energy produced by the patient, and absorbed by the braking device, should be independent of the angular frequency, since the energy is the product of the number of revolutions and the torque, or the capacity is the product of angular frequency and torque. The braking torque was adjusted by adjusting the energizing current of the electromagnet.

Although from a theoretical point of view this constructional principal will give favourable results, the practical effect on the patients is an unnatural one.

Now, according to my invention, the resistance torque of the braking device should be chosen such that in the range of the normal pedal frequencies it varies in the same sense as the pedal frequency. Thereby the device will be experienced as more natural: the higher the pedal frequency, the higher the power to be produced by the patient. In this way the disadvantage of the prior device—premature ending of the test because of the required too great physical and psychological effort after a slight decrease of the frequency—is obviated.

It has already been learned from tests with the aforementioned ergometer that a patient at any selected capacity experiences a definite pedal frequency as the most agreeable. This experience is attended with a minimum consumption of oxygen, consequently with the most efficient action of the metabolism of the patient, which action is the object of the study with the ergometer. A further disadvantage of the prior device appears from this, for when the tester orders the patient to stick to a number of revolutions per unit time differing from the optimum value mentioned, the results of measurement are influenced in an unfavourable sense.

Most surprisingly it has, however, appeared to me that for each person under observation there is an unambiguous quadratic relationship between the capacity and the optimum number of revolutions. This experience gives rise to a preferred embodiment of the ergometer according to my invention, in which the resistance torque of the braking device and the pedal frequency have a substantially linear relationship. Since, as stated already, the capacity is the product of the torque and the angular frequency, it becomes thus possible to obtain for each patient the desired quadratic relation between number of revolutions and capacity by suitable choice of a constant, e.g. in the form of the transmission ratio between the pedal shaft and the braking device.

The said linear relationship between the braking torque and the pedal frequency can for example be obtained by any mechanical braking mechanism, wherein the braking force is controlled electronically by the angular frequency of the pedal shaft. I have, however, realised that said linear relationship can also be obtained with the known eddy current brake. To explain this, reference is made to FIG. 1, showing a series of torque characteristics of eddy current discs, the magnetic field intensities being the parameter. In the above described known ergometer having an eddy current brake, one used to apply such a high transmission ratio between the pedal shaft and the eddy current disc, that the normal pedal frequency during the tests corresponded with the range of higher frequencies, so with the right hand portion of the torque curves, where the torque K_s is hyperbolically dependent on the disc frequency N_s —corresponding as said with an energy absorption in the brake which is independent of the disc frequency and the pedal frequency respectively.

FIGURE 1 shows also that in the range of the lower frequencies of eddy current discs there is a linear relationship between the braking torque K_s and N_s .

According to my invention one works exclusively in the linear area, which is practically bounded by the dotted line A. This means that simply the transmission ratio between the pedal shaft and the eddy current disc has to be chosen at a lower value than in the known device.

FIGURE 2 shows the result of medical investigations with several patients of various ages and physical strength; it represents the quadratic relationship between the energy produced P, and the pedal frequency N, which corresponds with the most efficient action of the patients' metabolism.

Any of the parabolic curves of FIG. 2 is related with any of the linear curve portions of FIG. 1 by a definite value of the transmission ratio between the pedals and the eddy current disc.

It has further appeared to me that for all people the parabolic characteristics of FIG. 2 fall within rather narrow bounds. For a very great number of persons investigated, the curves lie within the limits of the full lines a and b, varying not more than about 10% from the average represented by the dash line c.

This experience gives rise to an embodiment of the ergometer having a simple fixed transmission between the pedals and the braking disc. The transmission ratio will have to be chosen such that one curve of FIG. 1 is picked up, giving the average parabolic curve c of FIG. 2 as the fixed and definite property of the ergometer.

This means that one arrives at a simple ergometer without variables, all patients on an average producing the energy at any ordered capacity under almost optimum conditions. Especially in such an embodiment a simple permanent magnet suffices.

When the pedal crank has a length of 17.5 cm., the average curve c has been found to follow the expression $N=5\sqrt{P}$, N being in revolutions per minute, P being in watts.

It should be noted that temporary deviations from the number of revolutions established for each test have a negligible influence on the measurement of the energy and oxygen, respectively, because the reduced energy production is almost compensated by the supplementary energy required in order to return to the established number of revolutions.

The above mentioned experimental relation between the energy P produced by the patient and the pedal frequency N can, in the following manner, be converted into a relation between the braking torque on the pedal shaft K and the pedal frequency. P is equal to the product of K and the angular frequency of the pedal. When P is expressed in watts, K in newtons, and N in revolutions per minute: $N=5\sqrt{2\pi NK/60}$, or $N=2.6K$.

Starting from the experimental data as represented in FIGURE 2 it becomes possible to construct an ergometer in which such variables are maintained such that it becomes possible for the tester to adjust exactly the optimum characteristics for any patient. This means that the resistance torque of the braking device should manifest itself on the pedal shaft by a value which is adjustable to 10% on either side of the aforementioned average value in the equation $N=2.6K$. Such a possibility of variation can be realized constructively in various ways. One possibility is that a variable gear wheel transmission is intercalated, e.g. constructed as a gear hub of a bicycle.

Another embodiment will hereinafter be described with reference to FIGURE 3.

FIGURE 3 shows a frame structure with an enclosure 1, in which is incorporated a pedal shaft 2 with pedals 4 mounted on cranks 3, and on which is mounted a saddle 5 and a bicycle handle-bar 6. An eddy current disc 7 is mounted on the pedal shaft, the said disc being

embraced by two permanent magnets 8 and 9. Between the magnets is a travelling wheel 10 of a speedometer 11. Since according to the invention there is a fixed relation between the circumferential speed of the eddy current disc at the location of the magnets and the energy absorbed by the eddy current disc, the speedometer 11 may directly be gauged in power units such as watts.

The two magnets and the travelling wheel are jointly mounted on a sledge 12, which in respect of the disc 7 is adjustable in radial direction by means of a handle 13. The cable 14 of the speedometer is flexible. Provided at about the height of the face of the person under observation is an indicator 15 of the number of revolutions per unit time, which instrument may be readable on both sides, and of which the travelling wheel 16 runs against the disc 7.

The tester can, by means of the handle 13, make the property of the ergometer deviate to a desired extent from the average optimum relation $N=5\sqrt{P}$, in order to relate this property to the personal properties of the person under observation. At the same time the speedometer 11 is readjusted automatically so that the indication of the capacity remains correct.

There was another disadvantage of the aforementioned prior device, i.e. the eddy current disc in the selected working range rotates at a very high speed. As a result, the disc absorbs comparatively much energy, which gives rise to incorrect results of measurement when the number of revolutions is not held precisely constant.

Since as compared with the prior device the speed of the present disc is only a fraction of the speed of the prior art disc, the kinetic energy of the present disc is so small that an error of measurement in the event of fluctuations of the number of revolutions is negligible.

The constructional simplification which becomes possible according to the invention manifests itself, on using an eddy current disc, in such a way that the electromagnetic energization is replaced by one or more suitably chosen permanent magnets, instead of electromagnets, which were up to now required for adjustment of the braking torque.

Thus the invention provides an efficient and also simple and cheap apparatus in which non-registered friction losses are reduced to a minimum, and with which measurements can be performed under optimum conditions so that the results are dependable to a high degree.

It will be understood that my invention of an ergometer wherein the resistance torque of the braking device varies in equal sense with the pedal frequency, and especially wherein they have a substantially quadratic relationship, can be realized also in many other ways as those described and shown. I therefore do not want to be limited further than I am limited by the scope of the following claims.

What I claim is:

1. An ergometer comprising:

(a) a braking means including:

(I) a rotatable element and,

(II) means for applying a braking torque to said element which varies with variations in speed of said element,

(b) means adapted to be rotated by a patient being tested, and

(c) transmission means between said means (b) and element (a)(I) for rotating said element (a)(I) such that throughout the entire normally prescribed range of speeds of rotation of said means (b) the braking torque of said braking means increases as the speed of rotation of said means (b) increases, and decreases as the speed of rotation of said means (b) decreases.

2. An ergometer as defined in claim 1 wherein said braking means and transmission means are so constructed that variations in braking torque are directly proportional to variations in the speed of rotation of said means (b).

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3. An ergometer as defined in claim 2 wherein said rotatable element (a)(I) is an eddy current disc, and including means for providing a magnetic field in the vicinity of said disc, said transmission means (c) being constructed to provide a low enough ratio between the rotational speeds of said means (b) and said disc that the latter operates in the linear zone of its braking torque versus speed of rotation relationship.

4. An ergometer as defined in claim 1 wherein said transmission means is constructed to provide a fixed ratio between the rotational speeds of said means (b) and said element (a)(I).

5. An ergometer as defined in claim 1 including means for adjusting the braking torque applied to said element (a)(I) by said means (a)(II).

6. An ergometer as defined in claim 3 wherein said means for providing a magnetic field includes a permanent magnet adjacent to said disc.

7. An ergometer as defined in claim 6 including means for adjusting the position of said permanent magnet in a radial direction with respect to said disc to adjust the braking torque on said disc as a result of said magnet.

8. An ergometer as defined in claim 3 including a speedometer having an indicator graduated in units of

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power, and means engaging said disc for transmitting the movement of the latter to said indicator.

9. An ergometer as defined in claim 7 including a speedometer having an indicator, follower means engaging a face of said disc for transmitting the movement of the latter to said indicator, said follower means being coupled to said adjusting means for moving said follower means together with said magnet radially with respect to said disc.

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U.S. Cl. XR.

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