PHYSIOLOGICALLY PACED ERGOMETRIC SYSTEM

Filed Oct. 1, 1965 3 Sheets-Sheet 1

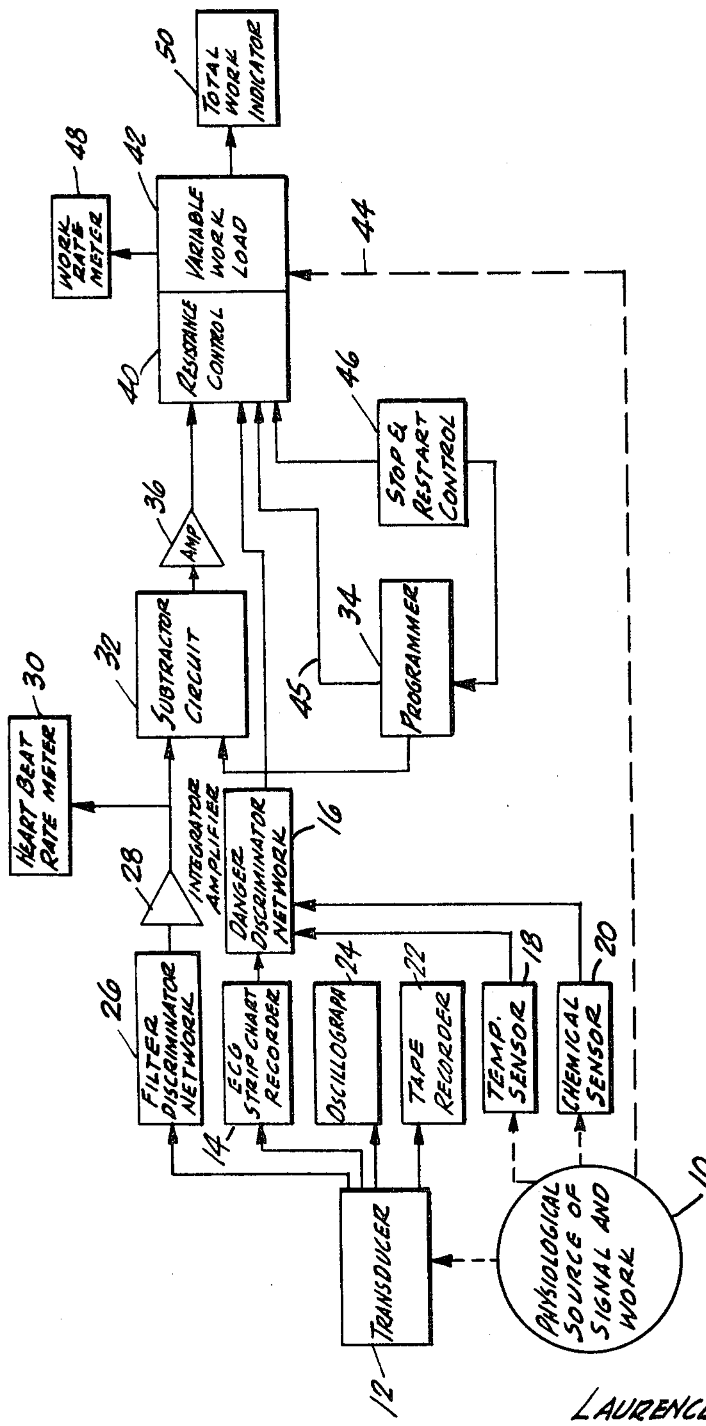


Fig. 1

INVENTOR.
LAURENCE E. MOREHOUSE
BY
Nilsson, Robbins & Anderson
ATTORNEYS

PHYSIOLOGICALLY PACED ERGOMETRIC SYSTEM

Filed Oct. 1, 1965 3 Sheets-Sheet 2

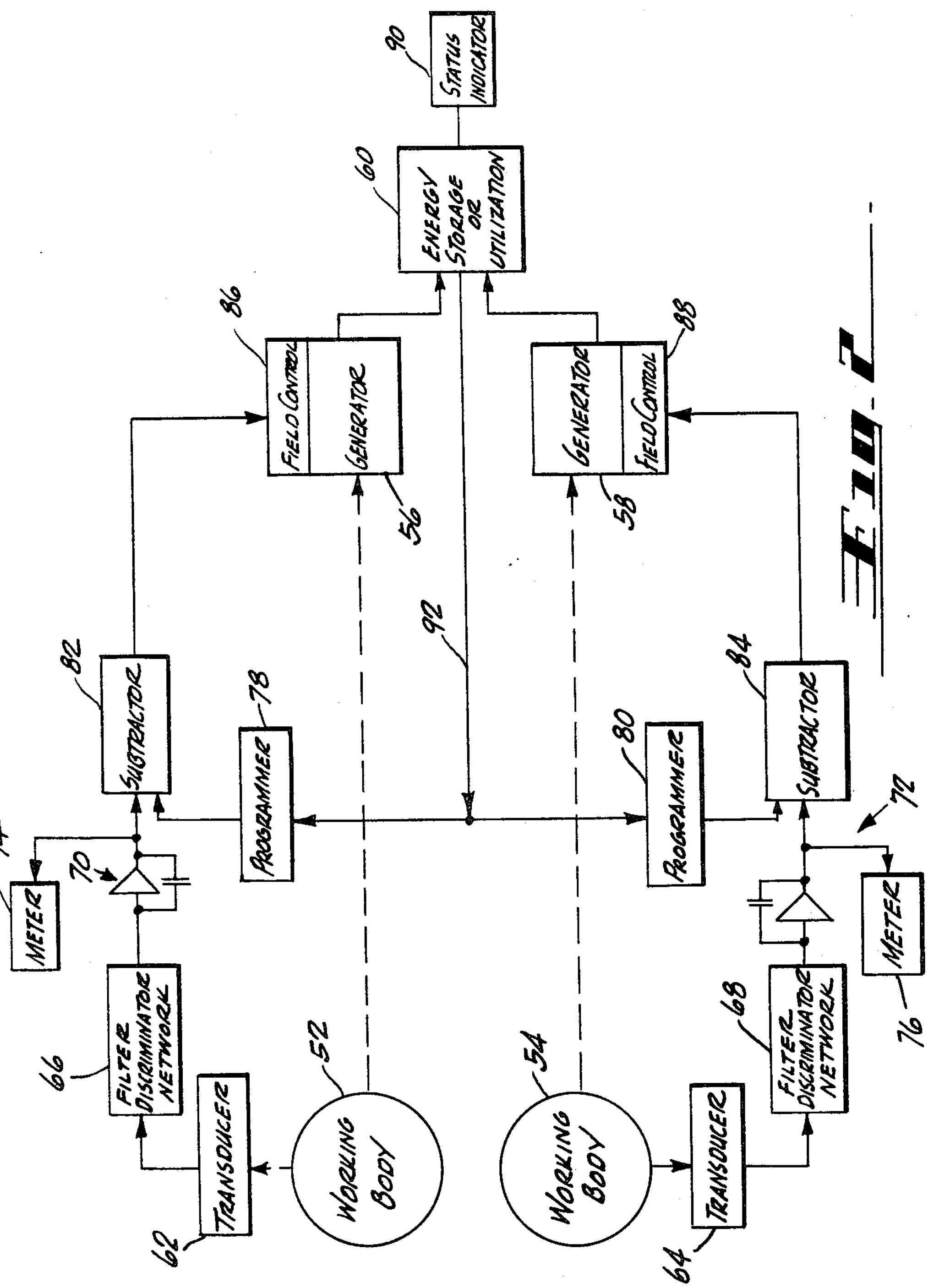
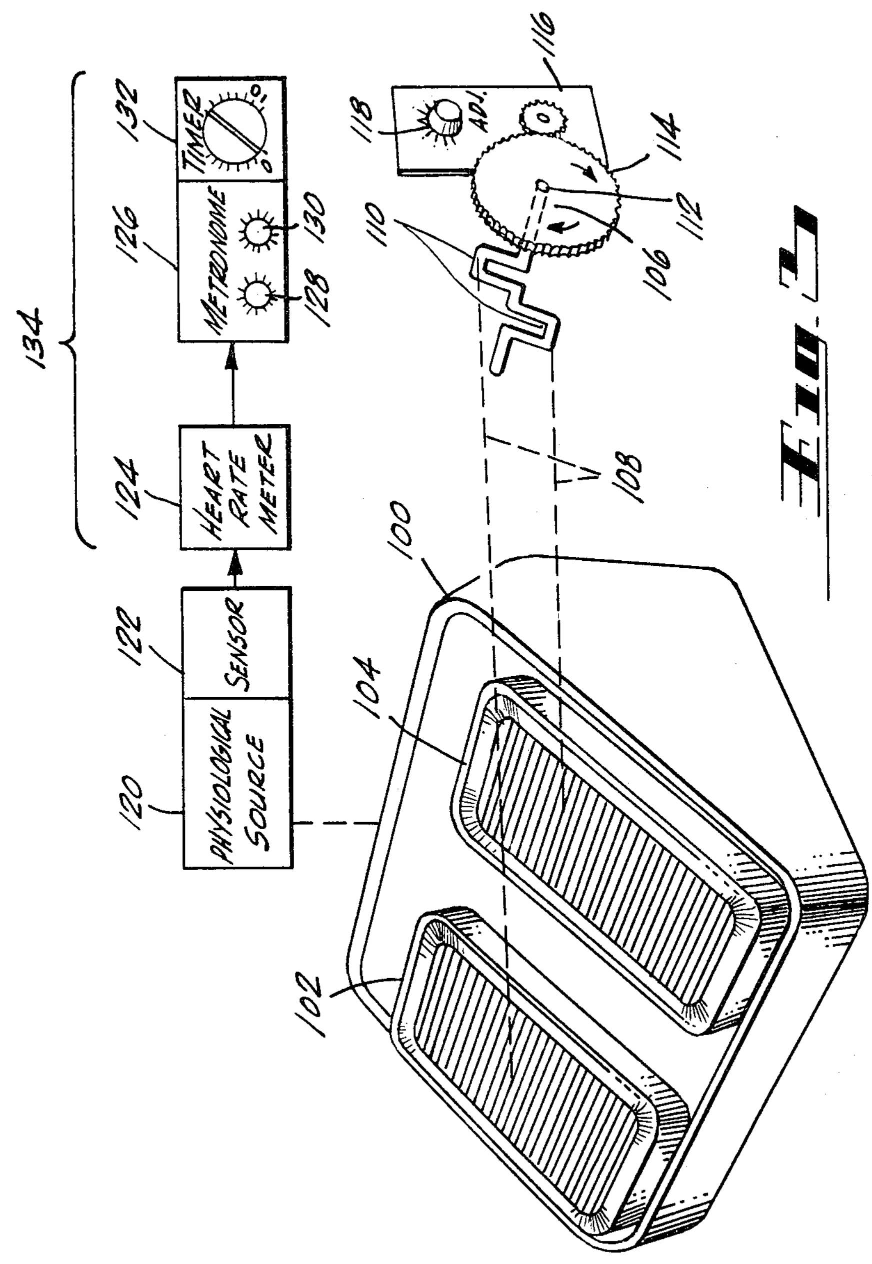


Fig. 2

INVENTOR.
LAURENCE E. MOREHOUSE
BY
Nilsson, Robbins & Anderson
-ATTORNEYS-

PHYSIOLOGICALLY PACED ERGOMETRIC SYSTEM

Filed Oct. 1, 1965 3 Sheets-Sheet 3



INVENTOR.
LAURENCE E. MOREHOUSE
BY
Nilsson, Robbins & Anderson
ATTORNEYS.

3,395,698
PHYSIOLOGICALLY PACED ERGOMETRIC SYSTEM

Laurence E. Morehouse, Los Angeles, Calif., assignor, by mesne assignments, to McDonnell Douglas Corporation, Santa Monica, Calif., a corporation of Maryland

Filed Oct. 1, 1965, Ser. No. 492,033
11 Claims. (Cl. 128—2.05)

This invention relates generally to physiological conditioning and exercising devices and systems and more particularly to such systems in which the magntiude of physical effort input is automatically controlled by a physiological output signal from the body of the person undergoing the conditioning.

It has recently become well established that prolonged lack of physiological stressing or exercising causes serious degenerative physiological effects in the human body. These effects include for example; deterioration of the structure, function and adaptation capability of the cardiovascular, neuro-muscular, metabolic, respiratory, and many other organic systems. Eventually the deterioration progresses to pathological states known as hypokinetic diseases. One serious example of such a disease is ischemic heart disease in which the heart muscle cells suffer from oxygen starvation; the heart becomes weaker, smaller and less efficient as a pump causing it to beat faster even when the body is at rest. This condition of the heart not only causes a high susceptibility to heart failure, particularly when placed under stress such as, for example, sudden exertion or emotional excitation, but, equally seriously, severly diminishes the ability of the heart to recover from heart failure or thrombosis whether caused directly by the ischemia or not. In addition the described deteriorative condition of the heart and other organs, whether or not acute, detracts severely from the individual's general physiological and mental welfare with obviously highly undesirable effects on the life, and all its physical, intellectual, and emotional products, of the individual.

The general problem has become gradually better known and understood with the development of industrialized societies in which large, statistically observable segments of the population lead sedentary, to varying degrees of inactivity, lives; while specific aspects of the problem have quite suddenly become critically of interest with the advent of recent experiments and proposed experiments in which the body is made inactive for prolonged periods of time while being isolated even from the stresses caused normally by the gravitational environment.

As may be inferred from the above, the present invention finds particularly useful application in the field of heart disease, its prevention and its cure; and, although in the cause of clarity and brevity of presentation, most of the following discussion and presentation of examples of the invention are directed to such applications and make use of direct signals from the heart, it is to be expressly understood that the many advantages of the invention are equally well manifest in the prevention and cure of other hypokinetic diseases and in which signals from the body utilized by this system may be other than from the heart. Such other signals for example may be chemical, electromyographic (i.e., skeletal muscle signals), thermo-electric, piezoelectric, or the like; and other diseases may be those of practically any other organ or part of the body. In addition, the invention's usefulness extends to non-human animals such as racing or working dogs or horses and porpoises.

Typical of such other parts of the body over which there has recently arisen a great deal of concern are the structurally rigid bones of the body which apparently suffer a severe softening, akin to dissolution, when totally inactive and when removed from stresses. Similarly skeletal and smooth muscles may become deteriorated due to nonstressing or injury or the like.

These effects or diseases for the most part are substantially identical to those which occur in the body during the aging process; however, although the latter natural processes apparently cannot be effectively controlled or reversed, the deteriorating effects due to inadequate exercise can be readily retarded and in most cases dramatically reversed by a proper program of physical exercise. These hypokinetic diseases and their cure are profound ramifications of the axiom that use of an organ makes it, while disuse destroys it.

The problem of reconditioning a heart is not a simple one and must be accomplished in a manner to rebuild the heart structure without endangering it by demanding from it a magnitude of work which will overtax it in its deconditioned state. At the same time, however, sufficient work in adequately increasing amounts must be provided or the program will be ineffective. Obviously a program proper for one individual may be substantially ineffective for another and probably dangerous for yet another. In addition the sedentary patient who is concerned or frightened and may be relatively physically lazy due either to his nature or his temporary condition, requires constant motivation, in the forms of confidence regarding safe exertion of his heart and satisfaction regarding progress, in reconditioning him.

It is presently accepted that at any age all deteriorations due to lack of exercise can be arrested and in most instances the deterioration can be reversed. In a proper regimen of exercise, the heart becomes richer in oxygen, more massive and powerful, more efficient as a pump and is able to beat more slowly and steadily under conditions of work and stress.

Increased resistance to heart disease as the result of reconditioning exercise may, in addition, be inferred from the epidemiological studies showing that the rate of heart attack deaths is significantly less among physically active than among sedentary populations. The mechanism underlying this relationship may be associated with the level of serum cholesterol concentration found in the blood of active people. Exercise reduces the serum cholesterol concentration especially when performed after meals. But probably contributing even more to heart attack resistance and particularly to recovery capability is the development of supplementary capillary blood vessels in the muscle tissues of one who has exercised strenuously. These extra vessels help to share the burden by providing blood flow to the myocardium when a coronary artery becomes occluded. It has been discovered that when a heart is caused by volume of work output to beat at the rate of 140 to 160 beats per minute these extra vessels begin to develop while at the same time the heart otherwise improves its condition in the respects noted above.

Exercising devices in the prior art which have been adaptable for use by sedentary persons typically require either a constant or unknown work input. In addition the subject does not know his heartbeat rate so that in using the device it may be causing his heartbeat rate to be dangerously high or ineffectively low. Furthermore, a work output magnitude which causes the proper heartbeat rate for a particular individual on one day may, because of a change of conditions, be thoroughly incorrect the next day. Still further it must be noted that the rate of work increase required for one subject in one period of the regimen will not be satisfactory for another person or for the same person during another portion of the program. In other words rates of recovery are highly nonlinear and different for different subjects.

Accordingly such prior art devices which require unknown or constant work inputs or which utilize a set program of increased work input suffer severe disadvantages in failing to extract from the subject the appropriate magnitude of work, which may be highly variable, required to cause the heartbeat rate, or other physiological condition, to follow a desired elevated value.

In addition to the above disadvantages and limitations of the prior art devices, it is further to be noted that the prior art devices are typically bulky, heavy, esthetically unattractive, and not readily portable and not adaptable for use in confined spaces. In addition they are generally formidably expensive for private use.

Other disadvantages of the prior art devices are that they often are not versatile to the needs of different types of subjects; and they are neither adequately reliable nor accurate. In addition, other disadvantages typically encountered in the prior art are that the device is not successfully designed for controlled use within safe limits or for ease and comfort and psychological pleasure in use. In other words, safety, personal satisfaction and incentive factors associated with the system are undesirably deficient.

It is accordingly an object of the present invention to provide an ergometric system which is not subject to these and other disadvantages and limitations in the prior art.

It is another object to provide such a system which automatically paces the work input in accordance with a physiological signal from the exercising subject and which eliminates the need for an additional operator thereby eliminating a source of possibly dangerous error in adjusting the work rate.

It is another object of the system to provide an ergometric system which extracts work from the subject at any rate whether steady or fluctuating whereby the subject's heartbeat rate or other physiological conditions is caused to follow a prescribed, predetermined desired program which is intrinsically and inherently safe for the subject.

It is another object of the present invention to provide such a system which is compact and portable, versatile to different patient conditions and needs, reliable and accurate, maintenance free and rugged, esthetically attractive, and motivationally desirable with respect to ease, comfort, and pleasure in use.

It is another object to provide such an ergometric system for calibrating persons or animals in terms of optimizing their rate of work output under certain conditions and requirements.

It is another object to provide such a system which automatically promptly shuts down when predetermined physiological signals are received from the subject.

It is another object to provide such a system in which the rate of work output from the subject is automatically infinitely, or smoothly, adjustable over a wide range of magnitude.

It is another object to provide a direct or absolute ergometric indicator of physiological work efficiency.

It is another object to provide such a system in which the subject need monitor no more than one simple parameter during the automatic system operation.

It is another object to provide such an ergometer system which, while being exceedingly compact, may be readily utilized to generate useful energy for use, for example, in earth isolated environments such as space capsules or interplanetary transports wherein the additional energy which may be generated for hygienic purposes may be stored for emergencies or otherwise put to use.

Very briefly, these and other objects of the present invention are achieved in one example thereof which includes a work resistance machine, or work sink, which the patient operates during the regimen of exercise. The magnitude of resistance in the work machine is electrically controlled and is determined by the electrical output signal from a heartbeat rate amplifier.

The electrical input signal to the amplifier in this example is derived from an electrical heart-rate meter, the

input terminals of which are in turn connected to a heart-rate sensing transducer physiologically coupled to the patient.

The mode of control of the mechanical resistance of the work machine component includes increasing the resistance until the patient's heartbeat rate has achieved a predetermined level, and automatically varying the resistance to cause the heartbeat to maintain the desired rate. The regimen may prescribe that the heartbeat rate be maintained constant for a predetermined period and then programmed through a decreasing work output to taper off the activity and gradually return the patient to his normal level of heart activity and heart excitation.

Alternately a desired heartbeat rate program for a particular patient may be set up on a programmer the output signal from which is compared at all times with the output signal rate from the sending transducer. The error signal generated from this signal of comparison is then continuously fed into the control mechanism for the variable work resistance. In this mode of control any desired program of heartbeat rate to fit the needs of an individual patient may be inserted in the program; and the patient, by simply monitoring at most one simple indicator and monitoring with his physical effort a predetermined reading thereon, will automatically follow the regimen prescribed for him irrespective of how complicated the work profile of the prescribed program may be and irrespective of the complex physiological effects which may be occurring in the subject. The subtle conditions and changes do not require anyone's attention, yet the procedure is intrinsically safe and effective for the patient. To reiterate, the very subtle changes required to match the external work load to the physiological level of effort are made automatically and do not demand the attention or concern of either the patient or of an observer. In his manner, both such persons can focus their attention on the patient's responses to the exercise.

In a presently preferred embodiment of the invention the work sink includes a bicycle type sprocket and pedals the drive from which is coupled to the variable resistance or load therefor. The machine is equipped with a revolutions rate meter indicating revolutions per minute (r.p.m.).

In practice the only instruction to the patient is that he maintain approximately a predetermined r.p.m. rate; the work that he does is then solely a function of the magnitude of the mechanical resistance against which his pedaling effort is accomplished. The system is found to be strikingly appealing to patients. They achieve a motivationally important satisfaction when they maintain the r.p.m. meter reading at the prescribed value against the varying resistance while pedaling, particularly when they understand that the resistance torque which they feel is a measure of their otherwise invisible heartbeat rate.

Further details of this and of other examples of the invention, including highly compact and portable examples thereof, and its principles of operation will be presented below in connection with a discussion of the accompanying drawings presented by way of example only and in which:

FIGURE 1 is a block diagram illustrating the structure and operation of one example of an ergometer system constructed in accordance with the principles of the present invention;

FIGURE 2 is a block diagram of an alternative example of such a system; and

FIGURE 3 is a schematic view of yet another example of an ergometric system constructed in accordance with the principles of the present invention.

With specific reference now to the figures in more detail it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and structural concepts of the invention. In this regard no attempt is made to show structural details of the physiologically paced ergometric system in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making it apparent, to those skilled in the fields of physiological practice and research, mechanics, and electronics, how the several forms of the invention may be embodied in practice. Specifically the detailed showing is not to be taken as a limitation upon the scope of the invention which is defined by the appended claims forming, along with the drawings, a part of this specification.

In FIGURE 1, a physiological source of work and physiological source of signal representative of the rate of that work is represented by a body **10** which may be a human body or that of an animal such as, for example, a horse, dog, or a porpoise. In a practical application of the invention the system may be utilized to regulate automatically a regimen of exercise for a human as indicated earlier, or it may be utilized for calibrating a body source of work in terms of, for example, maximizing the practical total work output of a particular subject by optimizing the rate of work output in the terms of duration of effort. Regarding humans, for example, one subject may provide one-half horsepower for 15 minutes to achieve his maximum safe work output for a day, while another subject maximizes his output by working at the rate of one-fourth H.P. for two hours. Such a calibration and "rating" for a person is of value in preparing for emergencies wherein additional energy may be needed, as for example, to complete a space mission. Other such human applications include aiding athletes in selecting sports for which they are best suited and on conventional military, research, or mountain climbing expeditions wherein such calibration studies aid in determining the optimum between maximizing the duration of the mission and minimizing the food supply and consequent weight of pack.

Regarding animals, it may be noted that the selection of the particular type of race or work best suited for particular animals can be most advantageously made if the optimum amount of work for the animal is known. Furthermore one of the goals of current sea laboratory work is to determine to what extent and for what durations of time sea animals can be used for useful work.

A transducer **12** is coupled to the body **10** and may be of the well known electrocardiogram electrode type for providing an electrical output signal representative of the heartbeat and the heartbeat characteristics of the subject. For many purposes of analysis and observation the remainder of a conventional electrocardiogram strip chart recorder **14** may be coupled to an output channel of the transducer **12**. The recorder **14** may be used continuously; however, typically it has been found adequate for the recorder to be used primarily for sampling and spot analysis of the output of the transducer **12**.

The input portions of the electrocardiogram, i.e., the non-recording portions thereof are, in this example, connected to a danger discriminator network **16** which may, when desired, continually monitor the heartbeat wave form in a manner to monitor electronically the output of the transducer **12** to watch for danger signals caused from, for example, over-exertion without continuously operating the electrocardiogram strip chart recorder as a whole. The operation of the danger discriminator network in this regard is to provide a system shutdown signal, when, for example, the *s–t* portion of the electrocardiograph drops below a certain predetermined level or when the *q–r* portion of the wave form manifests an undesired characteristic.

Similarly a temperature sensor **18** may be coupled thermally to the source **10** to provide a different type of physiologically actuated system shutdown signal. In this mode of control when the body temperature passes a certain predetermined level thereby presaging heat exhaustion the electro output signal of the sensor **18** is operated upon by the danger discriminator network **16** to form the desired shutdown signal. Still a further sensor which has been utilized is a chemical transducer **20** which is chemically coupled to the body **10** as by a probe insertion into the bloodstream thereof in a manner, for example, to monitor the blood lactic acid content whereby, when the latter reaches a predetemined undesirable level, the danger discriminator network again functions to create a system shutdown signal.

Utilized typically for purposes of continuous monitoring of the electrical output signal of the transducer **12** is a tape recorder **22** and a heartbeat triggered oscillograph **24**. The tape recorder provides a permanent record which may be analyzed or observed when desired and may be utilized for later comparison with other like records. The oscillograph **24** provides a continuous, real time, graph of the heartbeat wave form from the body **10**. When desired, motion or still photographs may be made of the scope presentation of the oscillograph **24** as for use in detailed analysis or later comparison work.

Further, in this example, discriminator network **26** is coupled to an open output terminal of the transducer **12** for purposes of operating on the heartbeat wave train signals from the tranducer **12** to prepore them for conversion by an integrator amplifier **28** into an analog voltage signal, the instantaneous amplitude of which is proportional to the frequency of the heartbeat rate. The filter-discriminator network **26** may be of substantially conventional design of the character to reject spurious signals outputted by the transducer **12**. These rejected signals may, for example, comprise spurious heartbeats or electromyogram signals from the skeletal or smooth muscles. The network **26** also operates on the wave train signals to reinsert therein a synthesized heartbeat signal when the subject's heart has skipped a beat or when for other reasons the transducer **12** has failed to output the typical signal.

The integrator amplifier **28** is in effect a converter which operates in cooperation with the discriminator portions of the network **26** to convert the frequency of the heartbeat signals into the voltage analog as mentioned above. The output terminal of the amplifier **28** may be coupled to a heartbeat rate meter **30** so that, when desired, the heartbeat rate may be visually monitored by either a trained observer or the subject himself.

The output terminal of the amplifier **28** is also coupled to an input terminal of the comparator network such as, in this example, a subtractor circuit **32**. Another, parallel, input terminal to the subtractor circuit **32** is connected to the output terminal of a programmer **34**.

The programmer **34** in this example provides an analog output signal which is like that which is desired to be outputted from the body **10** after proper operation thereon by the transducer **12**, the filter discriminator network **26**, and integrator amplifier **28**. In other words, the output of the programmer **34** is representative of the ideal or prescribed output from the body **10**. This signal is then compared in the subtractor circuit **32** with the output signal from the integrator amplifier **28** and the resulting analog error signal is coupled through an amplifier **36** to the control mechanism **40** for the variable work load device **42**. The work load device **42** may be, in this example, a stationary bicycle type ergometer the resistance to the pedaling of which may be varied by hysteresis or eddy current clutch type means, by hydraulic controls, by mechanical friction, by varying the field current in an electrical generator the armature of which is rotated by the patient, or the like. Alternatively, the work device may be a treadmill whose resistance and/or inclination angle is varied. It is to be noted, however, that in any case, the subject is required to observe, and "obey," only one simple parameter such as, for example, r.p.m. of the pedaling or the lineal velocity of the treadmill; the system automatically, then, controls the prescribed magnitude of effort to be outputted by the patient at every instant of time during the duration of the exercise regimen.

When the signal from the programmer **34** substantially matches that from the integrator amplifier **28** the resultant error signal at the output terminal of the subtractor circuit **32** is zero, whereby the resistance control mechanism **40** is not changed to alter the magnitude of resistance associated with the variable work load **42**. When however the signal output of the integrator amplifier **28** is, for example, less than the output signal from the programmer **34** at a particular instant of time, indicating that the heartbeat rate and therefore the effort being expended by the body **10** is less than the prescribed value for that moment, the error signal developed at the subtractor circuit **32** has a magnitude and polarity to cause the resistance control mechanism **40** to adjust the resistance associated with the variable work load **42** whereby to increase the resistance felt by the body **10** which is drivingly coupled thereto through the mechanical connection indicated by the line **44** as shown. This mechanical connection may of course be simply the placement of the patient's feet upon the pedals of a bicycle type ergometer, or other like harnessing connection.

Conversely from the example set forth below, when the output signal from the integrator amplifier **28** is greater at a particular instant of time than that from the programmer **34** thereby indicating that the subject is exerting more than the desired rate of work, the output signal from the subtractor circuit **32** is of the opposite polarity and of a magnitude to cause a resistance control mechanism **40** to adjust the variable work load **42** whereby the body **10** performs a lesser rate of work.

The programmer **34** may provide its prescribed output signal in response to an interval timer and an adjustment for a desired, for example, 150 pulses per minute, heartbeat rate analog signal. Alternatively the input for the programmer may be a card with a prescribed pre-punched program thereon or a magnetic tape instruction record or the like. When the desired duration of the program is indicated, a stop signal may be sent along a signal lead **45** directly to the resistance control mechanism **40**, thereby to decrease gradually, or abruptly, the amount of resistance associated with the variable work load **42**.

As mentioned above, the system may include a number of physiologically activated, cut off signal capabilities which cause the output signal from the danger discriminator network **16** to be fed to the resistance control mechanism **40** thereby to shut down the magnitude of resistance associated therewith. In addition, however, a trained observer who may be present in certain situations, such as for example, when an injured patient or a space traveller is being systematically reconditioned in a critical regimen of exercise; and the observer may determine from the oscillograph **24** or from observations and conversations with the subject that the exercise should be terminated. In such a case, the observer may institute an abrupt or programmed "stop" sequence by pressing a button on the stop and restart control network **46**. Similarly when the exercise program is to be resumed a "restart" control button may be pressed to cause the programmer **34** to begin its programmed analog anew.

It is often desirable to observer at any given point in time the rate of work being accomplished by the body **10**. To this end a work rate meter **48** may be connected to the variable work load **42**. Similarly a total work indicator **50** which integrates the work rate of the meter **48** is connected, as shown, to the variable work load **42**.

Referring to FIGURE 2, an example of the invention is illustrated in which a pair of working bodies **52**, **54** are mechanically coupled to respective electrical generators **56**, **58**. In this embodiment of the invention it is presumed that it is desirable not only to provide a prescribed regimen of exercise for the working bodies **52**, **54** but also to accumulate and utilize the energy produced by the prescribed exercise in an energy storage or utilization device **60**, which is coupled to both of the electrical generators **56**, **58**. It is further presumed in this example that the working bodies **52**, **54** have each been calibrated as discussed above so that the prescribed regimen of exercise is constructively proper for each of the bodies and whereby the energy accumulated or utilized from each of the working bodies is maximized by virtue of the same prescribed program.

As in the example, of the previous figure, each of the bodies **52**, **54** is coupled respectively to a sensor transducer **62**, **64** which is, in turn, coupled through a filter-discriminator network **66**, **68** and an integrating amplifier circuit **70**, **72** respectively. Again, a heartbeat rate meter **74**, **76** may be coupled to an output terminal of the amplifiers **70**, **72**, respectively, for the purposes of observing, when desired, the instantaneous status of the heartbeat rate of each of the working bodies **52**, **54**.

Each one of a pair of programmers **78**, **80**, functioning independently from the other, and with a particular program inserted therein, prescribed for its respective working body, is coupled to one of the comparing input terminals of a substractor **82**, **84**, while the other comparing input terminal is connected to a respective one of the programmers **78**, **80**. The error signal from each of these subtractor circuits **82**, **84** is fed to a field current control network **86**, **88** connected respectively to the generators **56**, **58** for purposes of varying the amount of resistance to armature rotation thereof and electrical current output therefrom which is fed to the energy storage or utilization device **60**. The status of the device **60** which may be indicated by an indicator **90** may be fed by means of, for example, an electrical analog signal along the conductor **92** to each of the programmers **78**, **80**, for the purposes of, for example, shutting down the system when the energy storage has achieved a desired level in the device **60**.

In FIGURE 3, an example of the invention is illustrated schematically which is particularly advantageous in use as a compact ergometric system which is portable, which may be readily and conveniently used by a desk worker, or which may be used by persons in confined quarters such as, for example, submarines, sea laboratory capsules, or space capsules.

This embodiment of the invention comprises a compact, aesthetically attractive foot pedal console **100** which contains a pair of reciprocatable pedals **102**, **104** which are connected to opposite sides of a sprocket **106** as indicated by the dashed lines **108** through a pair of reciprocating connecting rods **110**. The sprocket **106** has an axis of rotation, normal to the plane of the drawing, indicated at **112**, and is rotationally coaxially connected to a drive gear **114**. The drive gear **114** is in turn mechanically rotationally coupled to a variable resistance load mechanism **116**, the degree of resistance of which is adjustable by the setting of a control **118**. Thus, reciprocating action of the pedals **102**, **104** through the connecting rods **110** causes a work input to the variable resistance load mechanism **116**. The magnitude of the resistance associated with the mechanism **116** may be constant for a particular regimen of exercise and be set in advance for a particular patient by positioning of the control **118** by an expert observer or doctor.

Also coupled mechanically to the console **100** is the physiological source of energy **120** which again is presumably the human for whom the regimen of exercise has been prescribed. A transducer sensor **122** is also coupled to the source **120** and provides an electrical output signal which is converted by a heart rate meter **124** into an analog electrical signal which is proportional to the heartbeat rate of the patient. The heartbeat rate meter **124** is electrically coupled to a metronome **126** the frequency of which is electrically controlled thereby and which is of the character including a pair of alternately flashing lights **128**, **130**. The frequency of the flashing lights **128**, **130** constitutes an instruction signal to the patient giving him a cadence for the actuation of the pedals **102, 104**. When the heartbeat rate is low the metronome signals are of a relatively higher frequency; when on the other hand the heartbeat rate is high, the metronome flashing is caused to be slower thereby in either event the work outputted by the source **120** through the sprocket **106** is automatically controlled to be that which provides the prescribed heartbeat rate.

The duration of the regimen of exercise is also prescribed for the individual in accordance with his particular program of conditioning or reconditioning; and to this end a timer device **132** is included in the desk top console, indicated by the bracket **134**.

There have thus been disclosed and discussed a number of examples of a physiologically paced ergometric system which achieves the objects and exhibits the advantages set forth hereinabove.

What is claimed is:

1. Automatic physiologically paced ergometric system comprising:

sensor transducer means of the character adapted to be coupled to a physiological source of work and source of physiological signal representative of the magnitude of such work at a given point in time for providing an electrical output signal responsive to and representative of physiological effort associated with said source of work;

electrical means coupled to said transducer means for generating an analog signal representative of the status of a predetermined physiological criterion associated with said source;

programmer means for generating an electrical analog signal representative of a program of desired status of said predetermined physiological criterion;

comparator means having input terminals coupled to said electrical means and to said programmer means for generating an error signal representative of distinctions between the said analog signals; and

variable work load means adapted to be mechanically coupled to said source of physiological work and having an electrically actuated control means for regulating the amount of work inputted to said load means, said control means being coupled to said comparator means.

2. Automatic physiologically paced ergometric system comprising:

sensor transducer means of the character adapted to be coupled to a physiological source of work and source of physiological signal representative of the magnitude of such work at a given point in time for providing an electrical output signal responsive to and representative of physiological effort associated with said source of work;

heartbeat tachometer means coupled to said transducer means for generating an electrical analog signal representative of the heartbeat rate associated with said source;

programmer means for generating an electrical analog signal representative of a predetermined program of said heartbeat rate versus time;

comparator means having input terminals coupled to said tachometer and to said programmer means for generating an error signal representative of voltage distinctions between said analog signals; and

variable work load means adapted to be mechanically coupled to source of physiological work and having an electrically actuated control means for regulating the amount of work inputted to said load means, said control means having an input terminal coupled to said comparator means whereby said error signal is impressed upon said input terminal of said control means.

3. The invention according to claim **2** in which said heartbeat tachometer means includes filter-discriminator network means coupled to said transducer means for rejecting spurious heartbeat signals.

4. The invention according to claim **3** which further includes integrator-amplifier means coupled to said filter-discriminator network means for generating said electrical analog signal representative of said heartbeat rate.

5. The invention according to claim **4** in which said comparator means includes a subtractor network for generating said error signal representative of the difference between said analog signals.

6. The invention according to claim **5** which further includes an electrocardiogram type strip chart recorder means coupled to said transducer means.

7. The invention according to claim **6** which further includes a danger discriminator network intercoupled between said control means for said variable work load means and said strip chart recorder means for detecting danger indication characteristics in the heartbeat signals and for generating an override, system shut down signal to said control means in response thereto.

8. Automatic physiologically paced ergometric system comprising:

sensor transducer means of the character adapted to be coupled to a physiological source of work and source of physiological signal representative of the magnitude of such work at a given point in time for providing an electrical output signal responsive to and representative of physiological effort associated with said source of work;

electrical means coupled to said transducer means for generating an analog signal representative of the difference between the status of a predetermined physiological criterion associated with said source and a desired extraordinary status of said criterion;

adjustable pacer means coupled to said electrical means for generating an instructional signal, readable by said source representative of said difference analog signal; and

work load means adapted to be mechanically coupled to said source of physiological work.

9. The invention according to claim **8** in which said electrical means includes a heatbeat rate meter and in which said pacer means comprises flashing metronome means whose frequency of flashing is controlled by said analog signal.

10. The invention according to claim **8** in which said work load means comprises a compact housing positionable within a conventional desk knee well and further including a pair of foot operated reciprocatable resistance pedals carried by said housing.

11. The invention according to claim **10** which further includes adjustable resistance means coupled to said reciprocatable pedals.

References Cited

UNITED STATES PATENTS

2,848,992	8/1958	Pigeon	128—2.05
3,285,070	11/1966	McDonough	73—379

RICHARD A. GAUDET, *Primary Examiner.*

SIMON BRODER, *Assistant Examiner.*