AMBB

Patents on Development Work

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1. Both in my own interest and future financial interests of the government it would seem prudent to firmly establish the proprietory rights in a number of projects on which I have worked for the past 2 years. My current discharge date is June 26 and to date only one patent has been disclosed (on the spring mass pendulum). There has been no apparent action toward filing on this item in about a year now. There are 3 or 4 areas of exploration which I should like to have on record. Some of the projects are still to be completed while another has just recently been reduced to practice which accounts for lack of prior filing on these items.

a. For proprietory reasons the item which should be of most interest is the so-called total body ergometer. An ergometer is basically a device for measurement of external work performed by humans. In addition the workload should be variable to provide a variety of loading tasks to the subject. The art of ergometry has hardly changed over the past 20-30 years and typically consists of an electric generator whose output is taken as some measure of the mechanical input to the device, i.e., the work performed by the subject. This generator was usually coupled to a bicycle crank arrangement which the individual pedals. Other arrangements were sometimes used, such as translation of a handle which was in turn coupled to the generator. While the generator concept has become most widely used, other arrangements often used some form of mechanical resistance to provide a load for the subject. While these devices were adequate in some situations they were grossly insufficient in others since 1) the calibration of the device was at best a severe problem and more likely to be only an approximation, 2) only variations in the total magnitude of the force that was applied to the subject was possible, 3) devices were extremely inflexible in regards to the type of loading that could be provided to the subject.

b. I have long been interested in and actively pursued exercise physiology (under whose purview the field of ergometry falls) and had informally discussed many times the possibility of building an improved ergometer prior to and after entry into the Air Force; much prior to being formally presented with the problem. An urgent need arose for an improved ergometer in an Air Force space mission and in addition to regular duties I agreed to attempt a solution to the problem.

c. My approach to the problem which has certain unique features was as follows:

The device should allow variations in type as well as amount of loading. It should be stable and the total amount of input work should be capable of precise and instantaneous measurement. The device should be flexible enough to allow a variety of modes of coupling to the subject. It may be rather simply shown that the body must cope with a variety of forces which are usually combinations of 3 basic forces which are: 1) inertial (force is equal to mass times acceleration), 2) gravitational (force equals constant when displacement is above zero) and resistive (force is equal to a constant times velocity^n where n typically varies from 0 to 2). A unique set of force generators, which is one of the novel parts of this device, was made to satisfy these equations. For inertial forces it is a matter of converting moments of inertia of rotating weights into the correct vector and magnitude of the inertial force applied to the subject. For gravitational like (constant) forces, a so-called constant force spring was utilized. In the resistive forces a simple friction brake arrangement and a unique permanent magnet eddy current generator were used to generate resistive forces for n=0 and n=2, respectively. All of these mechanisms are inherently stable and also permit accurate variations in the magnitude as well as the type of applied force. A second unique feature of the ergometer is precise measurement of the input which is accomplished by placement of strain gauges to directly measure force at the point of input and direct measurement of displacement by means of a suitable transducer. By electronic or other means, velocity may be obtained from displacement and then multiplied times force electronically or by other means to obtain the rate of doing work or power. This in turn may then be integrated with respect to time to obtain work by electronic means. This measurement system has two unique advantages over previous ergometers in that the total work was measured directly at the input, and the measurements are instantaneous rather than the previously timed averaged measurements.

I did the overall design of this generator and measurement system and for practical realization combined it with a requirement for a so-called total body exerciser, a translational bar which may be moved for a distance of 8 feet or any two points in between. However, it should be noted that this is only one form of motion which the ergometer system allows. I supervised the detailed layout of the device which was performed by Southwest Research Institute and the fabrication and testing of the device which was performed in the SAM Instrument Shop and the testing which was again performed using SAM facilities. The device has proven to have all the advantages that were initially proposed for it and it is now programmed for several space missions. My feeling on this item is that the concepts of the device were a product of work accomplished prior to service and the actual design of the device was taken on in addition to other duties and in fact accomplished at the expense of weekends and evenings. For this reason I feel the government should have royalty free use of all aspects of this patent, but that any other rights should remain my property.

2. The second item which is still to be finally tested, which should be of interest to the Air Force is an ear piece densitometer. In addition to its other properties, blood changes colors, i.e., has a different optical spectral absorption depending upon its state of saturation with oxygen. This allows one to determine the amount of oxygen in blood by optical means. In addition, by injecting dyes into the blood stream, certain aspects of the hemodynamics may be determined, for example cardiact output and blood volume.

a. There is a very extensive and often frustrating history of attempts to devise a practical ear piece "oximeter," an instrument for blood oxygen determinations, since Kramer demonstrated such a device in 1938. Although the previously mentioned optical procedures are very successful and practical by means of sampling which requires opening of blood vessels, the ear piece has at best always been marginal.

b. I had worked on this problem in relation to gastric flow with the Department of Surgery of North Carolina Medical School prior to entry in service. Colonel J. W. Ord had devised a scheme for combining the functions of determination of arterial blood saturation and cardiac output by means of dye dilution prior to my joining the space medicine program. He, however, had been unable to have this reduced to practice. In addition the existing devices have severe technical limitations such that it was impossible to approach the problem with off-the-shelf devices.

c. My approach to the problem ran as follows: The behavior of solutions of hemoglobin at various oxygen saturations are well known and follow conventional optical absorption laws which may be summarized by $I = I_o e^{-abc}$. Where: I is the intensity of a monochromatic light beam after passage through a hemogenous solution of the absorbing material, I_O is the initial intensity of this beam of light, a is an absorption coefficient which is characteristic both of the material through which it passes and also of the wave length of the incident radiation, b is the quantity of absorbing material present, and c is total path length of this absorbing material. This exact law does not hold at all with non-hemogenous solutions such as hemoglobin containing corpuscles in blood. The behavior of such mixtures has not as yet been completely elucidated. However, by careful empirical methods, the amount of absorbing material may be determined from whole blood. Further, the studies with which we are interested involve only the arterial blood. It is fairly common practice to arterialize an area of tissue by application of some form local vasodilator such that blood flow through an area is many times the normal metabolic requirements and the venous blood in essence becomes arterial blood. The ear is a relatively transparent area of the body which allows passage of a beam of light. For this reason it is most frequently the site used and is used here. Vasodilation in this case is performed by means of ionotophoresis with histamine sulphate or phosphate, also a well-known procedure. It is essential that the light source be extremely stable, that only monochromatic light, i.e., of the single wave lengths (or color) be used, that the detecting cell be stable especially as regards relative sensitivity to various colors, that the post detector amplification also be stable and that certain mathematical manipulations be precisely performed by exacting electronic or similar means. The requirement for absolute source stability were met by the use of a carefully regulated incandescent bulb chosen for long life with other operating constraints to insure stability throughout its life. This light was in turn rendered monochromatic by a rotating "chopper," i.e., a series of narrow band interference filters which are time sequentially placed into the light beam. This filtered beam of light was allowed to fall on the pinna of the ear, pass through it, be selectively absorbed and the resulting intensity of light was detected by means of a rapid response, temperature compensated silicon photo diode. This in turn is handled by stable amplifiers and the information from each of the color beams of light separated from the composite signals by means of a synchronous detector, i.e., a series of relays which were closed only when a particular beam of light was present. Following this, exact analog elements take logs and perform other manipulations on the signal. Once a suitable instrumentation arrangement had been accomplished, it was necessary to very carefully and precisely choose the wave lengths of light to be used. This had to be accomplished empirically since previous measurements were not adequate to allow prediction of these wave lengths. The first wave length to be chosen was 805 mu, a point at which both oxygenated and reduced, i.e., non-oxygenated hemoglobin absorbs equally. Measurement at this wave length thus allows determination of absorption due to two components. One is that of the hemoglobin present, and the second that of the non-blood containing tissues of the ear. The two components must be separated and this is accomplished by rendering the ear approximately bloodless by means of two pneumatic capsules which are inflated well above the systolic arterial pressure. Such capsules had previously been used but only on one side of the ear which resulted in far from complete removal of the blood. Once the blood had been removed a "zero line" may be established and after blood flows back into the ear, the absorption due to the total amount of blood present may be determined by choice of another wave length of say approximately 700 mu. The ratio of the amount of non-oxygenated to oxygenated blood may be determined by taking the logarithm of the respective intensities and dividing them. This is accomplished by electronic methods. There was an additional requirement in this case for the determination of cardiac output. This may be done by knowledge of the time variation of the concentration of a tracer dye which is injected proximal to the heart with the dye concentration being sampled over a period of time from the arterial system. In this case it was also desired to obtain the total plasma volume which may be done by injecting a known concentration of dye which remains in the plasma and at some later time, after complete distribution has taken place, by measurement of the concentration of the diluted dye. Such a dye suitable for use is the Type 1824 (Evans Blue) which remains attached to the plasma proteins, i.e., remains within the blood stream and which absorbs heavily at the wave length of 620 mu. By setting the 3d wave lengths of light to register the absorption of 625 mu the concentration of dye could then be determined in the ear and the time course of this concentration may be determined and the cardiac output measured.

However, several variables are present which must be corrected. Changes in arterial saturation will be reflected in the change in absorption at this wave length also, and the path lengths must be determined. In the system devised here, the problem of variation with arterial saturation is solved by putting in a correction factor from the previously determined arterial saturation of blood measured from the initial two wave lengths described. The path length is obtained by allowing the dye to reach equilibtium in the ear and its optical absorption noted at this point. In addition the optical absorption of a small sample of dye contained in the plasma obtained from venipuncture is measured in a cuvette of known path lengths using the same ear piece densitometer. Since we now can determine the concentration the path length can be calculated from this. This gives us the required information to determine arterial saturation, cardiac output and blood volume from a single small instrument. A unique feature of the instrument was the use of microminiature motor and filter disk which reduced the device sufficient in size to place it directly on the ear. Rotating monochromators had been used before but had always to be coupled to the ear by means of some form of flexible light paths which was unsatisfactory.

d. Summarizing development of this device, because of previous knowledge I was able to take a concept for a three-wave length densitometer which was proposed by Colonel Ord, who did not have specific information in regards to the necessary wave lengths or as to the methods for actual accomplishment of the procedures and convert this into laboratory apparatus which has in fact demonstrated the practicality of the method. In addition a small prototype suitable for use directly on the ear has been constructed and is currently being tested but this testing is not complete at this time. The reduction to practice and some of the testing was performed with resources of the School of Aerospace Medicine, but a not inconsiderable amount of personal equipment not otherwise available was used. In this case I feel that joint application with myself and Colonel Ord should as inventors be made with the government retaining right to free use and any commercial rights remaining the joint property of the inventors.

3. A recurrent problem, particularly in neurological research, is the determination of the depth of sleep which may be staged from somewhat superficial "light" sleep to the profound sleep of which a certain quantity is required for the normal function of humans.

a. This staging has been most accurately carried out by means of EEG studies, which are more or less characteristic for the various stages of sleep. Crieria relating the frequency and amplitude of EEG wave forms, which by definition determines stages of sleep, have been established and are reasonably well known. However, an actual staging of sleep is at best a time-consuming process which requires a good deal of training. In addition the EEG wave form in its raw condition contains a great deal of information which makes it impractical to transmit over restricted data handling facilities such as occur in space flights and certain earth-bound situations.

b. I have worked with EEGs, particularly the instrumentation aspects, since 1955 and have also done a large amount of work in techniques of automatic data reduction. By application of this previous experience to the problem of EEG staging, it has been possible to demonstrate a bread board automatic sleep stager, using synthetic signals, which indicate that a small automatic sleep staging device is practical. It consists in essence of electronic sorting, by means of period analysis of EEG channels into several band widths, putting a temporal value over fixed epochs on these various channels of activity and then by means of logic performed by electronics to determine the level of sleep. The device is small and simple enough to be used onboard spacecraft. Again, I feel that the government should be granted free use of any rights which might have accrued from this work,,but that I retain any other rights. Finally, there has been a good deal of what might be considered non-specific electronic work which to my knowledge has produced nothing unique. This work includes the field of radiotelemetry, a field in which I have been engaged since 1959, prior to coming into service. The use of frequency shift keying for a miniature transmitter has been the only reduction to practice and this was accomplished largely with personal materials making use of some instruments in the School of Aerospace Medicine. However, frequency shift keying is a fairly well known procedure in other applications, and I doubt it would be worth pursuing alone here.

4. I will be happy to follow any equitable course on the pursuit of the patents and would in fact like to pursue them at my own expense, with royalty-free license to the government.

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