The General Radio Experimenter

VOL. V, No. 2 JULY, 1930

THE CONTINUOUS RECORDING OF PULSE RATES

By HORATIO W. LAMSON

AN illustration of the interrelation of the sciences is to be seen in the increasing use which the members of the medical profession are making of electrical equipment in the diagnosis and treatment of the ills of mankind. For example, it is well known that muscular contractions are accompanied by more or less pro-

FIGURE 1. The cardiotachometer in use in the laboratory of Dr. A. V. Bock at the Massachusetts General Hospital, Boston. The patient exercises on the treadmill while continuous records of the pulse rate are taken

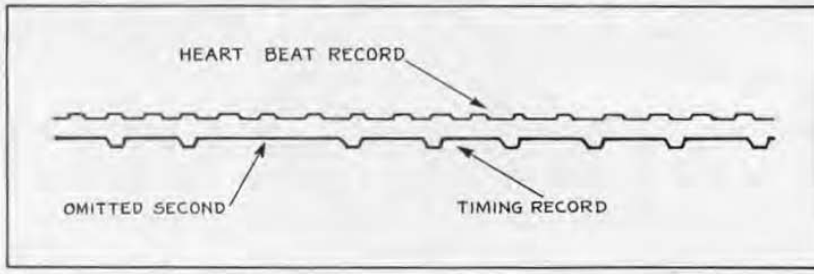

FIGURE 2. A full size sample record from the cardiotachometer

nounced electrical potentials. Extensive use has been made of this phenomenon in diagnosing and studying diseases of the heart.

By means of the electrocardiograph, the voltage wave produced by the systole, or contraction phase of the heart-beat cycle, may be introduced onto the vibrating element of an Einthoven or string galvanometer and thence recorded as an oscillogram upon a photographic film. For each complete beat of the heart, such a record shows a single pulse caused by the systole of the auricle followed by a quadruplex wave produced by the systole of the ventricle. This whole cycle is repeated about 80 times per minute. An analysis of the shape and timing of these complex waveforms gives the physician many data concerning the functioning of the heart.

In order that satisfactory records may be obtained from the electrocardiograph, the patient must be in a condition of comparative repose so that the systolic waves will not be confused or obliterated by other potentials due to the contraction of muscles not involved in the action of the heart. It is, therefore, impractical to use the ordinary electrocardiograph for recording or timing heart action when the patient is exercising or is in a state of physical exertion or muscular strain.

The heart is primarily a pump for supplying the revitalizing blood stream to all parts of the body. Mental emotion and muscular activity demand an increased supply of blood which is met, in part, by an increase in the pulse rate. It is, therefore, important to study in what manner the heart meets the demands made upon it, how soon it becomes fatigued, and how rapidly it returns to its normal rate after the cessation of muscular activity.

In carrying out such fatigue studies it was very desirable to have some technique for accurately measuring the pulse rate of the patient from moment to moment during exercise. For this purpose, as pointed out above, the electrocardiograph could not be used. Researches along these lines conducted by the Fatigue Laboratory at Harvard University disclosed the fact that the slow rhythmic electrical pulses, due to the systole of the heart, contained a certain "murmur" or higher frequency component of the order of 30 cycles per second. The magnitude of this murmur potential is very small compared to that produced by the primary systolic waves. Nevertheless, it is, fortunately, peculiar to the systole of the heart, and does not exist to any appreciable extent in potentials developed by the contraction of any of the voluntary muscles.

Use is made of this phenomenon in the cardiotachometer, or heart-beat counter, recently developed by the General Radio Company in collaboration with Paul S. Bauer, Scientific Assistant at the Fatigue Laboratory, Harvard University. This device contains a selective vacuum-tube amplifier which responds only to this "murmur" component of the systolic waves and is quite insensitive to the primary waves due to the systole or to any voluntary muscular contraction which, in either case, would have a much lower frequency than the murmur. In this manner, a distinguishable impulse may be obtained at each systole even though the patient be exercising. This impulse consists of an intermittent train of waves of 30 cycles per

second frequency which is subsequently magnified and introduced into a "pulse amplifier" which, in turn, produces a single direct-current pulse at each systole of the heart. These direct-current pulses are then used to drive one pen of a duplex syphon recorder, while the other pen is operated uniformly by a clock-driven mechanism, the latter giving one impulse per second. In this manner, by comparing the two simultaneous records, an accurate and continuous timing of the heart rate is obtained. A sample record is shown in Figure 2.

It is obvious that records made in this manner may be used only for timing the systole, and that the waveform traced by the syphon pen which is energized by the heart has no relation, as far as its shape is concerned, to the primary waves obtained with the electrocardiograph.

In order to pick up these muscular potentials to the best advantage, two small disc electrodes made of Monel metal and about one inch in diameter are worn by the patient. These are carried by individual elastic belts and are in contact with the bare chest, one below the left breast and the other over the center of the chest as high as the belt, passing under the armpits, will permit. Such an arrangement places the electrodes approximately along the "electric axis" of the heart where the maximum systolic potentials are obtained. In order to minimize the electrical resistance of the skin, the areas of contact are well moistened with soap lather before applying the electrodes.

The pulse rate may now be measured with the patient standing, sitting, or reclining. He may run at various speeds upon a treadmill, pedal a bicycle, or exercise on a rowing machine, and while so doing, a continuous record of his pulse rate may be obtained both during the exercise and the subsequent recuperative period.

Through the courtesy of the Fatigue Laboratory at Harvard University, we show two interesting curves taken with the General Radio cardiotachometer.

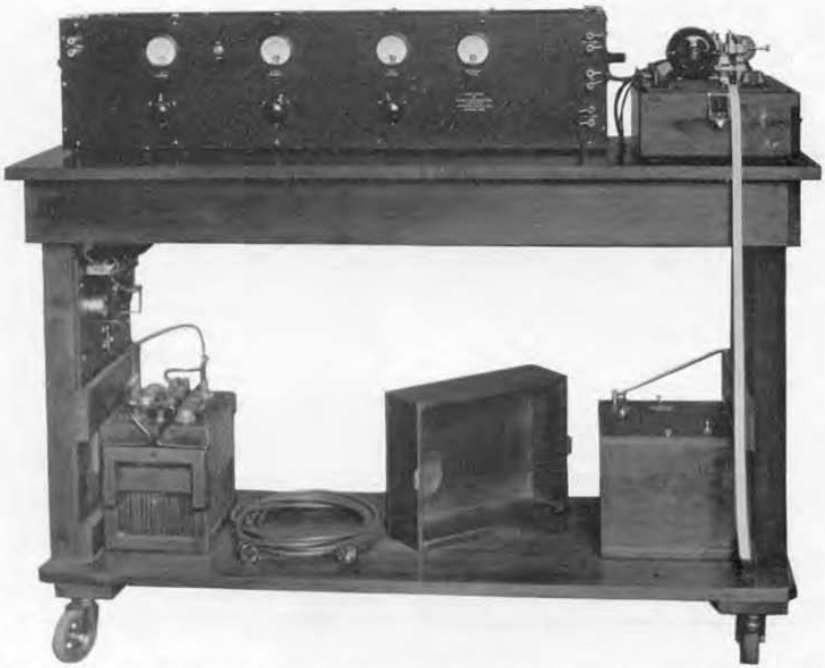

FIGURE 3. The cardiotachometer with amplifiers, syphon recorder, timing device, and power-supply accessories mounted on a castered table

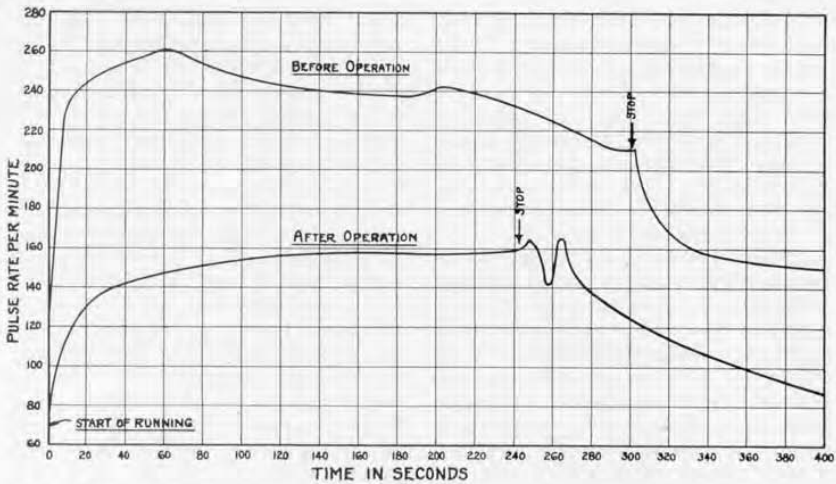

FIGURE 4. The behavior of a dog while running at full speed on a special treadmill. The upper curve was taken before the operation described below. The lower curve was taken after the operation

Figure 4 illustrates the variation in the pulse rate of a dog while running at a speed of 10.7 miles per hour upon a motor-driven treadmill. One curve shows the record for the normal animal, while the other curve shows the record of the same dog after complete recovery from an operation removing certain parts of the sympathetic nervous system. With the normal dog, the initial rise in rate is more rapid, reaching a considerably higher figure, and gradually subsiding after the first minute. After the operation, the rise in rate is seen to be much slower and no reduction occurs during the

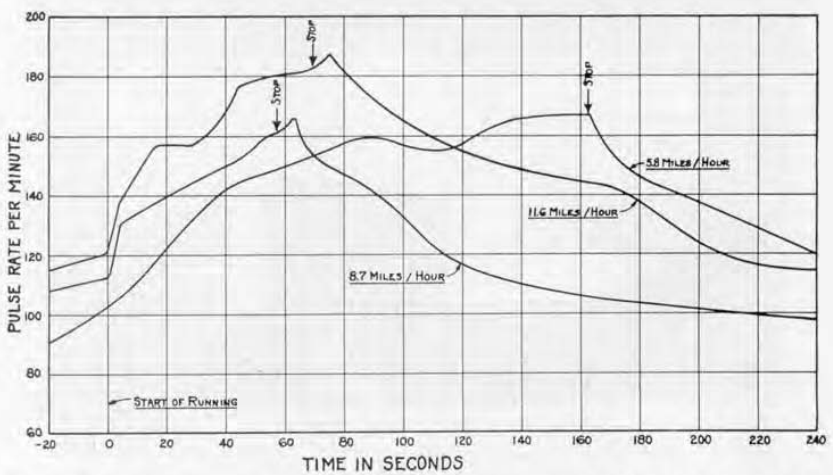

FIGURE 5. Three test runs made by a trained athlete on a special treadmill for three different rates of speed. The points marked "Stop" indicate the end of the exertion

exercise. The recovery of the normal dog after exercise is noticeably more rapid.

Figure 5 gives records obtained from an athlete running at different speeds upon the motor-driven treadmill. These curves are self-explanatory. It is interesting to note that the athlete's heart rate increases while he anticipates the exercise, an example of natural accommodation.

While experimenting with this equipment, the writer had an opportunity of making some interesting psychological tests to record the reaction of the heart rate of children, ages five and seven, while listening to the reading of "thrilling" fairy stories. A distinct irregularity, sometimes of acceleration and sometimes of deceleration, was observed during emotional passages of the stories. What data were obtained seemed to indicate that recovery to their normal rate was less rapid in the case of tales with which the children were thoroughly familiar than in the case of equally thrilling stories which they were hearing for the first time.

With the patient sitting quietly, a certain interval of time is required, with children at least, to become more or less unconscious of the presence of the electrodes. It is believed, however, that while exercising, muscular activity soon renders the patient sufficiently unconscious of the presence of the electrodes.

In addition to its application in fatigue researches, the cardiotachometer is useful in studying the time reaction of the heart to drugs and other stimuli. Likewise, by substituting an electric buzzer for the recording mechanism, arrangements may be made to enable the physician or surgeon to listen to the heart rate of the patient during treatment or operations. It is possible that equipment of this sort might prove of some value as a "lie detector" in criminal investigations.

Figure 3 shows the General Radio cardiotachometer. All of the equipment is mounted upon a castered table, thus making it readily portable. The three-stage amplifier unit utilizes special tuned 30-cycle transformers as the interconnecting-coupling units. Such transformers serve not only to eliminate low-frequency muscular potentials, but they also reduce, to a large degree, ordinary "background" potentials of audible frequency. The amplifier unit is followed by a small bridge-type oxide-junction rectifier and finally by a single-tube amplifier whose output plate current, consisting of pulses of from one to 10 milliamperes magnitude, energizes one of the pens of a newly designed duplex syphon recorder.

The magnet coil operating this pen carries two windings, through the second of which is passed an adjustable direct current, opposing or biasing the current pulses from the amplifier. This electrical method of adjusting the sensitivity and working range of the pen has been found to be the most suitable scheme for maintaining an optimum record, as the potential from the heart varies from time to time. These controls, together with the various plate-circuit and bias batteries, are contained in the metallic cabinet housing the amplifier.

The second pen of the syphon recorder is energized at one-second intervals by a clock-driven key contained in a cabinet on the lower shelf of the table. Provision is made for omitting every tenth second from the records in order to facilitate the counting of the tapes. The two independent pens, which are made from fine silver tubing and which operate upon the syphon principle, trace closely adjacent records upon standard $\frac{3}{8}$-inch ticker tape, the magazine roll of which is conveniently mounted in a drawer in the base of this instrument. The timing pen may also be separately controlled by means of a hand-operated key, thus permitting the tape to be marked for identification of any particular occurrence during the record.

The cardiotachometer shown in the illustrations was a model designed to be operated from a 110-volt direct-current source. A charging panel on the end of the table affords means for charging the storage battery. A slight modification in the design would render the equipment operative from a 110-volt 60-cycle-current source.

MISCELLANY

By THE EDITOR

THE General Radio cardiotachometer described by Mr. Lamson in this issue of the *Experimenter* will undoubtedly interest everyone who is concerned with the applications of the thermionic vacuum tube to non-communications uses, as well as those who are working in the particular field of biophysics where the instrument itself might be used. The important element in the new instrument is, of course, the tuned amplifier which amplifies the desired impulses and at the same time filters out most of the extraneous ones.

As a result of its varied experience in the development, design, and manufacture of measuring instruments for the communications industries, the General Radio Company's organization is peculiarly well adapted for work in the rapidly developing industrial field for vacuum-tube measuring and control apparatus. The cardiotachometer is only one example of our present interest and as information about new problems becomes available, it will be presented in the *Experimenter*.

It is our hope that *Experimenter* readers will find such discussions as this of interest to them and that, when they have a particularly knotty problem to solve, they will give us a chance to assist. Our facilities are available for help in every phase of the manufacturing process: development, design, and production itself.

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The editing of a new catalog of General Radio laboratory apparatus has been completed, and the first copies are off the press. Catalog F, as the new book is called, replaces all previous issues, the two most recent of which were the First and Second Editions of Catalog E, issued in September and December, 1928, respectively.

As a preliminary step in the distribution of Catalog F, we made a careful survey of the *Experimenter* mailing list and chose from it the names of all persons whom we believed would be interested in the uses of General Radio laboratory instruments. To each name in this latter group, we have mailed Catalog F. If you would like to have a copy and feel sure that you could make good use of it, please feel free to ask us for one. Be sure, however, to use your business letterhead and mention what position you hold with your firm, because we have found it necessary to definitely limit distribution of the catalog to laboratories, engineers, and other users or prospective users of General Radio laboratory apparatus.

Besides its regular line of laboratory apparatus the General Radio Company manufactures testing instruments, components, and miscellaneous accessories for the use of radio servicemen, public-address men, sound technicians, custom set builders, experimenters, and amateurs. For the special use of these groups, an abridged edition of Catalog F is now being prepared. It will replace the present Bulletin 931, but it will also describe our complete line of meters and inexpensive general-purpose testing instruments. Copies of this abridged catalog will be mailed to everyone on the *Experimenter* mailing list who has not been sent a copy of Catalog F.

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A unique feature of the two new General Radio catalogs is the method for keeping you in touch with new developments. The General Radio *Experimenter* has, in the past, described some of them, but we propose to send out catalog supplements, which will give more detailed data than it is possible to include in the *Experimenter*. We are maintaining a record of your name and address, so that these catalog supplements can be mailed to you without delay. The addressing-machine stencil from which the mailing will be done is identical with the stencil that addresses your copy of the General Radio *Experimenter*. If, then, your *Experimenter* is correctly addressed, you may be sure that your name is correctly listed on our mailing list for all catalog supplements.

Please cooperate with us in our efforts to keep you posted by notifying us promptly of any change in address. As the *Experimenter* is now being mailed, the post office will not forward it to your new address.

When copies are returned to us, we immediately remove the name from our mailing list. It is essential, therefore, that you notify us of address changes as far in advance as possible.

* * * *

On pages 28 and 29 of Catalog F are described the series of TYPE 214 Rheostats and Potentiometers which are high grade popularly priced units for use in high grade experimental installations. Effective at once all of those priced at $1.75 in Catalog F carry a price of $1.50. The two items priced at $2.00 in Catalog F are not affected by this change.

* * * *

Occasionally we receive inquiries from readers who wish to maintain a regular file of the *Experimenter*, as the result of which we are interested in hearing from anyone who has developed for his own use or for the use of others a workable filing and binding scheme. We are primarily interested in methods which bind the complete issue, because they are usually much less complicated than those which involve clipping. A number of suitable binders are on the market, and we should like to know whether readers who have tried them have any particular preference for one type as against another.

For our own use in the engineering department of the General Radio Company, we use a simple three-ring binder, and this seems to us to be entirely adequate. It has been suggested that we allow a greater binding margin on the *Experimenter*, and we hope to make this possible in the near future.

CONTRIBUTORS

An adequate sketch of Horatio W. Lamson, the author of the article in this month's *Experimenter*, was given in the June issue of the *Experimenter*. The interested reader is referred to page 11 of that issue for a biographical note and a photograph.

The General Radio *Experimenter* is published monthly to furnish useful information about the radio and electrical laboratory apparatus manufactured by the General Radio Company. It is sent without charge to interested persons. Requests should be addressed to the

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