IN THE LABORATORY

The Radio Inductograph—A Device for Recording Physiological Activity in Unrestrained Animals

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The problem of distortion of a measurement by the application of the measuring instrument is common to many fields of science. For example, placing a thermometer in a liquid changes the temperature of the liquid if the two are not previously at the same temperature. If the liquid volume is large, the error will be insignificant, but if the volume is small, the thermometer is useless as a measuring instrument. Similarly, a physiological process may be affected by the process of measurement. It is well known that human subjects may respond emotionally to procedures such as the application of a blood pressure cuff, resulting in increased blood pressure. The same is true of animals, as Allen (*1*) has shown for blood pressure. Fuller (*2*) has shown that the heart rate and respiration rate of dogs may vary greatly, depending upon the absence or presence of the experimenter. In these experiments, the animals were restrained by loops around the legs. It is certain that some animals are poorly adjusted to this restraint, and even those showing little overt signs of excitement cannot be said to be uninfluenced by the limitation of their activity. The Radio Inductograph has been developed in an effort to avoid this difficulty by utilizing a remote pickup from animal or human subjects.

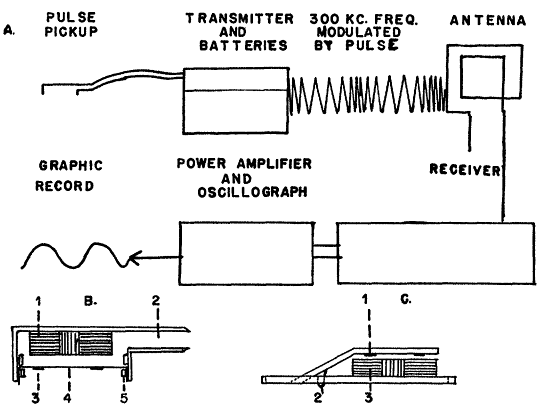

FIG. 1. (A) Schematic diagram of Radio Inductograph system. (B) Cross section of inductor-tambour: 1, coil; 2, air inlet; 3, modulating ring; 4, rubber diaphragm; 5, split ring to hold diaphragm in place. (C) Direct pulse pickup: 1, modulating ring; 2, button placed on artery; 3, coil.

This device uses physiological activity as a means of modulating a radio-frequency signal. The signal is detected and amplified by a special receiver whose output appears as a d–c potential, which is proportional to the frequency of the signal over a range of about 15 kc. This output may be used with a power amplifier and pen writer or with a suitable oscillograph to produce graphic records. A schematic diagram is shown in Fig. 1A. The system has great flexibility, and no attempt will be made in this paper to analyze it completely. The inductive pickups described below have great sensitivity and can be applied in devices which do not include a radio-frequency link. Thus, they may be applicable in other situations where a small movement or volume change is to be measured. A more detailed description and analysis will be presented later.

Four major components are included in the system:

(1) Pickup units[2] are of two types, pneumo-inductive and direct-inductive. Pneumatic pickups (Fig. 1B) may be actuated by balloons, capsules sealed over an artery, or pneumographs. These are connected by heavy-walled, fine-bore rubber tubing to an inducto-tambour located in the transmitter. The tambour contains the oscillator coil of the transmitter and carries a foil ring on its rubber diaphragm. Movements of this ring alter the inductance of the coil and frequency-modulate the R.F. signal. In the direct inductive pickups (Fig. 1C) the coil is located outside the transmitter, and the modulating ring is moved directly by the pulse or other physical movements.

(2) The transmitter is a simple, plate-tuned oscillator employing a 1S4 tube with plate and screen connected so that it acts as a triode. Power is supplied from a 45- or 67½-v B battery and a ''pen-lite'' dry cell. For use with the inductive pickups and external battery pack, the transmitter measures 3½″ × ⅞″ × ⅞″. With a pneumatic pickup the length is increased to 4⅞″ in order to accommodate the coil and tambour. The use of miniature B batteries designed for hearing aids permits enclosure of both batteries and transmitter in a larger case with an over-all reduction in size due to elimination of a separate battery pack. The transmitter fits into a pocket in the clothing or into a case attached to a harness on an animal.

(3) The receiver[3] uses 12 tubes, not including the power supply, and is designed to deliver direct current at a voltage proportional to the frequency of the signal. Even though the distance of the transmitter from the antenna varies as the subject moves about, thus changing the received signal strength, the output is not affected,

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[2] Patent applied for; no restrictions on scientific, medical, or educational use.

[3] Built by Inductograph Laboratory, Box 76, Brookfield, Connecticut.

provided the signal is strong enough to be detected. Provision is made for tuning so that other transmitters on adjacent wave bands may be received successively. Visual and auditory monitoring are provided by an electric eye and a phone jack supplied by a special A.F. amplifier.

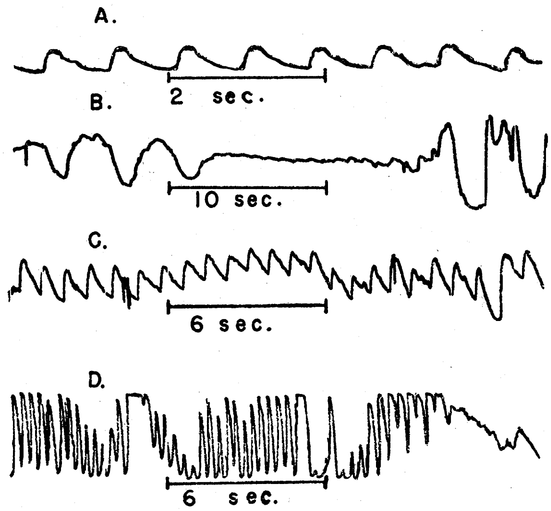

FIG. 2. Sample records made with Radio Inductograph: 1, human carotid pulse; 2, human pneumogram (note that heart rate can be read during period of apnea); 3, human finger pulse; 4, dog pneumogram.

(4) As a recorder we have used a Grass Model III electroencephalograph in which a special low-speed paper-moving mechanism has been installed. The output of the receiver is plugged into the input board of the electroencephalograph, taking care that a common ground connection is made. Because of the relatively high input voltage, the preamplifier of the electroencephalograph is not used, and the receiver output is applied directly to the power amplifier. Sample records made with this arrangement are reproduced in Fig. 2.

The performance of the Radio Inductograph has not been completely determined. Using an antenna zigzagged across an open field approximately 100′ × 25′, it has been possible to obtain satisfactory records of respiration over the entire area. Some difficulty has been experienced with interference from radio direction beacons operating in the same frequency range. A simple loop antenna hung from the wall will pick up satisfactorily from any part of an average-sized laboratory room. Care has been taken in designing the device to keep the power output within the limitations of the Federal Communications Commission's regulations.

Two types of artifacts may be troublesome. Microphonics may be produced by excessive jarring, but records can be satisfactorily made during moderate activity. Capacitance effects may change the frequency as the subject approaches a large object or turns so as to block the transmitter from the antenna. These difficulties will be corrected in later models.

When adapted to animal or human subjects, the device is inconspicuous and is not uncomfortable when worn for considerable periods of time. Thus, it may be used to indicate physiological changes with the subject practically unaware that his responses are being recorded. It can also be used in situations when the restraint of the subject would defeat the purpose of the experiment.

References

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Design of a Collapsible, Lightweight "Iron Lung" Respirator[1]

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When the muscles providing respiration are paralyzed, as in poliomyelitis or high section of the spinal cord, life can be sustained by subjecting the patient to rhythmic negative pressure over all the body excepting the head. The recumbent patient is placed in an iron cylinder (the "iron lung") with the head and neck protruding through an adjustable airtight seal, such as sponge rubber or a rubber iris diaphragm, so that suction in the cylinder can be produced without much leakage around the neck. The suction is commonly produced by a motor-driven bellows or diaphragm attached to the cylinder. Controls are provided so that positive pressure may be eliminated and the desired rate and depth of respiration are obtained. With a peak vacuum rarely higher than 20 cm of water, the chest is expanded, and inspiration occurs. The elasticity of the lungs and chest wall, aided by gravity, produces expiration when the suction is released in the remaining portion of the cycle of the bellows or diaphragm.

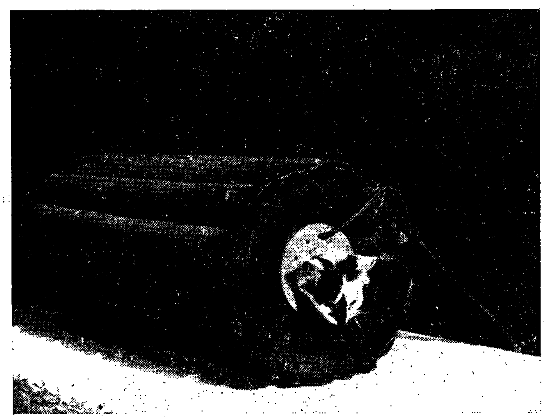

FIG. 1

The "iron lung" has disadvantages under particular circumstances. It is heavy and rigid so that it is difficult to transport, occupies considerable storage space, and is expensive. A rubber bellows modification of the "iron

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