AN ULTRASONIC DEVICE FOR DETERMINING THE SIZE OF DIFFERENT ORGANS IN THE LIVING ANIMAL

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In determining the functional activity of any organ of a living animal it is of great interest to be able to make a continuous record of the linear dimensions of the muscles, heart, or spleen.

The problem was first defined and solved by Rushmer [1] who applied it to the left ventricle of the dog.

We have developed this apparatus, and have based it on Rushmer's principle, which consists in measuring the time for a short pulse of ultrasound to pass through an organ to reach a piezo-electric receiver attached to the far side. At the output of the device a potential is developed whose amplitude is proportional to the distance between the two piezo-electric units. This signal is taken to recording devices, which make a continuous record of the linear dimension.

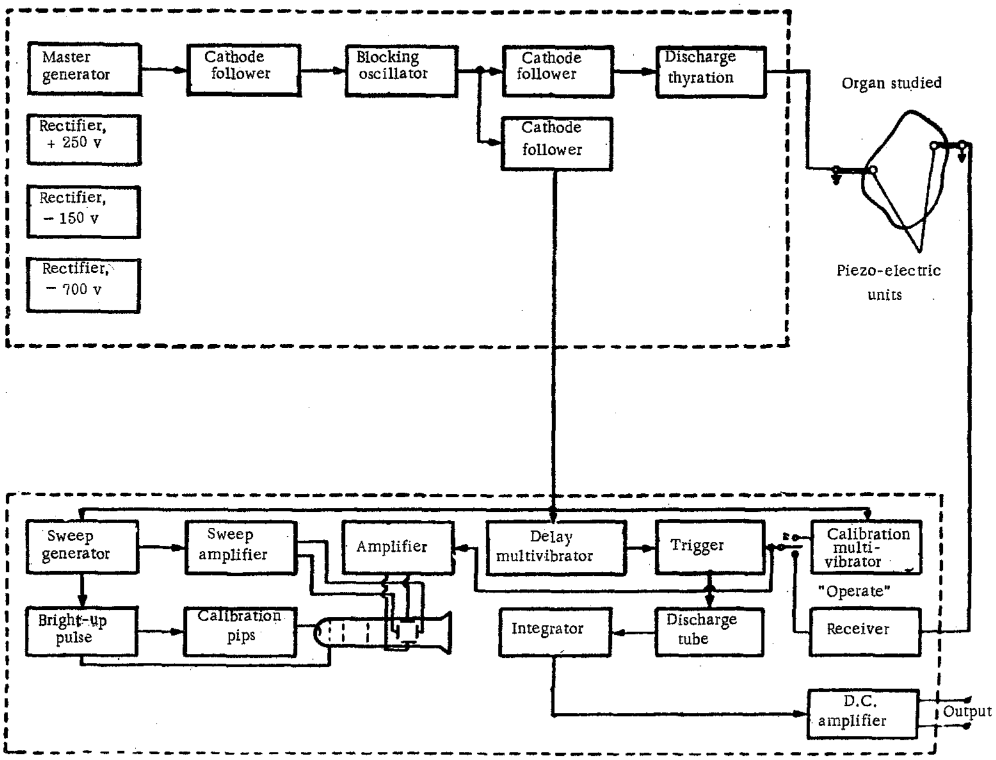

Fig. 1. Block diagram of the apparatus.

The following are some of the constants of the apparatus: carried frequency of the ultrasound 2.5 mcS, repetition frequency 1,000 cycles, pulse duration 0.5 μsec, power taken from the mains 150 w. A block diagram of the apparatus is shown in Fig. 1.

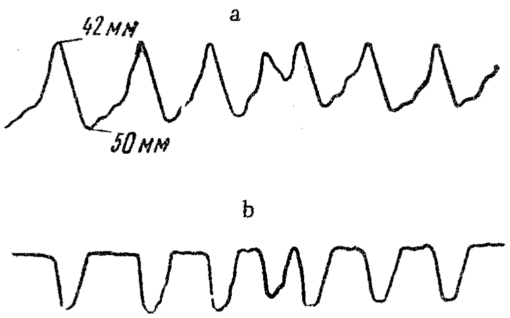

Fig. 2. Record of the change in diameter of the left ventricle of a dog under conditions of artificial sortic insufficiency (a), and a record of the pressure in the left ventricle made by an electromanometer (b).

Both the source and the receiver of the ultrasound were disks of barium titanate 6 mm in diameter and 1 mm thick. They had a radius of curvature of about 150 mm. The convex surface was turned towards the operative side. With this arrangement a more even distribution of the sound is obtained, and the relative direction of the plates has less influence on the amplitude of the received signal. The disks were held in special brass capsules. Between the back side of the disk and the base of the capsule there was an air space to eliminate radiation in the opposite direction.

The apparatus was built in two blocks: 1) transmitter and power supply, and 2) receiver and indicator block.

1. The master generator was a symmetrical multivibrator operating at a frequency of 1000 cycles. A pulse from one anode was differentiated, and was fed through a cathode follower to release a biased-off blocking oscillator.

The blocking oscillator produced a pulse of 180 v amplitude and 1 μsec duration. A discharge thyratron which was normally held nonconducting by a negative bias voltage of 150 v was made to conduct by the arrival at its grid of the pulse from the blocking oscillator.

The storage condenser was discharged through the thyratron, in whose cathode circuit a pulse of amplitude 200 v and 0.5 μsec duration was formed, and which was applied to the piezo-crystal to excite it.

In addition, the pulse from the blocking oscillator passed along a special cable into the receiver-indicator block.

2. The oscillograph of the receiver-indicator block serves for calibration and visual inspection of the visual signal received. It consists of a sweep generator, amplifier for the bright-up pulse, sweep amplifier, amplifier for the vertical deflection, and calibration-pip generator. For a frequency of ultrasound in tissue of 1.5 mm μsec, the calibration marks correspond to 2 and 5 mm. The intermediate frequency amplifier had a frequency of 2.5 Mcs and a pass band of 1 Mc.

The measuring circuit consists of a calibration multivibrator, a multivibrator giving a delay of 15-20 μsec, a trigger, discharge tube, integrator, and D.C. amplifier.

Fifteen-20 μsec after the transmitter has fired, the trigger valve is operated by a pulse from the delay multivibrator. The trigger is thrown back into the previous condition by a pulse from the output of the receiver, or when working in the position "calibrate" by a pulse from the calibration multivibrator.

Thus the duration of the pulse from the trigger circuit determines the time for the wave of ultrasound to pass between the two piezo-electric elements (or, more accurately, the duration of the trigger pulse + the duration of the delay multivibrator pulse).

The negative pulse from one of the anodes of the trigger pair cuts off the discharge tube, so that the capacitor connected in parallel with it now charges through the relatively high resistance included in the anode circuit.

Because the time constant for the charging of the capacitor is high, the wave form across it has a saw-tooth shape. The amplitude of the saw-tooth voltage will evidently be proportional to the duration of the trigger pulse, which in turn is proportional to the distance between the piezo-electric elements.

The integrator carries out the usual amplitude integration of the saw-toothed voltage. The amplitude of the output voltage of the integrator corresponds to the distance between the piezo-electric elements, and the frequency to the frequency at which this distance is changed. The introduction into the measuring circuit of the delay multivibrator greatly increases the accuracy of measurement and the sensitivity of the device to small changes in the linear dimensions of the organ studied. When in the position "calibrate" the calibration multivibrator gives out a pulse which artificially represents the pulse from the output of the receiver.

By moving continuously the pulse from the calibration multivibrator on the screen of the cathode ray tube, and by using the distance calibration pips, any point of a curve recorded on the device may be measured.

A test of the apparatus was made in an acute experiment on a dog heart. The piezo-crystals were attached to opposite sides of the myocardium of the left ventricle. At the same time as recording the diameter of the ventricle, a record was made of the pressure in the left ventricle. The experiment was carried out under conditions of artificial aortic insufficiency (Fig. 2).

In conclusion, we must note that the accuracy of the measurements and the minimum size which can be recorded depend ultimately on the frequency of the ultrasound selected.

SUMMARY

A description is given of an ultrasonic apparatus for determining the size of organs in a living animal by means of a piezo-electric transmitter and receiver sutured to the organ to be investigated. The results are given of investigations made by this apparatus on the dog heart under conditions of simulated aortic insufficiency.

LITERATURE CITED

1. R. F. Rushmer, D. L. Franklin, and R. M. Ellis, Circulat. Res., Vol. 4, p. 684 (1956).

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.