AN APPARATUS FOR THE CONTINUOUS RECORDING OT THE VOLUME BLOOD FLOW AND THE PERCENTAGE OF OXYHEMOGLOBIN IN ACUTE EXPERIMENTS

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(Presented by Active Member AMN SSSR A. L. Myasnikov)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 50, No. 11, pp. 130-133, November, 1960
Original article submitted December 29, 1959

Apparatus of the "bubble flowmeter" type is widely used for recording the volume blood flow velocity [2, 4, 5, 6, 7].

In addition to the advantages of these types of apparatus (the wide range of measurable velocities, the low percentage of error, the possibility of taking recordings synchronously with other indices) they have several essential defects. The most serious of these is the possiblity of production of a turbulent flow of blood, accompanied by a considerable increase in resistance. The principal points at which the laminar movement of the blood is disturbed are are the bubble traps.

The contraction of these traps, in places highly complicated, creates a high additional resistance and conditions favoring thrombosis and frothing of the blood.

The relatively large size of the apparatus, thereby making its fixation in the immediate vicinity of the vessel difficult, the complex radioelectronic system and the necessity for constant watch on the air accumulating in the trap complicate the work of the experimenter and make it impossible to carry out the simultaneous recording of the volume velocity of the blood flow in different vascular fields.

These considerations led us to introduce certain modifications into the construction of apparatus of this type.

The modifications were basically as follows: 1) elimination of turbulence of the blood flow; 2) simplification of the construction of the bubble trap; 3) maximal elimination of conditions favoring thrombosis and frothing; 4) doing away with the necessity for constant entry of atmospheric air into the system of the apparatus; 5) facilitation of the continuous recording of the oxygen saturation of the blood; 6) making the work of the apparatus as automatic as possible; 7) considerable simplification of the radio circuit.

The apparatus consists of two main parts: an artificial vascular bed with devices for measurement of the volume, and an independently assembled electrical system.

The measuring system, which is placed directly by the blood vessel, consists of two blood-vessel cannulas (Fig. 2, 1), a glass and a polythene loop, which form the artificial part of the vascular bed, the photoelectric cell of the oxyhemometer (2), vitrified resistors (3), stabilizing the skin temperature, 2.5 v electric lamps, photoresistors (6), an effector relay (5), ejecting the air bubbles into the blood stream, an air reservoir of volume 2.5 cc with valves (4) and a bubble trap (7). All the components are mounted on a plastic base, measuring

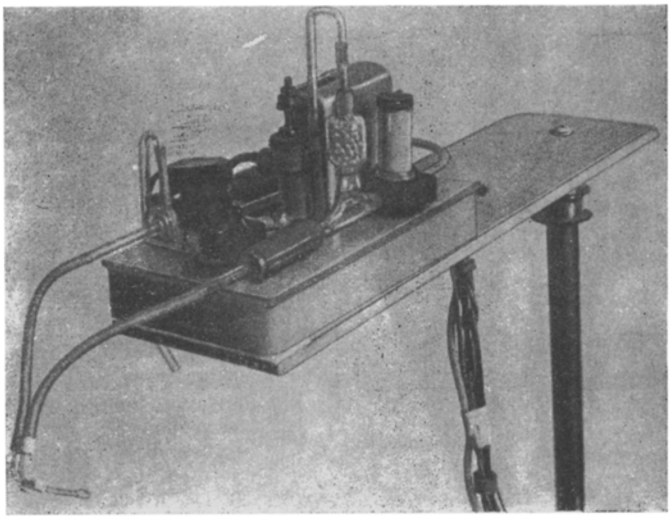

Fig. 1. General view of the recording part of the apparatus for continuous recording of the volume velocity of the blood flow and percentage of oxyhemoglobin in actue experiments.

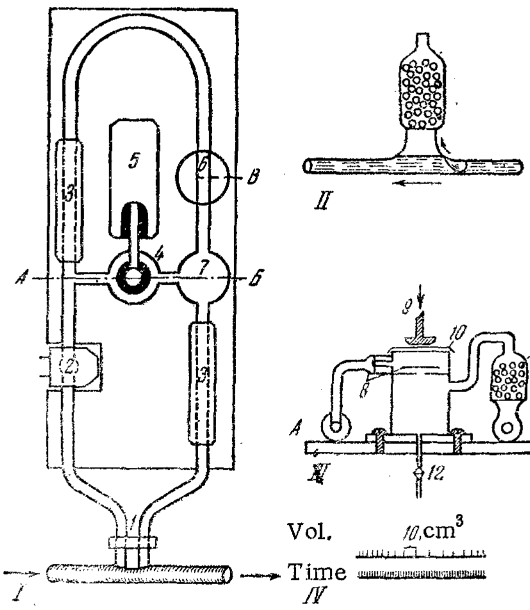

Fig. 2. Diagrammatic scheme of the arrangement of the parts of the apparatus (for explanation see text).

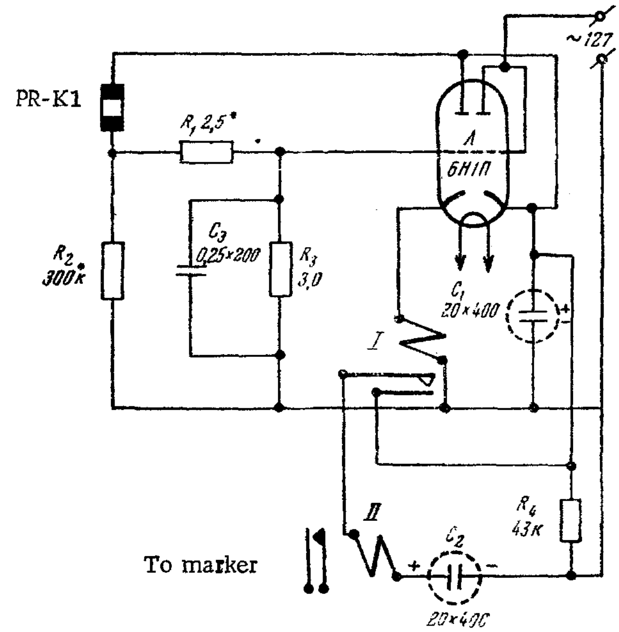

Fig. 3. Principles of the electrical circuit of the apparatus.

9 × 15 cm, which is fixed to a special stand permitting the system to be brought close to any part of an animal's body (Fig. 1).

The principle of action of the apparatus is as follows: blood enters the artificial vascular bed through the entry cannula and passes through an oval enlargement whose internal orifice measures 1 × 6 mm, on which is mounted the photocell of the oxyhemograph (Fig. 2, 2). At the point A the first air bubble is introduced into the blood stream by means of a slight blow from the reed of the effector relay (5). The air bubble, completely filling the tube in cross section, is moved by the blood along the part AB, the volume of which is accurately measured and may be altered at will by the experimenter by replacement by PVC or polythene tubes of suitable length.

At the point B the air bubble passes through a beam of light from the source to the photoresistor (6), as a result of which the effector relay (5) is put into action.

The reed of the relay strikes the membrane of the air reservoir (4) and a fresh air bubble enters the blood stream, isolating the next volume of blood, equal to the first.

Meanwhile the effector relay closes the contacts leading to the marker relay, and a mark is made on the kymograph indicating that a given volume (1, 2, or 5 cc) of blood has passed along the vessel (Fig. 2, IV).

The air bubble, the size of which is controlled at the beginning of the experiment by means of a screw, mounted on the reed of the effector relay, after passing through the photoresistor, enters the bubble trap (7), from which it passes to the air reservoir (4), where it takes the place of the bubble previously expelled into the blood stream.

The initial volume of air is thus maintained and it is no longer necessary to add air constantly from the atmosphere, thus ensuring optimum conditions for recording the oxyhemoglobin concentration.

The mechanism of the continuous circulation of the same sample of air will be more clearly understood from the diagram of a section of the apparatus along the line AB (Fig. 2, III).

At a blow from the reed of the relay (9) on the rubber membrane (10), the next bubble is sent towards the point A from the space between the two petal-shaped valves (8). Its place is accurately taken by an identical bubble from the bubble trap (Fig. 2, II).

As already mentioned, the principal point at which turbulent movement of the blood and thrombus formation develop is the bubble trap. After studies of numerous models of bubble trap in action, we devised the simplest possible variant (Fig. 2, II).

This type of construction permits bubbles to be trapped at velocities greatly in excess of those observed in experimental conditions, does not disturbe the laminar flow of blood and considerably diminishes the possiblity of thrombus formation.

In order to prevent thrombus formation effectively, we used a special silicone coating for the surfaces of the glass and plastic tube (dimethylchlorosilane for glass and aminosilane for plastic) [1].

This coating, which makes the surfac nonwetting, also leads to a considerable decrease in the resistance of the system and to the improved definition of the air bubble, which provides a bettwer light contrast and a sharper shadow on the photoresistor.

To prevent frothing we used the foam suppressor polysiloxane [3]. Glass beads dipped in the foam suppressor, were placed in the ampulla of the bubble trap, and completely prevented the deposition of froth on the valves.

Temperature stabilization was achieved by two vitrified resistors, the magnitude of which was selected by means of electrothermometers so that the temperature difference between the inlet and outlet of the apparatus did not exceed 0.1-0.2° within a range of variation from 32 to 39°.

The electrical circuit of the apparatus was also considerably simplified (Fig. 3).

In this circuit the winding of the positive relay is included in the cathode circuit of the tube. The ohmic resistance of the winding is an automatic bias resistance which compensates for the positive bias voltage arising as a result of the presence of the resistor (PR) between the anode supply pole and the grid of the tube, and it protects the tube from being put out of action if high positive voltages are applied to the grid, as may occur when a high intensity of illumination falls on the photoresistor. The resistor R_4 and the capacitor C_2 control the time of operation of the relay II, the contacts of which are used for the marker.

The modifications in construction which we suggest ensure great accuracy of recording of the volume velocity of the blood flow and a high degree of automatism, so that several such apparatuses may be used simultaneously.

SUMMARY

The authors describe an apparatus of the bubble-flowmeter type. It is superior to other similar instruments since it is capable of removing the turbidity of the flowing blood, has a simplified design of the bubble absorbed

and ensures optimal conditions for eliminating thrombus and foam formation. This instrument has a simplified electric scheme.

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