USE OF HIGHLY SENSITIVE CADMIUM SELENIDE PHOTORESISTORS TO STUDY THE PERIPHERAL CIRCULATION IN MAN AND ANIMALS

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The possibility of using photoelectric cells to study the circulation of the blood in various parts of the skin was demonstrated by the work of Hertzman and co-workers [3, 4], Matthes [5], and others. More recently semiconductor photoresistors (PR) have begun to be used as sensitive element in photoplethysmographs. These are characterized by very sharp (by hundreds or thousands of times) changes in electrical resistance during illumination. L. P. Shuvatov [2] used lead sulfide and cadmium sulfide PR to record the pulse in the human ear. However, these PR are not absolutely suitable for this purpose. Cadmium sulfide PR are sensitive to the visible part of the spectrum and lead sulfide to the neighboring infrared part. However, the absorption spectrum of blood, on which the permeability of the tissues to light mainly depends, lies on the border between the visible and the neighboring infrared regions of the spectrum. To study the circulation of the blood cadmium selenide PR must be used, for their maximum of spectral sensitivity coincides with the absorption spectrum of the blood. These PR are also distinguished by maximal sensitivity (up to 9 A/lm), which means that weak light sources can be used. Cadmium selenide PR are widely used in the West for plethysmography [6-9, etc.].

Five types of cadmium selenide PR are manufacture in the Soviet Union: FSD-0, FSD-1, FSD-G1, SFZ-1, and SFZ-2 [1]. The last two are most suitable for the study of the circulation. In the detectors to be described below, cadmium selenide photoresistors of type SFZ-2 were used.

The photoelectric system for recording the pulse consists of the following principal elements: the photodetector containing the PR and illuminating lamp, the sources of power for the PR and lamp, the Wheatstone bridge, and the sensitive recording device.

The SFZ-2 photoresistor is small in weight and size (8 × 13 × 3.5 mm), its photosensitive surface is adequately large, and it has a hermetically sealed photosensitive layer. By comparison with others, this PR is designed for use at the lowest working voltages (2-5 V), which is most important from the points of view of technical safety and convenience of operation. As the source of light for illuminating the tissues, baseless endoscopy microlamps are used (working voltage 2.5-3 V, diameter 1.5 mm, length 11 mm, heating temperature of bulb 60°). The lamps can operate in conditions of incomplete incandescence, so that the heating temperature of the bulb can be lowered and the useful life of the tube considerably prolonged. The photodetector incorporates the PR and illuminating lamp.

For the ear detector (Fig. 1) two hollow plexiglass disks, 20 mm in diameter, are turned and the PR is fitted into one of them and the lamp into the other. The disks are connected on the outside by a curved strip of organic glass, glued with dichloroethane. Rims of microporous rubber are glued to the inside of each disk.

The detector, when fixed to the ear, does not compress the tissues and does not move. When necessary the rubber rims may be smeared with glue or anchored externally by strips of adhesive plaster. The weight of the apparatus with the leads is 6 g. In the case of the human ear the detector is fixed to the lobe or to the upper part of the concha. In dogs, after preliminary shaving of the hair, the detector is placed over the central artery of the concha auriculae.

The detector for a flap containing the carotid artery is made of organic glass in the form of a horseshoe (see Fig. 1). The lamp is fixed to its upper part and the PR to the lower part. The diameter of the inner hole corresponds to the thickness of the flap, and the gap at the side enables the detector to be fitted over the flap. The apparatus weighs 3.7 g.

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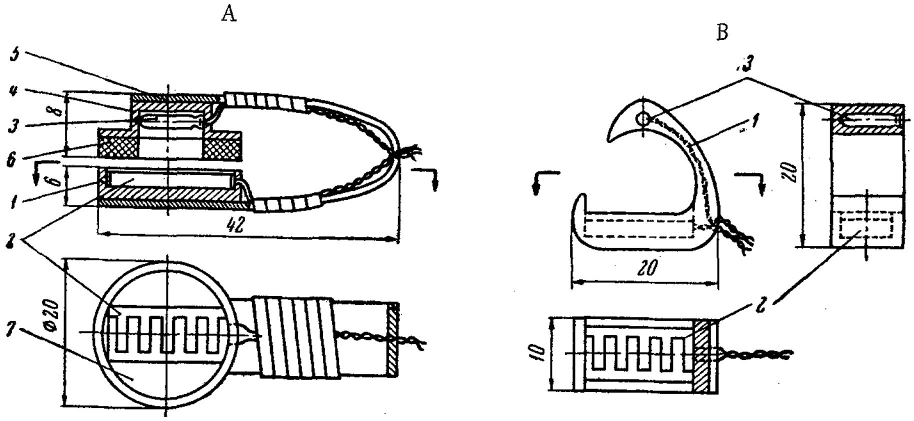

Fig. 1. Construction of photodetectors for recording the pulse. A) Ear detector. Top: viewed form the side; bottom: lower part of the detector viewed from above. 1 and 4) Hollow organic glass disks; 2) photoresistor; 3) lamp; 4) curved organic glass plate connecting the two parts of the detector; 6 and 7) rims of microporous rubber. B) Detector for a cervical flap with the carotid artery. On the left: viewed from the side; on the right: viewed from in front. Below: lower part of the detector viewed from above; 1) organic glass block; 2) photoresistor; 3) lamp.

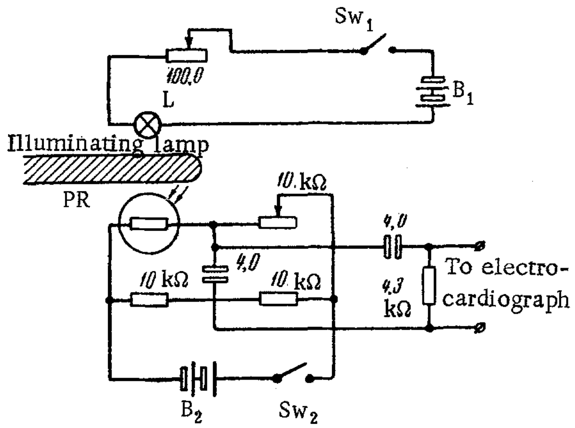

Fig. 2. Circuit of the photoelectric apparatus for recording the volume pulse. L) lamp; PR) photoresistor; B_1) source of power for lamp; B_2) source of power for bridge; Sw_1 and Sw_2) switches.

Power for the lamp is supplied by a battery, ensuring constancy of the source of light. The photoresistor is included in one arm of the Wheatstone bridge, power for which is supplied by a pocket flashlight cell.

The photoelectric apparatus (Fig. 2) works as follows. Light from the lamp passes through the illuminated tissue and falls on the photoresistor. Depending on the degree to which the vessels are filled with blood, the amount of light falling on the PR will vary. With an increase in filling of the vessels the absorption of light is increased and the intensity of illumination of the PR falls; in these circumstances the resitance of the PR increases and the current in the circuit falls. The signal from the Wheatstone bridge is fed into the input of a two-channel electrocardiograph, so that the ECG and pulse can be recorded simultaneously (Fig. 3). These detectors, in conjunction with a compression device, may also be used for recording the blood pressure.

SUMMARY

The article describes photodetectors registering the volume pulse from the ear in man and animals as well as from the carotid artery exteriorized into a skin flap in a dog. The sensitive element of the detector is a film-type selenium-cadmium photoresistor. The above photoresistors are distinguished by their small size, hermetic isolation of the photosensitive layer, and great integral sensitivity, which makes it possible to use weak light sources not

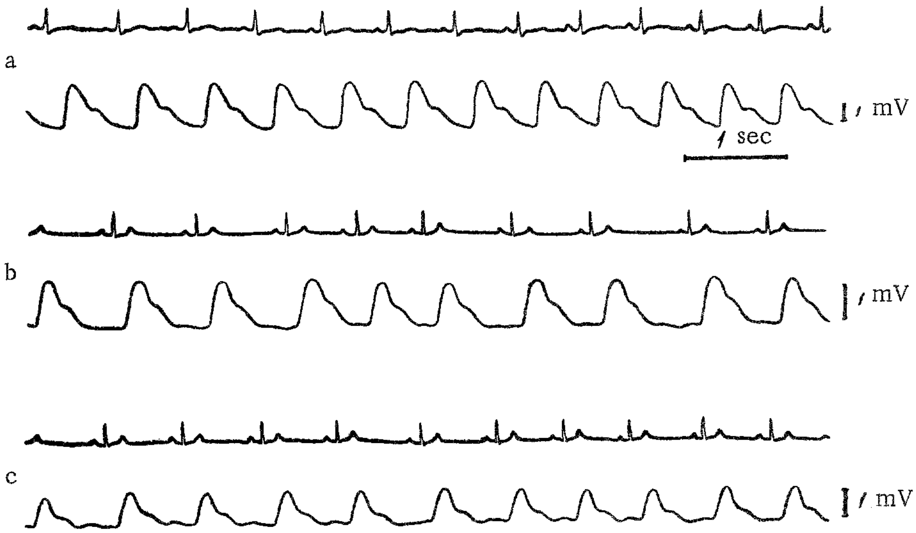

Fig. 3. Synchronized recording of ECG (lead 2) and the volume pulse. a) Recording of the volume pulse from the human concha auriculae; b) recording of the volume pulse from the concha auriculae of a dog; c) recording of the volume pulse from the carotid artery, exteriorized in a skin flap, of a dog.

damaging living tissues and by a spectral characteristic optimal for plethysmography. The use as light sources of baseless microlamps with a tungsten glow filament and the manufacture of the detector frame from organic glass has enabled a sharp reduction in the detector size and weight. The pickups have been noted to have high sensitivity, convenience in fixation and slight distortions during movements of the patient under examination.

LITERATURE CITED

1. A. O. Olesk, Highly Sensitive Cadmium Selenide Photoresistors [in Russian], Leningrad (1958).
2. L. P. Shuvatov, A Microapparatus for Recording Certain Physiological Functions by Radio [in Russian], Moscow (1959).
3. A. B. Hertzman, Am. J. Physiol., Vol. 124 (1938), p. 328.
4. A. B. Hertzman, W. C. Randall, and K. E. Iochim, Ibid., Vol. 150 (1947), p. 122.
5. K. Matthes, In: Ciba Foundation Symposium, Visceral Circulation, London (1952), p. 180.
6. T. M. Posteli, In: 4th International Conference on Medical Electronics, New York (1961), p. 248.
7. M. B. Raber, Ibid., p. 205.
8. R. O. Rawson, J. Appl. Physiol., Vol. 14 (1959), p. 1049.
9. J. Weinman, C. Bicher, and D. Levy, Ibid., Vol. 15 (1960), p. 317.