DROP COUNTER, PHOTOCELL, AMPLIFIER, AND COUNTING DOWN CIRCUIT FOR MEASUREMENT OF BLOOD FLOW WITH PEN-RECORDER

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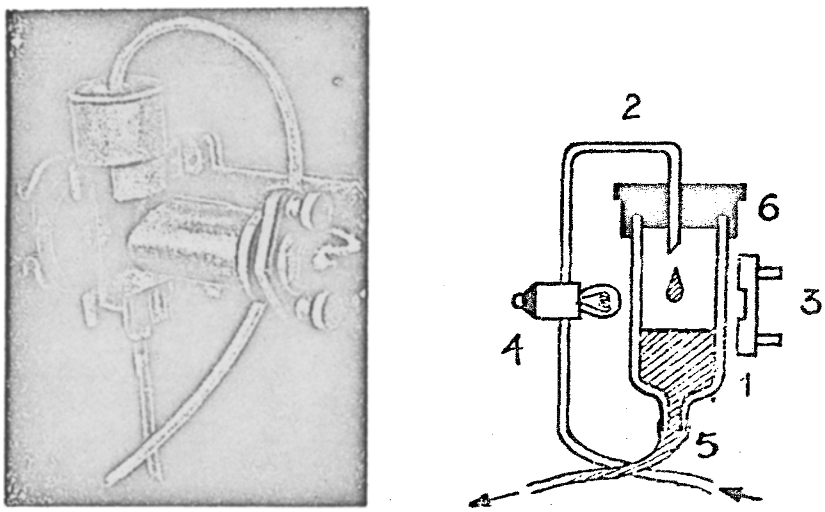
Two types of counter have been used for measuring blood flow by means of a pen-recorder [3]. In the first of these, the blood drops close contacts inside a chamber [4], and in the second they interrupt a light beam which passes through the transparent dropping chamber onto the cathode of a gas filled photocell [5, 6]. However these counters are not satisfactory.

In order to prevent the formation of fibrin on the contacts of the first type of counter, the voltage has to be considerably reduced and the amplification correspondingly increased. During the measurement, the inner wall of the dropping chamber and the contacts become covered with a film of moisture and small fragments of blood, and this causes the contacts to close, and it becomes necessary to interrupt the experiment frequently to prevent this happening. On account of the size of the photocell (in the counter we used, the photocell was a TsG-3) and the comparatively large lamp and focusing system, the second type of counter was very large, and it was not easy to use because of the necessity of directing the drops of blood rather accurately through the narrow light beam inside the dropping chamber.



a b

Fig. 1. Photograph and drawing of counter.

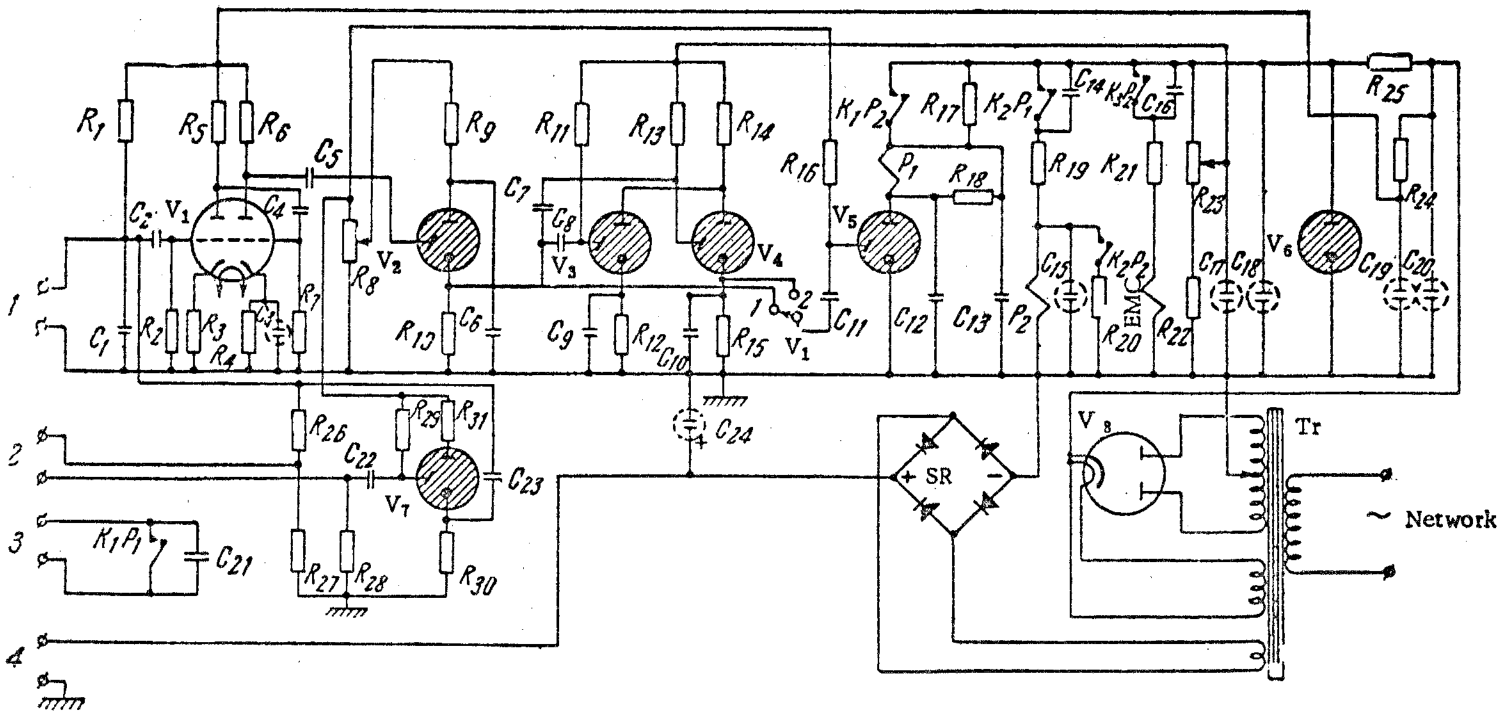


Fig. 2. Circuit of the amplifier.

Resistances R_1, R_9, R_{10}, R_{11}, R_{31} – 1 kohms; R_3, R_4 – 1.5 kohms; R_{23} – 3.3 kohms; R_{21} –5 kohms; R_{25} – 6 kohms; R_{22} – 6.8 kohms; R_{20} – 7.5 kohms; R_{17}, R_{24}, R_{30} – 10 kohms; R_{16} – 15 kohms; R_{19} – 18-22 kohms (selected); R_{29} – 30 kohms; R_{18} – 39 k ohms; R_{13} – 47 kohms; R_5, R_6, R_{14}, R_{28} – 100 k ohms; R_{27} – 150 kohms; R_{12}, R_{15} – 180 kohms, R_{26} – 200 kohms; R_2 – 510 kohms; R_8 – 680 kohms; R_7 – 820 kohms.
Condensors: C_7, C_8, C_{22}, C_{23} – 100 $\mu\mu$f; C_{11} – 300 $\mu\mu$f; C_1 – 2200 $\mu\mu$f; C_5 – 3300 $\mu\mu$f; C_9, C_{10}, C_{13} – 0.01 μf; C_6, C_{12}, C_{14}, C_{16}, C_{21} – 0.03 μf; C_2 – 0.04 μf; C_4 – 0.05 μf; C_{15} – 5 μf; C_{17}, C_{18}, C_{19}, C_{20} – 10 μf; C_3 – 30 μf; C_{24} – 2000 μf. Tubes: V_1 – 6H8; V_2, V_3, V_4, V_5, V_7 – MTX – 90; V_6 – SG4S; V_8 – 5Ts4S. Relays: R_1, R_2 – 500 ohms. Tr – power transformer. SR – selenium rectifier feeding lamp in counter; input terminals: 1) photocell, 2) counter contacts, 3) windings on pen-recorder in series with separate 60 volt rectifier, 4) lamp in counter; P_1 – "times 2" counting down circuit.

These difficulties were overcome by using a small size resistance-type photocell [1, 2]. The blood passes into the plexiglass vessel(1) through the tube(2) forming a drop on the end (Fig. 1). In falling from here the drop passes in front of the photocell (3), partly cuts off the light beam from the lamp (4), and again passes into the blood vessel along the tube(5). The rubber stopper (6) seals the system hermetically so that it is possible to record blood flow not only in the veins but in the arteries.

When recording venous flow using wide bore rubber tubes and the usual glass cannulae, separation of the blood cells from the plasma may occur. This is due to the slow flow of blood in the wide tubes and the increased sedimentation rate due to adding heparin to the blood. It is therefore important that tubes 2 and 5 should have a diameter approximately equal to that of the corresponding blood vessels. We used polyvinyl chloride or polyethylene tubes, and joined them directly to the blood vessels. Before attaching them the dropping chamber was one-third filled with physiological saline.

The amplifier (Fig. 2) operates as follows. A pulse which occurs when light is cut off from the photocell by a falling drop passes to the grid of the amplifying tube V_1. The latter sends a pulse to the trigger electrode of the cold cathode thyratron V_2, causing it to ignite. The condensor C_6 discharges through it until the potential difference across its plates falls to a value at which the thyratron no longer conducts. The pulse now passes from the cathode of the thyratron through switch (1) in position 1 and is taken to the trigger electrode of a second similar thyratron V_5. This fires causing relay R_1 to operate so that voltage is now supplied to the coils of the electromagnetic pen-recorder through the contact K_1R_1. This voltage is supplied by a separate rectifier connected to the amplifier through the binding posts (3) in series with the windings.

In order to eliminate any systematic error in the pen-recorder caused by a different position of the pen at the end of successive half cycles and differences in the length of the pulse from the counter (1) a circuit for stabilizing the length of the output pulse is included, and this consists of condenser C_{15} and relay R_2. When relay R_1 operates K_2R_1 closes so that C_{15} charges through R_{19} to a potential which operates relay R_2.

When this happens K_1R_2 opens breaking the anode circuit of V_5, which ceases to conduct so that current fails in R_1. Thus the duration of the pulse to the pen-recorder is determined by the time elapsing between the closures of relays R_1 and R_2 and is always equal to the discharge time of condenser C_{15} (0.1 ± 0.01 seconds). Contacts K_2R_2 or relay R_2 allow condenser C_{15} to discharge rapidly, after which the circuit returns to its original condition.

The maximum frequency of impulses which can be satisfactorily recorded is not greater than 5 c/s for a pen velocity of 200 mm/second. This limits blood flow measurement to 18-20 ml/minute (4-5 drops per second), although even at 30-35 ml/minute the drops have not merged into a continuous stream. To record processes occurring at a higher frequency than this, the counting down circuit, composed of the two cold cathode thyratrons V_3 and V_4 is introduced. When switch P_1 is in position 2 only every second input pulse passes through the counting down circuit to the output thyratron V_5 which causes the pen of the recorder to operate. Thus the upper frequency limit is increased to 9 c/s.

If necessary the electromechanical counter EMS, connected through contacts K_3R_2 of relay R_2 may count impulses without them being recorded.

The scope of the apparatus is increased by introducing valve V_7 which allows the recording meter to be operated by a switch connected to binding posts (2). In this way for instance it is possible to use devices operated by waves of arterial pressure which enables uninterrupted recordings of the pulse rate etc. to be made.

The power supply is derived from the mains through the rectifier consisting of V_8 with an RC filter and neon stabilizer L_6.

Tests showed that displacement of the shadow of the drop on the surface of photocell did not affect the operation of the counter. This made its precise positioning unnecessary. Condensation of moisture or blood fragments on the walls of the dropping chamber caused no interference with the recording of the drops. The sensitivity of the circuit was sufficient to record not only blood drops but also transparent liquids such as perfusates. In the latter case direct closure of contacts connected on to binding posts (2) could be used.

Since the dropping chamber is hermetically sealed, the system through which the blood flows constitutes a siphon. The additional resistance to the blood flow consists therefore of that due to viscosity effects in the connecting tubes, and is independent of the height of the counter above the body of the animal. This is very important in recording blood flow from veins. The small size of the counter facilitates simultaneous registration when recording outflow or inflow of blood to many organs.

SUMMARY

A hermetically sealed photoelectric drop impulse pickup has been constructed for measuring the volumetric blood flow in veins and arteries by means of the pen-recorder. A miniature semi-conductor photoresistance is used in this pickup. The wiring circuit of the electron amplifier which controls the pen-recorder is presented. The amplifier allows the internals to be registered either between each drop or after every drop and automatically controls the displacement of the recorder pen at regular intervals. The amplifier also registers the frequency of mechanical impulses (heartbeat, etc.) by means of the pen-recorder.

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