Electronic Tonometer For Glaucoma Diagnosis

Glaucoma can be detected by a probe that measures pressure within the eyeball. Early diagnosis makes ultimate cure possible

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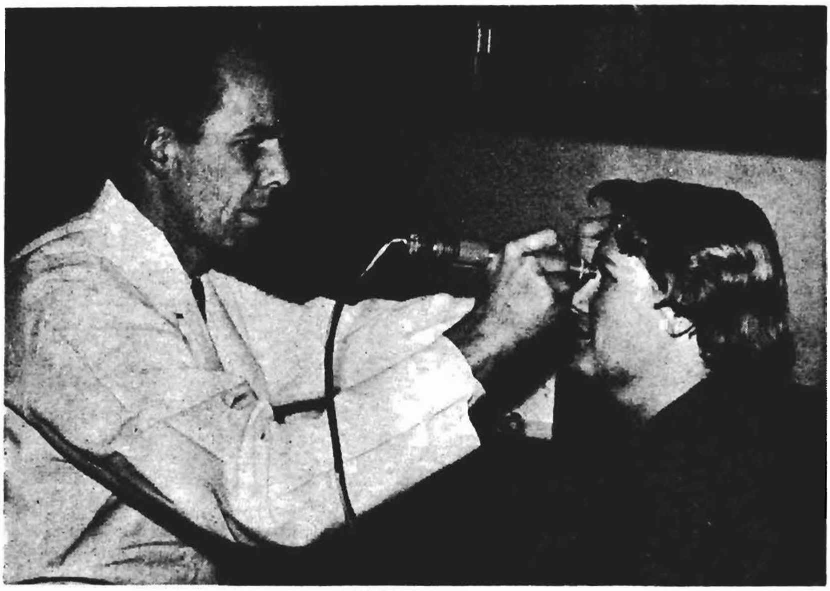
Of all people over forty, it is estimated that two percent are going blind from what is known as simple glaucoma. In this malady an increase in pressure, if not detected and corrected in time, causes irreparable damage to the optic nerve. Its onset is diagnosed earliest by measuring the pressure within the eye using devices called tonometers, after which the pressure can be relieved by drugs or surgery. A new electronic tonometer has been conceived that is so fast and gentle that it does not require anesthetics and yet it is more accurate because it does not respond to extraneous factors that lead to uncertain readings in the classic devices.



Eye pressure measurement can be completed in less than one second

Probe is shown with shield removed

Close-up of central unit and probe

Conventional tonometers measure pressure in one of two ways. Either a plunger is placed upon the front surface of the eye in a vertical position and the indentation due to loading with a known weight measured, or else the area flattened by pressing a transparent plate against the eye with a given force is measured optically. Bending of the cornea introduces an uncertainty into the reading because of its stiffness or rigidity. The difficulty is increased in an astigmatic eye where the curvature may be different in different directions. Even the surface tension of tears introduces an uncertain component of force.

Operational Principles

Figure 1 shows the arrangement of the new tonometer. The eye is momentarily flattened beyond the pressure sensitive region. Since the bending takes place at the periphery of the probe, the central plunger is not acted upon by bending forces. Any tension in the tissues is a centrifugal force that does not act on the pressure sensitive area. The probe is a small handheld device that is momentarily touched to the eye. As long as the front surface of the probe remains approximately flat, essentially the only variable that will be recorded is the intraocular pressure.

In the present device flatness, as well as freedom from drift caused by changes in amplifier gain or changes in resiliency of the mechanical components, is assured by a feedback mechanism. Any tendency for the plunger to be deflected inwards is sensed by a sensitive motion transducer and is counteracted by the resulting change in

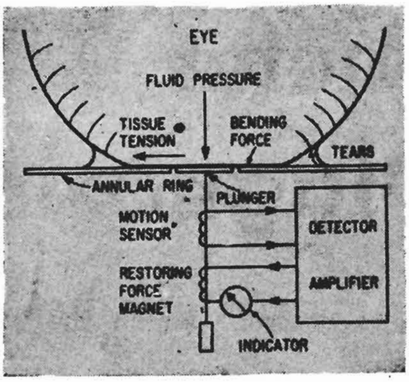


FIG. 1—Magnetic feedback is phased so that plunger resists eyeball pressure and remains approximately co-planar with surrounding annular ring

current in a direct coupled magnetic actuator. A measure of the pressure is then obtained by recording the current to the feedback magnet. The scale is linear and free from involved calibration because the plunger never moves appreciably and thus changes in transducer sensitivity with deflection, or variations in restoring force field, are not introduced.

In using the device the probe is momentarily pressed against the eye. As the force of contact increases, the recorded reading will increase until the plunger, which is about two millimeters in diameter, is covered. The further increase in force will not change the reading until the pressure within the eye begins to be raised by the external force. Thus the reading, which can be recorded on a pen-writer, displays a plateau whose elevation is a measure of intraocular pressure (Fig. 2).

Circuit Operation

The requirements of the motion-transducer are twofold. It must (1) be extremely sensitive to small displacements and (2) very little force should either be required by the transducer, or reflected back into the system by it. The transducer employed made use of the motion of a ferrite core which altered the inductance of an adjacent coil. The change in inductance is measured by a circuit resembling some types of frequency-modulation detectors. The circuit is shown in Fig. 3.

Changes in position of the moving ferrite core cause a signal to be developed across capacitor C_1, with signal polarity dependent upon the displacement direction. The signal (voltage) is fed to the d-c amplifier via the shielded probe-cable and the output from the d-c amplifier feeds the transistor-pair, Q_1 and Q_2. The amplified signal drives the restoring coil which forces the probe into the plane of its surrounding annular plate. The actuator consists of the voice coil and magnet from a small loudspeaker.

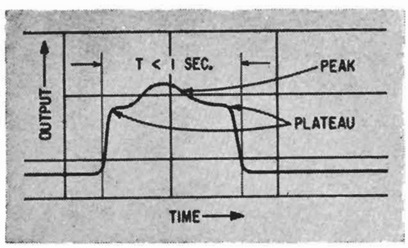


FIG. 2—Recorded response as probe is applied to, and taken away from, the eyeball. The peak indicates extra pressure caused by probe

The signal from the displacement sensor is about 0.1 volt per micron of movement of the plunger. The feedback system applies a force of about 0.8 gram to the eye for a normal intraocular pressure of 16 millimeters of mercury. The deflection of the system is 0.6 microns for a pressure of 40 millimeters of mercury. A change in oscillator frequency from 5 megacycles down to 100 kilocycles decreases the sensitivity to uselessness.

In Fig. 3, T_1 and T_2 are Miller transformers, type 1467, the primary of T_1 being L_1. Coupled to T_1 and T_2 are L_2 and L_3, which each have 16 turns in two layers of No. 22 wire. The primary and seconday of T_2 are labeled L_4 and L_5 respectively. The probe is shielded and the shield has an axial slit so that it does not act as a shorted turn. The probe shield is grounded to the shield of the connecting cable. This connecting cable carries both radio frequency to the probe and the detected signal from it.

The plunger diameter is approximately 2 millimeters and the diameter of that part of the eye flattened by the surrounding plate is approximately 3 millimeters. The mass of the moving parts in the device is kept to a minimum so that accelerometer or seismograph effects are minimized in the recording as the probe is moved. Problems of friction were minimized in the design of the probe but their remaining interference was removed by including in the feedback loop a small 200 cycle voltage signal (fed in by T_3). The resulting small amplitude motion introduces no noticeable signal but eliminates the effects of static friction.

The help of Mr. Raymond Oechsli in perfecting the circuits and the probe is gratefully acknowledged.

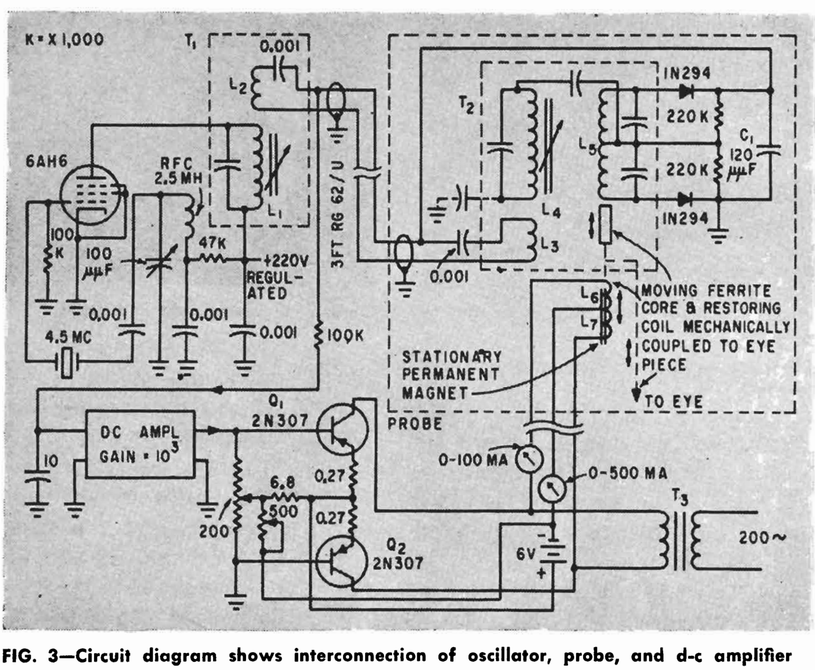


FIG. 3—Circuit diagram shows interconnection of oscillator, probe, and d-c amplifier