short, cylindrical sections. He points out that certain procedures to secure "permanent waves" are "inseparable from irreversible changes in the keratin molecule, changes that must be described, however reluctantly, as damage." We obtained from different subjects values of tensile strength which, in some cases, did not differ appreciably after several times of stretching, while in others the tensile strength decreased markedly.

Pilometric measurements may prove to be useful in testing both local and systemic treatments of any given substance in experimental subjects. The pilometer promises to be a tool by which the experimental biologist and dermatologist may test certain locally or systemically applied treatments for hair in health and disease.

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A New Method for the Direct Recording of Prolonged Time-dependent Processes[1]

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Loop and cathode-ray oscillographs at the present time have superseded all other methods of recording processes with temporal variations, although for some purposes they have certain deficiencies.

In medicine, for instance, it is regarded as a disadvantage that the process of photographic developing intervenes between recording and evaluation. Also, the standard recording scale requires excessive quantities of paper and film if a long record is to be made without changing the cassette. Thus, not only are there development difficulties, but analysis of the process as a whole is difficult. For these reasons some primitive, direct methods of recording (e.g. the soot kymograph) are still in use, although they do not meet present requirements as far as their frequency characteristics are concerned.

Medical research requires an efficient method of direct and continuous recording. A method of this type would serve essentially to correlate the experimental phenomena with the recording, to control the experiment according to the changes in the oscillogram, or to enable observation of certain functions (e.g. electrocardiogram) during an operation. It would also be useful for teaching and demonstration in schools. In many cases the greatest advantages of the loop and cathode-ray oscillographs, their frequency characteristics, are not exploited. In medicine, for example, while frequencies below 200–300 cycles often are recorded with the cathode-ray oscillograph, it is possible to develop devices for direct recording. It is of no importance that the recordings are not as large as usual. If the thickness of the record curves is sufficiently small compared with the maximum amplitude, the recording may easily be magnified suitably by projection on a screen. Moreover, a small recording has the advantage that a substantially longer period of registration is placed on the same amount of material. Generally speaking, this is the only method possible for making actual continuous study.

Such a method[2] has been developed on an electromechanical basis and is described below.

The cutting of a phonograph record may serve as an example in which maximum amplitudes of 0.08 are recorded. The resonant frequency of the phonograph recording system is about 5,000 cycles. Since an upper cutoff frequency of 500 cycles is sufficient for the present problem, the maximum amplitude required may be brought to the necessary magnitude by a small elastic force coupled to a lever transmission. For an electromagnetic recording system with a frequency range up to 500 cycles and an electrical input of 3 watts, this amplitude is 0.5 mm. (length of stroke, 1 mm.).

Such a magnitude may be seen directly, as may be, therefore, the total recording. On the other hand, for accurate evaluation of individual parts of the recording, they may be magnified optically to a maximum of 4–10 cm. by ordinary means and with normal space requirements. With suitable optics a much larger magnification is possible and may be used for lecturing and similar purposes.

The oscillographic method developed on this basis works as follows (Fig. 1):

The processes to be recorded (electrocardiogram, cerebral potential variations, blood pressure, etc.) are converted into electric quantities and conducted to an amplifier; this operates the recorder (S) which carries a stylus to cut the lacquer coat of the glass disc (G). While the disc is rotating, the recorder is moved radially by foot gears (V); thus, as on phonograph records, the groove forms a spiral. An illuminating device (B, below disc), placed close to the stylus, is coupled to and moves with the recorder. The optical system (A, above disc) magnifies the process recorded by means of an angular mirror (W) and projects it onto a screen (P). At a moderate disc velocity (about 20–30 cm./second on the screen for electrocardiograms) it is easy to observe the process while it is being re-

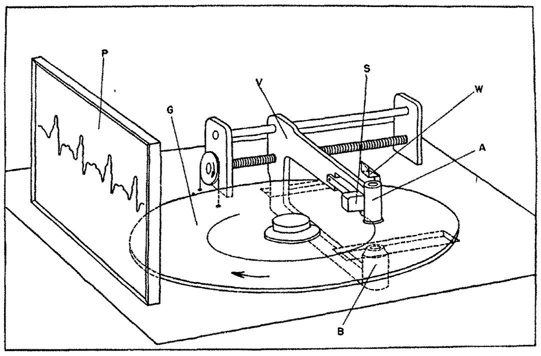

Fig. 1. Schematic representation of the recording method.

[1] Technical Report No. 11 of the AAF Aero Medical Center, Helmholtz Institute, Branch Nussdorf/Inn, Germany, March 23, 1946.

[2] The measurements were carried out by A. Habermann.

corded and to reproject it later for exact evaluation or for copying.

The "pitch" of a spiral record whose maximum amplitude is 0.5 mm. is about 2 mm. If 5 cm. of a 30-cm. disc is used, there is an available recording length of 19 m. Compared with the usual electrocardiogram, the maximum amplitude of which is about 4 cm., this corresponds to 760 m. of film. An electrocardiogram may therefore be recorded continuously for 100 minutes without changing the disc.

When the angular velocity is kept constant, the spiral recording has the disadvantage that the time scale is different at different radial distances from the center of the disc. This can be compensated by a special timing device. Or, since the speed of rotation is low (0.25/minute for the electrocardiogram), a drive which will maintain a constant linear velocity just at the recorder can be designed relatively easily.

Fig. 2 shows a laboratory model of the apparatus. If required the zero line may be recorded at the same time by the addition of a stationary stylus, or another process may be recorded simultaneously by a second recorder. The device is superior to photographic methods because the thickness of the lines is constant, whatever the recording velocity.

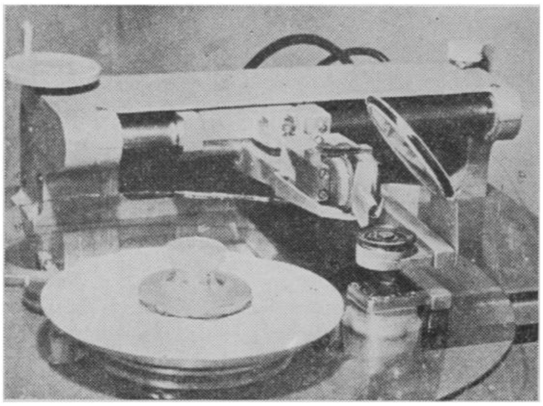

FIG. 2. Laboratory model of the recording device.

An electromagnetic phonograph system was first used as the recorder. It was adapted to the present purpose because of the experience gained while designing it. The stylus amplitude required was determined by varying the armature's elastic control force and by lever transmission. Optimal conditions (*i.e.* amplitude as great as possible at linear amplitude characteristics and the armature's resonant frequency as high as possible) are ensured by adapting the geometric shape of the vibrating system correctly to the magnetic forces available. By utilizing the magnetizing curve up to saturation (Saettigung), these were increased to the limit attainable. The recorder is arranged in such a way in relation to the disc that the armature's axis of rotation is not parallel to the disc's face (as in cutting phonograph records) but perpendicular to it. This is necessitated by the fact that the stylus' point describes a flat arc and otherwise would move off the glass surface.

The recorder is operated with constant current in order to obtain a straight frequency characteristic. This presumes that the inner resistance of the voltage supply is large compared with the resistance of the recorder. If operated from an amplifier tube, matching by a transformer is difficult due to the very low cutoff frequency required. The recorder, therefore, is connected directly to the anode circuit of a pentode (high inner resistance) and the direct-current anode is compensated. For the type described, the maximum amplitude requires a current of 20 Ma. At a frequency of 700 cycles, the impedance being 6,000 ohms, this corresponds to an alternating-current input of 2.5 watts.

Because of its electromagnetic system, the recorder has some hysteresis, and the recording of absolute quantities is subject to a certain error (about 5 per cent). Therefore, the development of an electrodynamic system was begun.

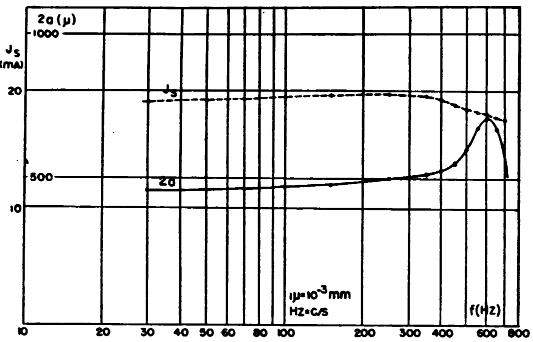

FIG. 3. Electromagnetic recorder: frequency characteristic of the current and of the recorded amplitude.

In Figs. 3, 4, and 5 the frequency and amplitude characteristics of the electromagnetic and electrodynamic systems are compared.

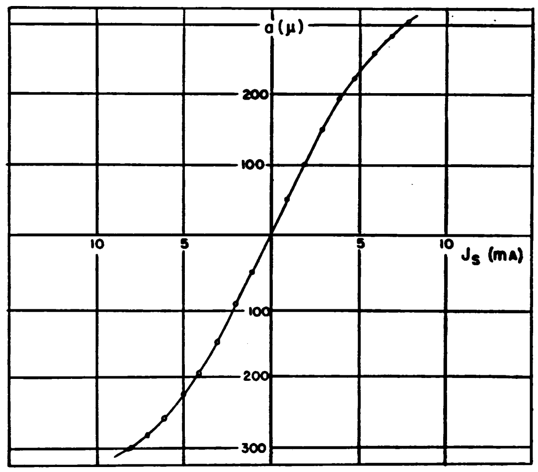

FIG. 4. Amplitude characteristic of the electromagnetic recorder.

Since the development of the electrodynamic recorder is not complete, its frequency characteristic cannot be given. It is probable that it will be linear and in the range from 0 to 250 cycles.

In order to obtain a sufficiently narrow groove, the point of the stylus should have a radius of curvature of about 0.01 mm. It must be resistant to abrasion but should not be so hard as to scratch the glass surface (tungsten). Since such a radius of curvature cannot be produced by a machine, the needle is made by a chemothermal process.

The first experiments were carried out with a disc of sooted glass. The resulting grooves had a thickness of 0.05 mm., despite the fact that the stylus used had very fine points,

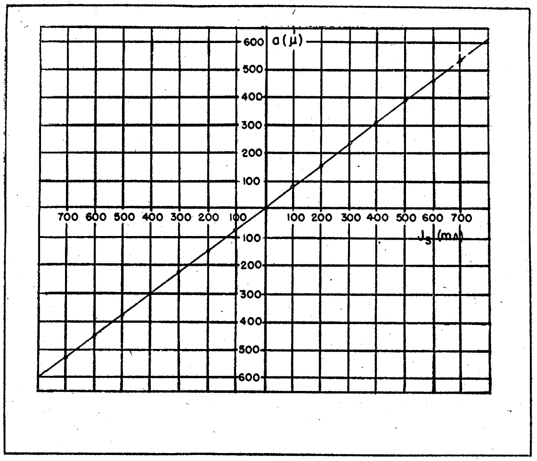

FIG. 5. Amplitude characteristic of the electrodyne recorder.

because the soot was removed in clinging flakes. The requirements which the coating must meet are: homogeneity (no crystal formation), pliability (minimal effect upon the ampli-

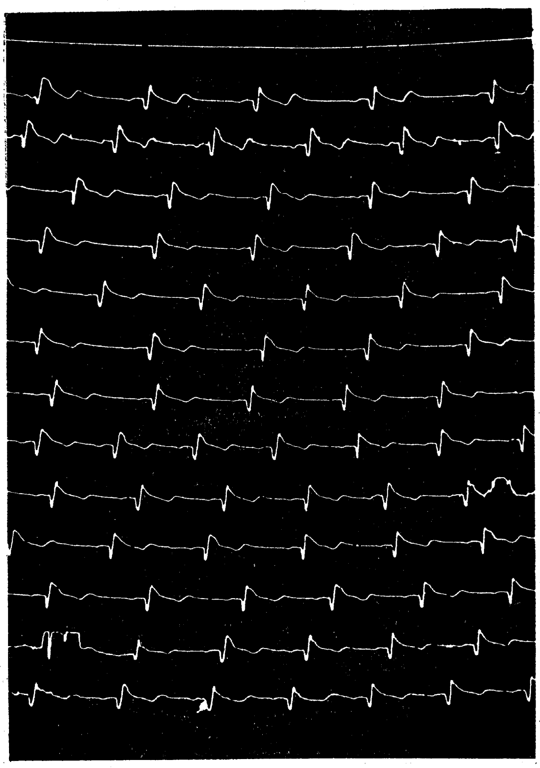

FIG. 6. Photomagnification of a part of an electrocardiac record.

tude and frequency characteristics of the recorder), sufficient opacity of very thin layers, and fine tracings during recording.

After several trials with pigmented albumin, gelatin, and paraffin coatings, a pigmented and desiccated solution of soap proved most appropriate. The tungsten point mentioned produces a groove 0.01 mm. thick in the soap. At an amplitude of 0.5 mm. the capacity of customary oscillographic methods is exceeded considerably. Not every soap is suitable for this purpose. The best results were accomplished with an American soap; the reason for this is now being investigated.

Discs of plate glass 30 cm. in diameter and 8 mm. thick were used as recording material. The disc should have an absolutely smooth surface, since even fine scratches damage the stylus. The manufacture of recording material is practicable and simple with the standard laboratory outfit. The cost is low, since the discs may be reused indefinitely.

Fig. 6 shows an electrocardiogram obtained with the method described above. The disc rotated constantly at 0.25 r.p.m. so that points on two adjacent grooves lying on the same radius represent events occurring 4 minutes apart.

This new electromechanical method of oscillography, although developed primarily for medical use, may, of course, be applied to other fields. Technical details of its development will be given in a later report.

Experimental Production of Anti-Rh Sera by the Use of Human Erythrocyte Stromata

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It was shown by Landsteiner and Wiener (*3*) that erythrocytes of *Macacus rhesus*, when injected into rabbits or guinea pigs, will produce an antiserum which, after suitable absorption, reacts with 85 per cent of human Caucasian bloods but fails to react with 15 per cent. Later, Gallagher and Jones (*2*) produced anti-Rh sera of the same specificity by the injection of human Rh+ erythrocytes into guinea pigs. Also subsequently, Wiener and Belkin (*4*) demonstrated that the Rh agglutinogen resides in the stroma of the erythrocyte and that it is of a haptene nature.

It had been shown earlier by Witebsky and Heide (*5*) that the injection of rabbits with boiled stromata of type N human erythrocytes produced sera having a high titer of N antibodies and a low titer of species specific antibodies. Calvin, *et al.* (*1*) have shown that the Rh haptene is probably a lipoprotein and is heat labile. We have inoculated guinea pigs with freshly prepared stromata of Rh+ human erythrocytes and produced antisera which, when absorbed with Rh− red cells until they no longer reacted with the absorbing cells, gave reagents that distinguished between Rh+ and Rh− erythrocytes.

The stromata were prepared by lysing Rh+ red blood cells in distilled water. The suspensions were passed through a Sharples supercentrifuge and the lysate discarded. The stromata were repeatedly washed with distilled water and centrifuged until the wash water was free of hemoglobin. With the resulting pale pink, gelatinous residue guinea pigs were immunized by repeated intraperitoneal inoculation. One week or more following the last injection the pigs were bled and the sera separated. After inactivation at 56°C. for 30 minutes the sera were absorbed as indicated above