were tried, among which were 2,4,5-trichlorophenoxyacetic acid and its isopropyl ester.

Both the acid form and the ester, in concentrations of 10, 25, 50, 75, and 100 ppm, were sprayed on fruits and foliage, using 5 branches/treatment. At the time of application each branch bore 5 figs, the oldest of which had been macroscopically evident for approximately 45 days. In 15 days the above concentrations of the acid had induced, respectively, 56%, 64%, 69%, 72%, and 65% mature fruits of average size. At the 10-ppm concentration there were 8 (32%) green, immature fruits, 1 (4%) at the 25 ppm concentration, and none at the other concentrations. Even the youngest fruits, although they did not attain full size, were yellow and soft. Comparable results were obtained with the isopropyl ester. Parallel treatments with 2,4-D failed to elicit this response.

At 10 ppm the 2,4,5-trichlorophenoxyacetic acid resulted in no injury or only a very mild leaf chlorosis. At higher concentrations, however, the injury became increasingly severe, and death of the treated branches occurred at the 75- and 100-ppm levels about 4 weeks after spraying. It is believed that the injurious effect of the treatment was accentuated because the branches were bagged for three weeks to exclude caprifying wasps. In some instances, unbagged branches adjacent to those sprayed received small quantities of spray as drift, and, although the fruit matured similarly to that fully treated, there was little or no injury, even at 100 ppm.

A similar acceleration of the ripening processes was found in 1947 following the injection of a solution of 1,500 ppm of indole butyric acid into the cavities of the receptive syconia (*1*). In this case, mature fruits were obtained 12 days after treatment, or 6 weeks previous to the normal maturity date. As far as the writers are aware, these are the first reported instances in which the normal developmental pattern of a fruit has been so radically accelerated.

Such a phenomenal speeding-up of fruit development is believed to be of considerable interest. It is a strong indication of the hormonal nature of fruit ripening. The 2,4,5-trichlorophenoxyacetic acid apparently raises the hormone level in the plant to such a high point that the mobilization in the fruit of the stored reserves is almost immediate, whereas, under the influence of the normal hormone level, the same process occurs much more slowly. The present finding, coupled with the work of van Overbeek on the hormone induction of flowering in the pineapple (*2*), indicates that the entire physiological mechanism of flower and fruit production is, at least in part, under the control of hormones.

These results further emphasize the high degree of specificity of the synthetic hormones and the responses they induce. 2,4-D, even at 100 ppm, was ineffective in hastening maturation, whereas the very closely related compound, 2,4,5-trichlorophenoxyacetic acid, was strikingly effective.

It is to be expected that this rapid mobilization of food reserves in response to hormone application would occur only in plants in which the reserves were large enough to support the accelerated development. In those plants in which there is a clear correlation between leaf area and fruit size, the food supply might become the limiting factor rather than the hormone level. However, the fig is rather unique in many respects, and it may be that the above response is peculiar to the fig alone.

What aftereffects a treatment with 2,4,5-trichlorophenoxyacetic acid would have on the continued vigor of the fig tree is not known. If no major damage results, however, it seems logical to assume that following fruit maturation the leaves could replenish the depleted reserves, and the tree would be capable of repeating the process the next season.

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Electronic Mapping of the Activity of the Heart and the Brain[1]

STANFORD GOLDMAN, WESTON E. VIVIAN, CHI KUANG CHIEN, and HENRY N. BOWES[2]

Research Laboratory of Electronics, Massachusetts Institute of Technology

The electrocardiograph and the electroencephalograph provide information concerning the activity of the heart and the brain. In recent years it has become quite common to compare the wave traces picked up at different points on the chest in studies of the heart and also those picked up at different points on the skull in studies of the brain. The present paper describes a new way of collecting and presenting such information which has been developed to assist the observer in distinguishing easily those items which are most significant in the melee of confusing data obtained by conventional electrocardiographic and electroencephalographic means. The new method involves an "area display,"[3] the development of which has been based upon considerations of perception selectivity.[4]

The conventional electrocardiograph or electroencephalograph shows the time variation of potential at a point on the surface of the body in the form of a wave trace, with time as abscissa and potential as ordinate. Except for the fact that there is no superposition of successive traces, this is similar to the so-called "type A" presentation used in radar systems. The method described

[1] This research has been supported in part by the Signal Corps, the Air Materiel Command, and ONR. The authors wish to thank Mr. Fred Rosebury for the construction of the election beam pickup tubes used in the early experiments and Messrs. R. M. Redheffer, T. Moreno, A. B. Macnee, and G. Duvall for serving as subjects for the heart displays.

[2] Now at Stromberg Carlson Telephone Mfg. Company, Rochester, New York.

[3] The area display was originally proposed to the senior author by Dr. Douglas Goldman for the purpose of locating brain tumors and other pathological areas in the brain.

[4] In this connection see the section on "Perception Selectivity" in the article, "Some Fundamental Considerations Concerning Noise Reduction and Range in Radar and Communication" (*Proc. I.R.E.*, May 1948).

herein results in a two-dimensional display of the distribution of potential over the surface of the chest or the skull. This display appears on the screen of a cathode-ray tube as a ''map'' of the area under investigation and is thus somewhat similar to the so-called ''PPI'' presentation used in radar. The brightness at a given position on the screen is proportional to the potential of the corresponding point on the chest or the skull.

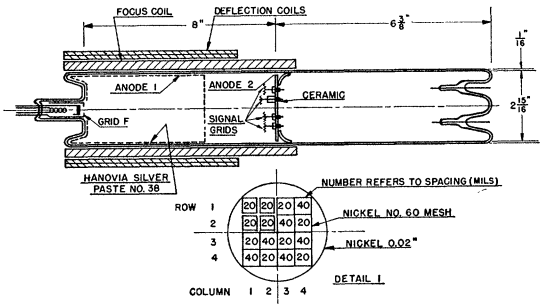

Fig. 1 First complete pickup tube for electronic potential mapping.

In order to obtain the area presentation, a pickup tube as shown in Fig. 1 was first used. Pickup electrodes are located at 16 individual grids in the tube. The locations of the electrodes on the chest correspond approximately to the locations of the grids to which they are connected. The array of 16 pickup grids is located in front of a single anode (called anode No. 2), and an electron beam is scanned across the grids. The potential on an individual grid regulates the amount of beam current to anode No. 2 at the time that the beam is passing through the grid in question. Consequently, if a standard type of cathode-ray tube with a phosphorescent screen is

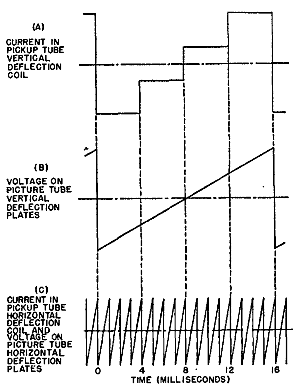

Fig. 2. Wave shapes of the scanning signals of the pickup and display tubes.

scanned in synchronism with the tube in Fig. 1, and if the signal current from anode No. 2, after suitable amplification, is applied to the intensity grid of the cathode-ray tube, the screen of this tube will show the approximate potential distribution across the chest.

The scanning signals used in this case are shown in Fig. 2. It will be noted that each horizontal line of grids in the pickup tube is scanned four times before proceeding to the next line. At the same time, the vertical motion of the beam in the display tube is uniform. This method improves the area display, as illustrated in Fig. 3. Because of the spot size of the pickup tube, it was decided to scan the centers of the grids each time. This is the reason for the step-scanning signal in the pickup tube.

It was originally hoped that the system might be made to operate without amplifiers between the pickup electrodes and the signal grids of the pickup tube. This was not successful. The principal reason for difficulty was the spurious signal pattern which was introduced as the beam crossed over from one signal grid to another. A

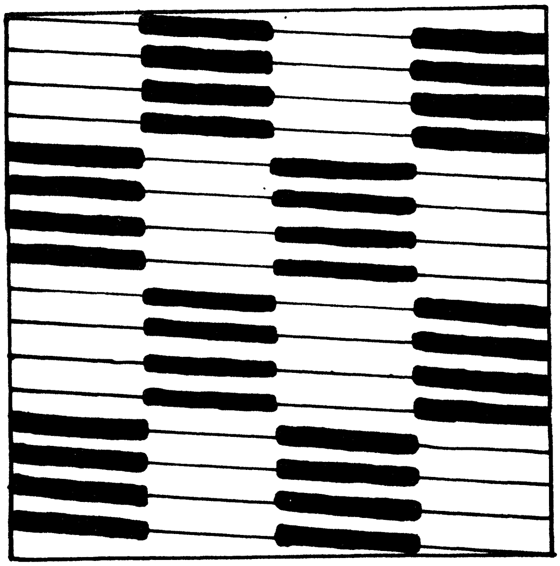

Fig. 3. Sketch of observed display pattern when signal grids of pickup tube are connected to d-c potentials arranged in a checkerboard pattern.

second pickup tube which used electrostatic focus and deflection and a high-voltage screen in front of the pickup grids gave a much finer spot size and generally improved performance, but still gave too much residual pattern.[5] It was therefore decided to introduce amplifiers between the pickup electrodes and the signal grids to raise the desired signal to about a 1-v level at the grids. When this was done, the signal pattern was considerably stronger than the residual pattern, and a potential area display showing the activity of the heart could be seen on the screen.

These original displays of heart activity were not satisfactory for several reasons: (1) The spurious residual pattern was always present and could not conveniently be removed even with amplification of the desired signal; (2) the 16 different grids, although of apparently identical structure, were of widely different sensitivities, probably because of local work-function differences of the screen material; (3) there was interaction between

[5] The details of this work will be given in a later paper to be submitted to the *Proceedings of the Institute of Radio Engineers.*

the different grids, presumably due to secondary electrons. It appears probable that these difficulties could be eliminated by suitable modifications in the pickup tube. In order to avoid the delays which would have been necessitated by extensive redesign and development of the pickup tube, however, it was decided to substitute an electronic circuit commutator for it in the later experiments.

The electronic circuit commutator has the same function as the pickup tube in the over-all system, but the details of its operation are completely different. A block diagram of the circuit is shown in Fig. 4. Instead of

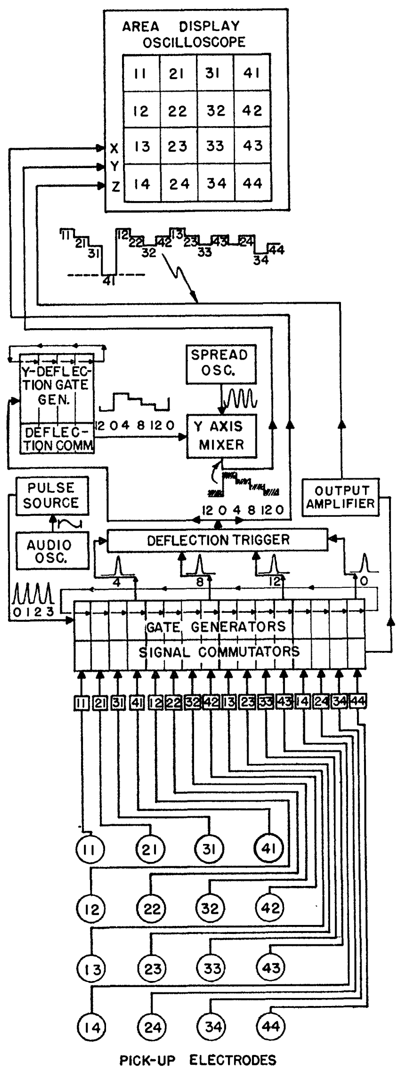

FIG. 4. Block diagram of the electronic circuit commutator system.

the 16 signal grids of Fig. 1, we now have 16 signal commutator units. Each of the 16 amplifiers whose inputs are connected to the 16 pickup electrodes is connected to a different one of the signal commutators in a definitely planned sequence, as shown in Fig. 4. When a commutator is activated, it amplifies the signal coming to it and transfers it to the output amplifier. When a commutator unit is deactivated, it has no output. At any one time, only one commutator unit is activated and the other 15 are deactivated.

The commutator units are activated by the gate generators in the sequence shown in Fig. 4. These generators are synchronized by pulses derived from an audio-oscillator; the latter is therefore the primary timing source. The generators also operate in sequence, and the same operation which deactivates one commutator unit activates the following one. Deactivation of the 16th unit activates the first one, and the sequence starts all over again.

The output of the signal commutators, which is of the same wave shape as that of the output amplifier, then consists of a step-like signal, as shown in Fig. 4. The height of each step is proportional to the electrical potential at the corresponding pickup electrode. This step-like signal is then transmitted to the Z-axis (intensity grid) of the Area Display Oscilloscope.

For reasons explained elsewhere,[5] it is necessary to use one of the steps as a d-c reference level to prevent interaction between the other steps. The corresponding elementary square in the Area Scope is therefore inactive. We used elementary square 41 as the inactive reference element.

The sweep circuits of the oscilloscopes are synchronized by the same pulses which actuate the gate generators (Fig. 4). In order to fill in the areas of the elementary squares in the Area Scope, a high-frequency sine wave is superimposed on the Y-axis deflection voltage. This takes the place of the fourfold scanning of the elementary squares shown in Fig. 3 and used in the earlier system when a pickup scanning tube was used.

With the use of the electronic circuit commutator excellent displays of the area distribution of potential on the surface of the chest were obtained. These show striking moving pictures of the electrical activity of the heart. The activities of the auricles and ventricles are distinguished by both their location and timing, and the movement of the exciting potential across the heart is clearly seen. It is interesting to note that, immediately after exercise, the size of the active area on the chest is increased and the direction of motion of the exciting potential is changed from a diagonal to a more horizontal direction. Following the motion of the excitation potential is a motion in almost the opposite direction, but somewhat more horizontal. The latter activity has been tentatively identified as the recovery period of the heart by cardiologists who have seen the displays.

Motion pictures have been taken of the area displays with a 16-mm camera. Prints of 16 consecutive pictures of the reel covering a total period of $1\,^1/_{15}$ sec are shown in Fig. 5. These pictures show slightly more than one complete period of the heart's activity (the subject had a pulse rate of 68/min). The locations of the pickup electrodes are shown in Fig. 6. The left forearm was used as an indifferent electrode.

While photographs such as those shown in Fig. 5 should give valuable information, particularly if the number of frames per second is increased, it is very difficult, if not impossible, to synthesize the movements of the potentials across the chest from a study of a set of these photographs. However, the original reel from which the photographs came, when projected as a motion picture, shows the movements almost as clearly as direct observation of the screen of the cathode-ray tube. These movements are the most striking characteristic of the display.

Arrangements are being made with cardiologists for correlation between clinical findings and the appearance of the displays, and it is anticipated that these area displays will be useful both in clinical studies and in investigations of the physiology of the heart.

Area displays of the instantaneous skull potentials were also obtained. As anticipated, these could not be interpreted readily because of the speed of the activity. Special apparatus for obtaining useful skull displays is now being completed. This consists of a tuning unit and rectifier for each of the 16 amplifiers attached to the pickup electrodes. The tuning units have a band width of about 1 cycle/sec. The units are all tuned to the same frequency at any one setting, and the output of each unit is rectified and transmitted to the commutator. This provides a ''spectroheliograph'' type of display in which the area distribution of the rms potential at the tuning frequency will be shown. It is anticipated that such displays will be significant. The units are also arranged so about 100 cycles and has a pass-band approximately 1 cycle wide in this range. All 16 tuning units in the respective channels are preset at the same frequency. In this way the 16 channels can be tuned through the frequency range between 0 and 50 cycles by varying the oscillator frequency through the range from 100 to 150 cycles. If the same oscillator is used to supply a carrier for all 16 channels, the tuning can be done with a single control dial.

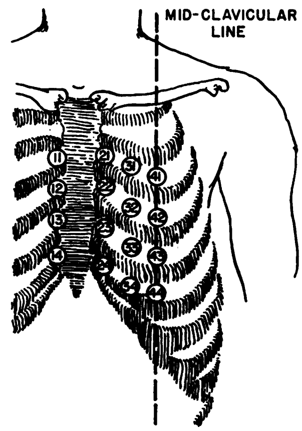

FIG. 6.

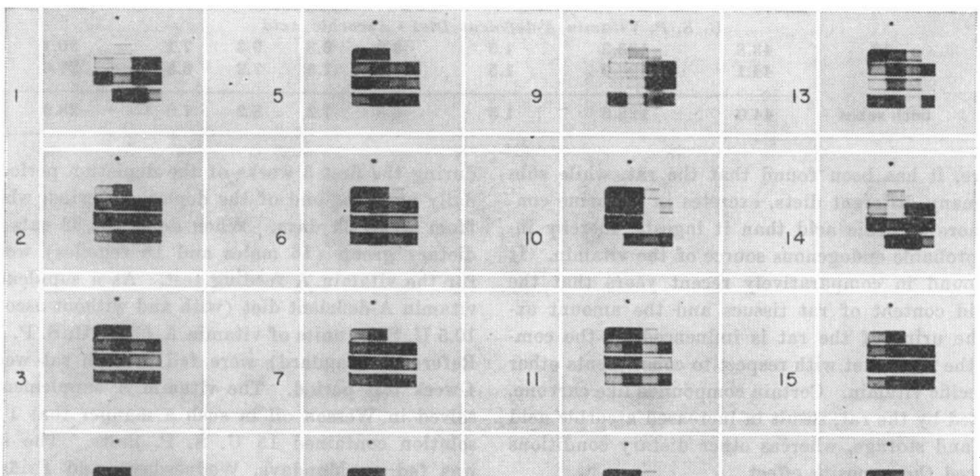

FIG. 5. Sixteen consecutive frames from a motion picture reel of the heart's activity (approximately 13 frames/heart beat).

that the rectified signal of the entire frequency band (without tuning), *i.e.* the envelope, can also be displayed.

Provision is made for tuning through the frequency range from 1 to 50 cycles by a superheterodyne method. The signal picked up is heterodyned in a mixer tube with an oscillator signal which has an adjustable frequency between 100 and 150 cycles. The output of the mixer enters the tuning unit, which is preset at a frequency of

One possible extension of the method is the taking of motion-picture photographs of the direct instantaneous displays and their subsequent observation in slow motion. Another possible extension is the use of a ''stroboscopic'' type of display, in which the frame frequency (frequency of scanning an entire picture) is continuously varied from 1 to 100/sec. This should select the activity which occurs near the frame frequency or its harmonics.