

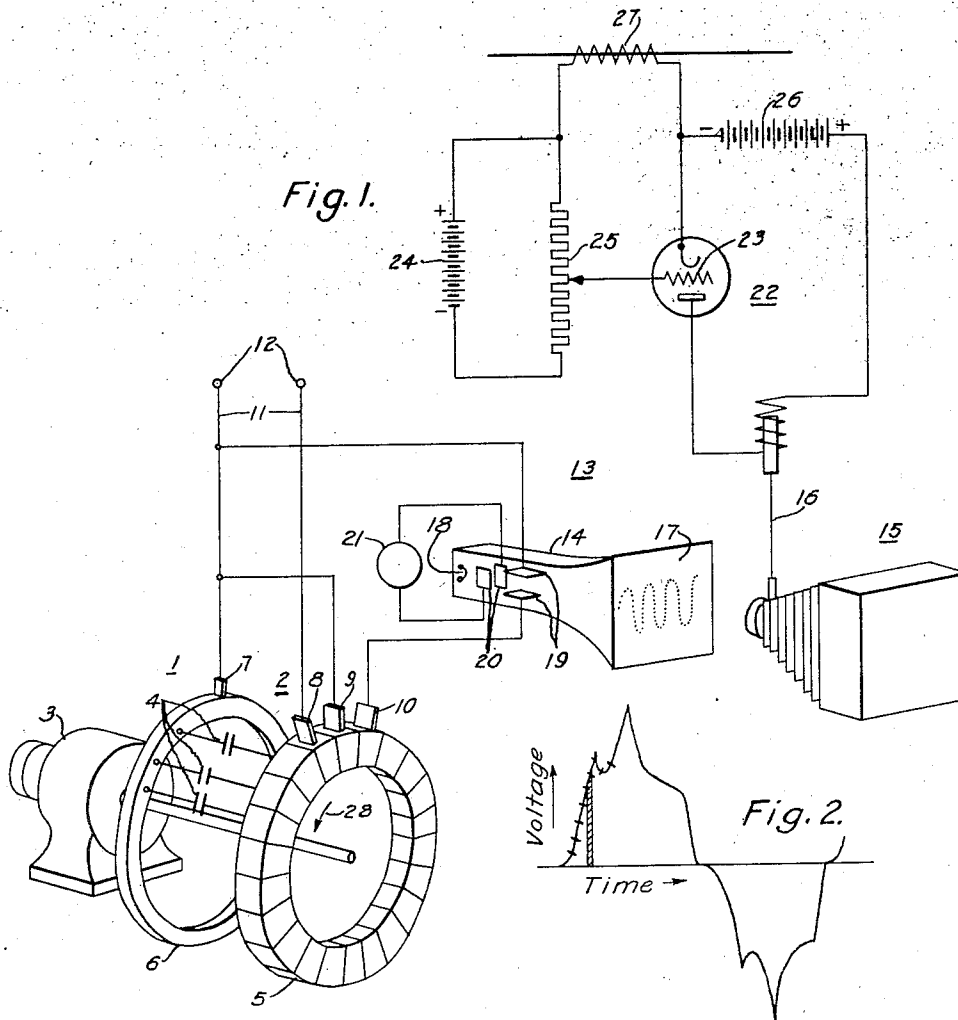
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RECORDING OSCILLOGRAPHIC APPARATUS

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WITNESSES;

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RECORDING OSCILLOGRAPHIC
APPARATUS

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My invention relates to apparatus for recording variable quantities such as voltages, currents, temperatures, speeds or torques, for example, and particularly to such apparatus which may be put into operation at a given instant of time and which will thereafter make an accurate record of the variable quantity under observation as it existed for some time prior to the given instant of time.

In its more specific aspects, the invention relates to oscillographic apparatus of the type in which a record of the variable quantity under observation is temporarily stored in some form of retentive medium, such that at the instant of starting the permanent oscillographic record, the variable quantity can be recorded for a time interval preceding the instant of starting. As examples of the retentive media heretofore proposed in the art for such applications, may be mentioned electrical networks or artificial lines in which are variable quantities are temporarily stored as travelling waves, air columns in which the variable quantities are stored as sound waves, and rotating discs of magnetically retentive material on which a temporary magnetic record is made.

The above-mentioned expedients, although satisfactory for recording major variations of the variable quantity, introduce distortion of the wave form because of the effects of attenuation. In order to avoid distortion of wave form in such apparatus, it is necessary that the retentive medium have a negligible frequency error, and that it produce the same time delay for all frequencies. That is to say, the ratio of the voltage, mechanical force or other variable which affects the retentive medium, to the current, displacement or other effect produced in the medium, must be substantially constant at all frequencies; and also, the time delay between the application of the voltage, mechanical force or other variable and the appearance of the variable from which a record is made, must be constant for all frequencies. With such a retentive medium, the fundamental and all harmonics of the variable quantity under observation would be reproduced in correct ratio and correct relative phase position, so that no distortion would be produced.

It is, accordingly, an object of my invention to provide a novel oscillographic recording device in which the variable quantity under observation can be recorded, without distortion, for a period of time preceding the disturbance which initiates the permanent recording operation.

Other objects of my invention will become evi-

dent from the following detailed description taken in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic view of a recording oscillograph embodying my invention; and

Fig. 2 is a graphical record illustrating the operation of the invention.

In accordance with my invention, the desired characteristics of the retentive medium, as discussed above, are secured by means of a capacitive recording device having a dielectric medium, which serves as a charge-retaining means, and motor driven rotary apparatus for successively including increments of the dielectric medium in an electric circuit upon which a voltage, dependent upon the variable quantity under observation, is impressed. In this way a record of the variable quantity, in the form of bound electric charges, is produced. By making the resistance of the electric circuit negligible, the time constant RC of the circuit becomes negligible, and the increments of dielectric receive their final value of charge substantially instantaneously, thereby avoiding distortion of wave form. The time lag of the capacitive recording device is fixed by the speed of rotation and is constant for all frequencies. Although my invention may be embodied in various structural forms, I prefer to provide separate small capacitors as the dielectric increments, and to control the connections of these capacitors by means of a commutator.

Referring to Fig. 1 in detail, the capacitive recording device 1 comprises a rotor 2 arranged to be driven at substantially constant speed by any suitable driving means such as a synchronous motor 3. The rotor 2 comprises a plurality of small capacitors 4, a few of which are shown diagrammatically in Fig. 1, and a rotating commutator 5, such as is usually provided in a direct-current machine. Each of the capacitors 4 is connected to an individual bar of the commutator 5, and the remaining terminals of the capacitor 4 are connected to a suitable conductor of common potential, such as a slip ring 6, or may be grounded on the machine frame.

The slip ring 6 is engaged by a stationary slip ring brush 7, and the commutator 5 is engaged by three stationary angularly displaced brushes 8, 9 and 10. The brush 8 may be termed a charging brush, inasmuch as its function is to supply a charge to each of the condensers 4 in succession. The brush 9 serves to discharge the condensers 4 preparatory to a recharging operation by means of the brush 8. The brush 10 serves to transfer a delayed indication of the charges

impressed on the condensers 4 by the brush 8, to suitable recording apparatus which will be hereinafter described.

The brushes 7 and 8 are connected to an input electric circuit 11 having terminals 12, upon which a voltage dependent upon the variable quantity under observation, is impressed.

The output brush 10 and the slip ring brush 7 are connected to a suitable recording oscillograph 13, which may be of any of a number of forms known in the art. In the form shown, the oscillograph 13 consists of a cathode-ray tube 14, and a photographic camera 15 mounted in a position to photograph the image projected on the screen of the cathode-ray tube 14. The recording oscillograph 13 is provided with a suitable release device 16 for initiating the making of a permanent record. In the form shown, the release device 16 consists of an electromagnetic shutter opening device for the camera 15. It will be understood that upon operation of the release device 16, the camera shutter opens and thereafter automatically closes after a time delay determined by an adjustment of the camera 15.

The cathode-ray tube 14 consists of an evacuated envelope having suitable apparatus (not shown) for projecting a beam of electrons from a cathode 18, between a pair of electric field plates 19 and a pair of sweep plates 20, to a suitable screen 17 which becomes luminous at the point where the electron beam impinges.

A device 21 is provided for energizing the sweep plates 20 in accordance with the remaining variable to be recorded on the oscillographic record. In some cases the device 21 may be a current transformer or other current responsive device so that the curve traced on the screen 17 will be a function of current and voltage. In other cases, however, the device 21 may be a source of alternating voltage of constant magnitude but variable frequency, for causing the image on the screen 17 to include as many cycles of the voltage impressed on the plates 19 as may be desired. It will be assumed that the device 21 is a source of adjustable sweep frequency voltage, such as commonly provided with cathode ray tubes.

The electromagnetic release device 16 is connected in the output circuit of a suitable gas-filled electric discharge device 22 of the so-called grid-glow or Thyatron type. The electric discharge device 22 is provided with a control electrode 23, which serves, when properly biased, to prevent a discharge between the anode and cathode of the device 22. A bias battery 24 is provided for biasing the control electrode 23 negatively with respect to the cathode of the electric discharge device 22, to such a voltage value as to block the discharge device 22 during all normal conditions. The control electrode 23 is also connected to suitable apparatus for rendering the device 22 conducting upon the occurrence of a predetermined condition, such as a reverse current flow of fault magnitude, or other abnormal disturbance, which is to initiate a recording operation of the oscillograph 13. In the embodiment shown, the apparatus takes the form of a current transformer 27, which for purposes of illustration will be assumed as energized in accordance with the anode current of a rectifier (not shown), in such manner that the initial half-cycle of induced voltage during an arc-back will neutralize the bias potential applied to the control electrode 23, and cause a discharge current

to traverse the device 22. A suitable source 28 of plate voltage is included in series with the principal electrodes of the electric discharge device 22 and the electromagnetic release device 16, in accordance with the usual practice.

The operation of the above-described apparatus may be set forth as follows. The rotor 2 is continuously driven at a constant speed by the motor 3 in the direction of the arrow 28. Assuming that an alternating voltage is impressed upon the input terminals 12, as each segment of the commutator 5 passes over the brush 8, the condenser 4 connected thereto, is charged to a voltage equal to the instantaneous voltage impressed upon the terminals 12 at the instant that the segment leaves the trailing edge of the brush 8. The condensers 4 travelling from the brush 8 toward the brush 10 accordingly carry a point-for-point record of the voltage wave impressed upon the terminals 12. As the commutator segments travel from the brush 8 in the direction of the arrow 28 around to the brush 10, a time delay is introduced, dependent upon the synchronous speed of the motor 3 and the angular displacement between the brushes 8 and 10.

Upon arriving at the brush 10, each commutator segment causes the electric field plates 19 to be charged to a voltage substantially equal to that upon the condenser 4 connected to the segment. In this way, the voltage upon the electric field plates 19 is caused to follow a succession of stepped values, the initial point of each of which corresponds exactly to a point on the original voltage wave impressed upon the terminals 12.

Referring to Fig. 2, in which voltage is plotted as ordinates and time as abscissa, it will be seen that by making the time during which a single commutator segment is in contact with the brush 10 small, the stepped wave may be made to more and more closely approach the exact form of the voltage wave impressed upon the input terminals 12. I have found that for a motor speed of 1800 R. P. M., and a commutator having a number of segments of the order of several hundred, the wave form appearing on the screen 17 bears no visible irregularities and appears to be a smooth curve. In some cases, however, it is desirable to have the wave form appear stepped or dotted, so that the distance between dots, or the length of stepped portions, may be taken as an indication of time. For this purpose, the motor speed or number of commutator bars may be reduced, or the wave amplitude increased sufficiently to break up the smooth curve. With a broken wave form, the 60 cycle timing wave, sometimes required for oscillographic work, becomes unnecessary. Such a broken wave, also, may be used to record three variables on the same trace; for example, current and voltage may appear as Cartesian coordinates of the trace, and time as the number of dots appearing between various points on the trace.

The shutter of the camera 15 is normally closed, but upon the occurrence of the predetermined condition which causes the electric discharge device 22 to become conducting, the camera shutter is open, thereby making a photograph record of the image appearing upon the screen 17 at the instant of shutter opening. I have found that it is practicable to open the camera shutter in a time interval of the order of .3 to .4 of a cycle of 60 cycle supply.

Because of the time lag resulting from the travel of each commutator segment from the brush 8 to the brush 10, the image appearing upon

the screen 17 at the instant of shutter opening, represents the voltage which was impressed upon the terminals 12 at some time previous to the instant of shutter opening. For the particular values given above, the time delay would be of the order of $1\frac{1}{2}$ cycles of a 60-cycle supply, so that if the sweep frequency supplied by the source 21 were such as to embrace, say, three cycles of the 60-cycle supply, the image appearing upon the screen 17 would consist of approximately $1\frac{1}{2}$ cycles of the variable quantity under observation, previous to the disturbance which initiated operation of the release device 16, and approximately $1\frac{1}{2}$ cycles of the variable quantity following the disturbance.

It will be obvious that various other forms of oscillographic apparatus or other recording apparatus may be substituted for the specific recording oscillograph 13 shown. It will also be obvious that any other phenomena than voltage may be recorded by this apparatus, by merely translating the quantity to be observed to a voltage and impressing it upon the terminals 12. The numerical values given above are arbitrarily chosen for purposes of illustration, and it will be obvious that the invention may be practiced with numerical values of an entirely different order.

I do not intend that the present invention shall be restricted to the specific structural details, arrangement of parts, or circuit connections herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of my invention. I desire, therefore, that only such limitations shall be imposed as are indicated in the appended claims.

I claim as my invention:

1. In apparatus for recording a variable quantity, an electric circuit to be energized in accordance with the quantity to be recorded; a capacitive storing device having a plurality of electric charge-retaining portions, said storing device comprising means for successively including said portions in said circuit for variable energization in accordance with instantaneous values of said electrical condition; and means for translating the successive charges bound on said portions into a graphical representation of said variable quantity.

2. In apparatus responsive to a predetermined condition for automatically recording a variable quantity for a time interval commencing at least as early as the start of said condition, an electric circuit to be energized in accordance with the quantity to be recorded; a capacitive storing device having a plurality of electric charge retaining portions, said storing device comprising means for successively including said portions in said circuit for variable energization in accordance with instantaneous values of said electrical condition; and means effective upon the occurrence of said predetermined condition for translating the charges bound on said portions during said time interval into a graphical record of said variable quantity.

3. In apparatus responsive to a predetermined condition for automatically recording a variable quantity for a time interval commencing at least as early as the start of said condition, an electric circuit to be energized in accordance with the quantity to be recorded; a capacitive storing device having a plurality of electric charge-retaining portions, said storing device comprising means for successively including said portions in said circuit in a predetermined cycle, and remov-

ing the charges from said portions prior to a repetition of the cycle; and means for translating the successive charges bound on said portions into a graphical representation of said variable quantity.

4. In apparatus for recording a variable quantity, an electric circuit to be energized in accordance with the quantity to be recorded; a capacitive storing device comprising a plurality of capacitors, and commutating apparatus for cyclically connecting each of said capacitors in said circuit for variable energization in accordance with instantaneous values of said electrical condition; and means for translating the successive changes on said capacitors into a graphical representation of said variable quantity.

5. In apparatus for producing a delayed oscillographic record of a variable quantity, an electric circuit to be energized in accordance with the quantity to be recorded; an oscillograph; a plurality of capacitors; and commutating apparatus for connecting each of said capacitors in rotation in said circuit and for thereafter connecting each of the charged capacitors in rotation to said oscillograph.

6. In apparatus responsive to a predetermined condition for automatically recording a variable quantity for a time interval commencing at least as early as the start of said condition, an electric circuit to be energized in accordance with the quantity to be recorded; a plurality of capacitors; commutating apparatus for connecting each of said capacitors in rotation in said circuit; and means effective upon the occurrence of said condition for translating the charges bound on said capacitors during said time interval to a graphical record of said variable quantity.

7. In apparatus responsive to a predetermined condition for automatically producing an oscillographic record of a variable quantity for a time interval commencing at least as early as the start of said condition, an electric circuit to be energized in accordance with the quantity to be recorded; a recording oscillograph having a release device effective to initiate a recording operation; a plurality of capacitors; commutating apparatus for connecting each of said capacitors in rotation in said circuit and for thereafter connecting each of the charged capacitors in rotation to said oscillograph; and means responsive to said predetermined condition for operating said release device.

8. In apparatus responsive to a predetermined condition for automatically producing an oscillographic record of a variable quantity for a time interval commencing at least as early as the start of said condition, an electric circuit to be energized in accordance with the quantity to be recorded; a recording oscillograph having a release device effective to initiate a recording operation; a rotary device comprising a plurality of capacitors mounted for rotation, a rotating commutator having a plurality of bars each connected to one of said capacitors, and stationary brushes in engagement with said commutator, said stationary brushes including a charging brush connected to said circuit and an output brush connected to said oscillograph; said output brush being angularly displaced from said charging brush, motive means for driving said rotary device; and means responsive to said predetermined condition for operating said release device.

9. In apparatus for recording a variable quantity, an electrical circuit to be energized in ac-

cordance with the quantity to be recorded; a continuous energy storing device having a plurality of individually effective energy storage elements of similar characteristics, said storing device comprising means for successively energizing said elements from said circuit, in a timed sequence, to variable degrees dependent upon the instantaneous values of said electrical condition; and electroresponsive means for translating the individual quantities of energy stored on said elements into a graphical succession of indicia following said sequence, each of said indicia indicating a quantity corresponding to the energy storage in one of said elements, whereby the variations of said variable quantity as a function of time may be determined by the incremental variations of magnitude of successive indicia.

10. In apparatus responsive to a predetermined condition for automatically recording a variable quantity for a time interval commencing at least as early as the start of said condition, an electric circuit to be energized in accordance with the quantity to be recorded; a capacitive storing device having a plurality of discrete charge-retaining elements of similar characteristics, said storing device comprising means for successively including said elements in said circuit, in a timed sequence, for variable energization in accordance with instantaneous values of said electrical condition; and means effective upon the occurrence of said predetermined condition for translating

the charges bound on said elements during said time interval into a graphical succession of distinguishable indicia following said sequence, whereby the variations of said variable quantity as a function of time may be determined by the incremental variations of magnitude of successive indicia.

11. In apparatus responsive to a predetermined condition for automatically producing an oscillographic record of a variable quantity for a time interval commencing at least as early as the start of said condition, an electric circuit to be energized in accordance with the quantity to be recorded; a recording oscillograph having a release device effective to initiate a recording operation; a capacitive storing device having a plurality of discrete charge-retaining elements of similar characteristics, said storing device comprising means for successively including said elements in said circuit, in a timed sequence, for variable energization in accordance with instantaneous values of said electrical condition and for thereafter connecting each of the charged elements to said oscillograph in the order of said timed sequence at intervals sufficient to produce distinguishable oscillographic records of individual charges on said elements, and means responsive to said predetermined condition for operating said release device.

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