

Oct. 15, 1968

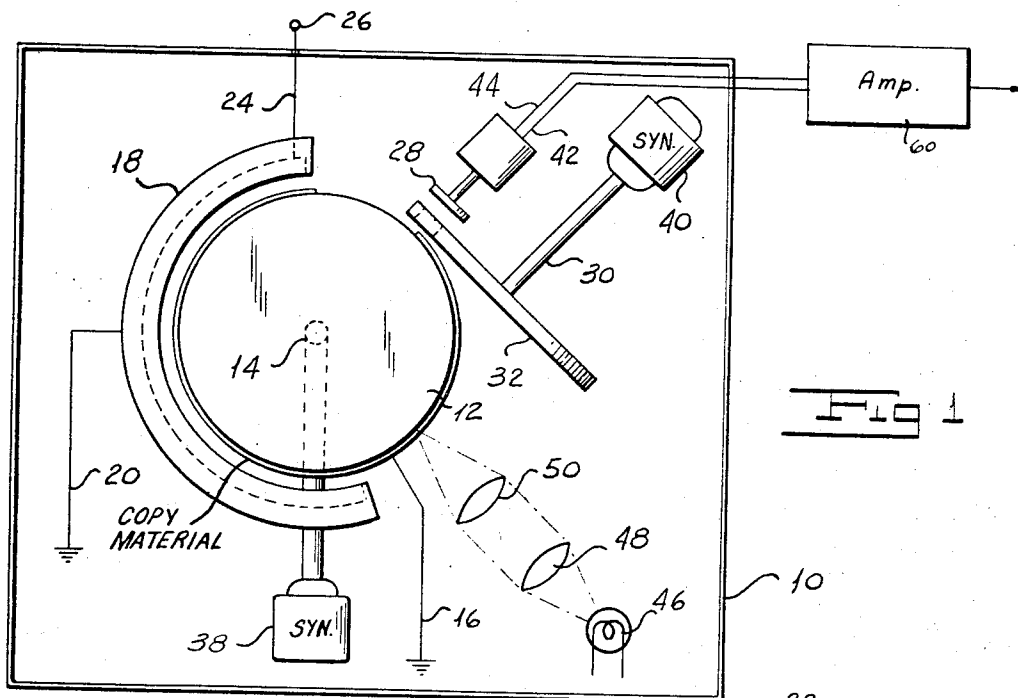
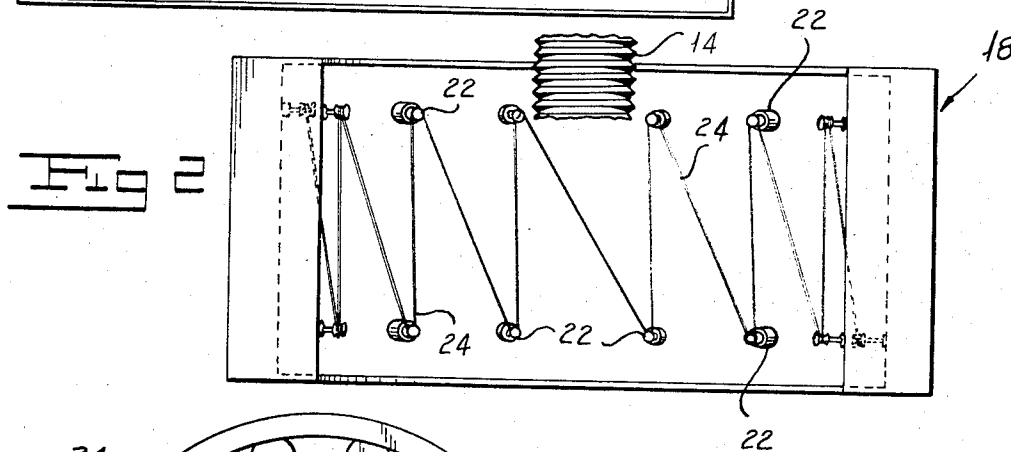
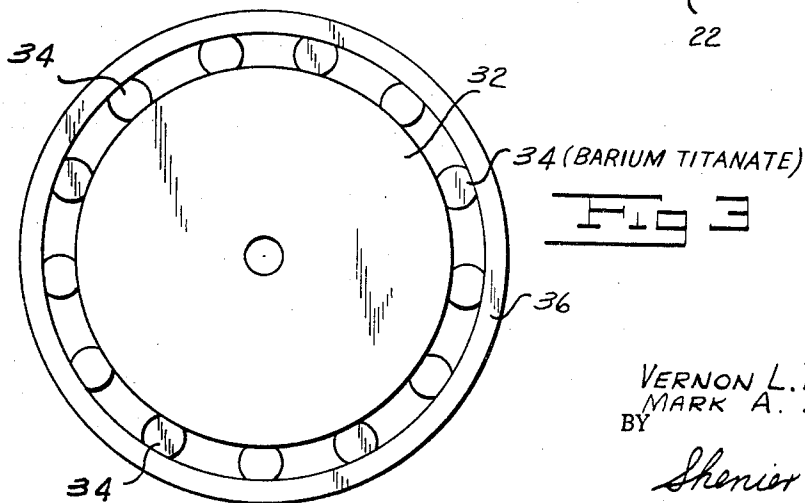
V. L. MARQUART ET AL

3,406,334

APPARATUS FOR TESTING ELECTROSTATIC COPY MATERIAL

Filed July 27, 1964

3 Sheets-Sheet 1



INVENTORS
VERNON L. MARQUART
MARK A. STOLLE
BY

Shenier & Connor
ATTORNEYS

Oct. 15, 1968

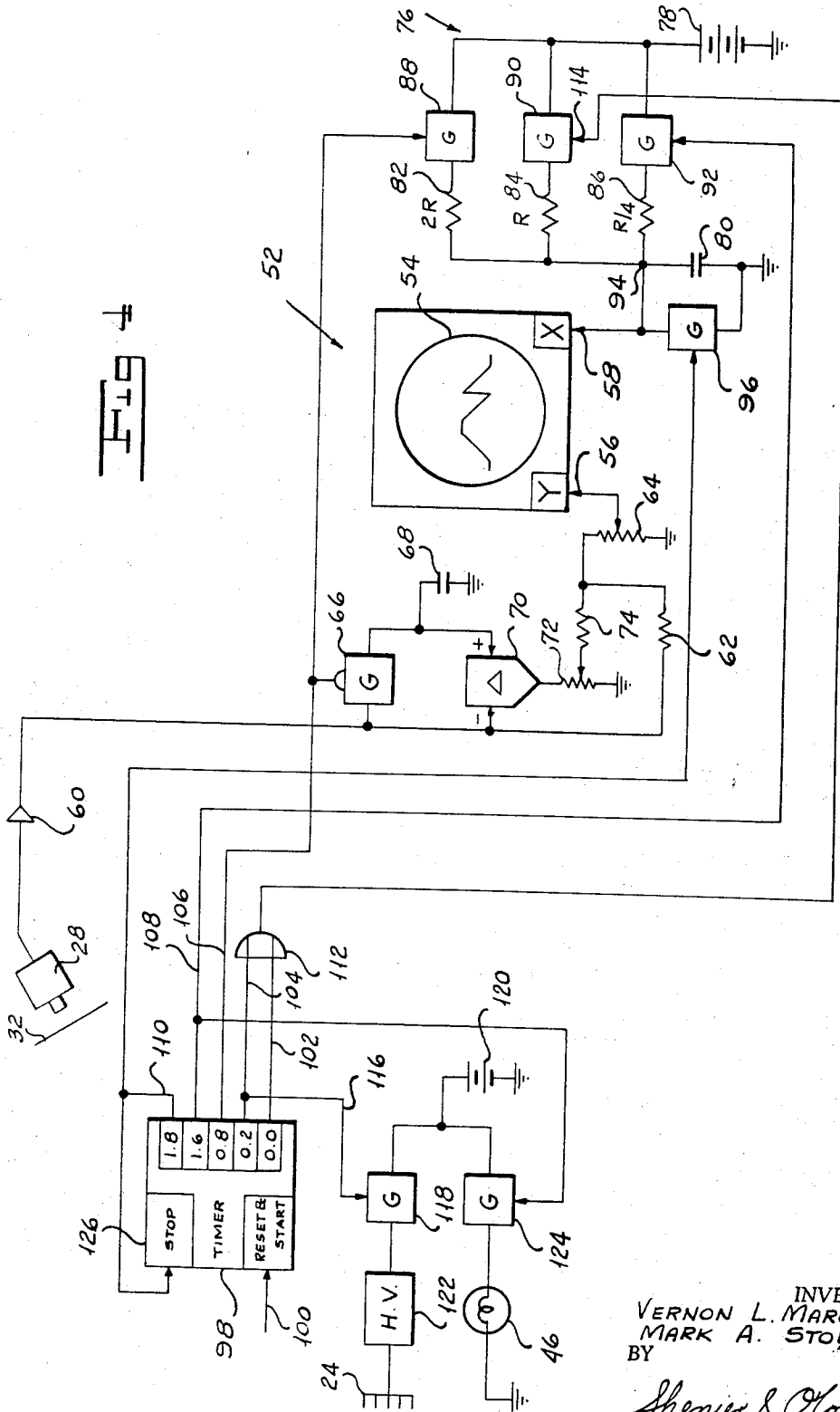
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5 Sheets-Sheet 2



INVENTORS
VERNON L. MARQUART
MARK A. STOLLE
BY

Shenier & O'Connor
ATTORNEYS

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3 Sheets-Sheet 3

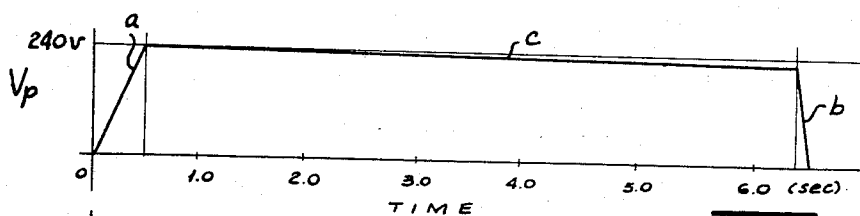


Fig 5

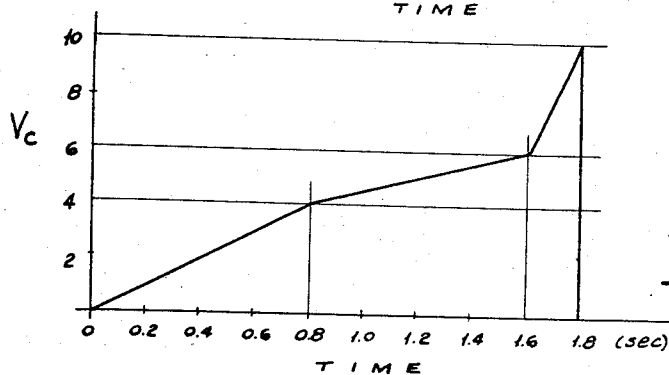


Fig 6

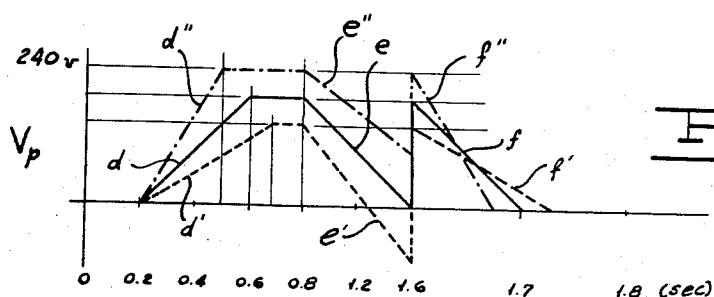


Fig 7

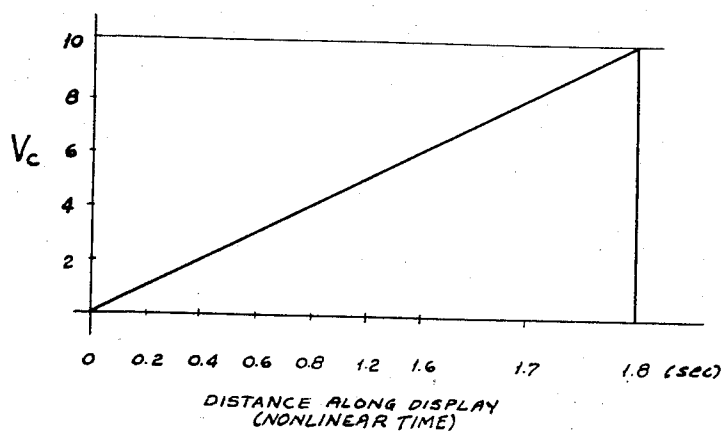


Fig 8

INVENTORS
VERNON L. MARQUART
MARK A. STOLLE
BY

Shenier & O'Connor
ATTORNEYS

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APPARATUS FOR TESTING ELECTROSTATIC COPY MATERIAL

Vernon L. Marquart, Philadelphia, Pa., and Mark A. Stolle, Glendale, Ariz., assignors to Nuclear Corporation of America, Phoenix, Ariz., a corporation of Delaware

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9 Claims. (Cl. 324—32)

ABSTRACT OF THE DISCLOSURE

A system for testing electrostatic copy material in which means is provided for subjecting the copy material to the action of an electrostatic field for a predetermined time and for measuring the rate of acquisition of charge by the material during that time. Following the period of time the measuring means measures the rate of dark discharge of the material. Subsequently the material is illuminated and during the time of illumination the measuring means measures the illuminated discharge rate of the material.

Our invention relates to an electrometer system and more particularly to a system for determining the characteristics of electrostatic copy material in a rapid and expeditious manner.

There are known in the prior art electrostatic copy machines in which a length of copy material carrying a photoconductive coating is fed through a corona to produce an electrostatic charge over the area of the length. The charged length is fed through an exposure zone in which an image of the original to be copied is focused on the material. Owing to the photoconductive nature of the material, the charge leaks off over the relatively lighter areas of the image but is retained over the relatively darker areas. The result is a latent electrostatic image of the original on the copy material. The length of material carrying the latent electrostatic image passes through a developing station wherein it is subjected to the action of a developer made up of a carrier and toner particles having such an electrostatic relationship that the toner particles adhere to the charged areas of the material while the carrier is repelled thereby. Thus, the latent electrostatic image is developed. After being developed, it passes through a fixing zone wherein the toner is fixed to the copy material which is then delivered to the user of the machine.

It will readily be apparent that copy material in order to be acceptable for use on a machine of the type described above must meet certain standards. It must not take too long a time to accept a charge. Having accepted a charge, it must not discharge too rapidly in the dark. While retaining its charge in the dark, the copy material should discharge relatively rapidly upon exposure to light so that the latent image can be applied thereto.

In order to assess the suitability of copy material, at least three of its characteristics must be measured. Specifically, the time required to charge the material, the rate at which the charge decays in the dark and the rate of discharge in light, all must be measured. It will be obvious from the above considerations that, considering an acceptable copy material, an extremely long time is required before a measurable loss of charge in the dark takes place in relation to the time required to charge the material. Moreover, the time required for discharge in light is relatively short as compared with the time required to charge the material and is extremely short as compared with the time required for a measurable decay of charge in the dark to take place. Thus, it would be thought that the tests outlined above of the characteristics

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of copy material must by their nature be required to be individually performed if intelligible results are to be achieved.

In order to perform any of the tests outlined above, some form of static charge measuring device such, for example, as an electrometer is required to measure the charge on the copy material. An instrument of this nature which converts the direct current electrometer voltage to alternating current is the vibrating reed electrometer. Some of the disadvantages of such a device are the difficulty of maintaining a stable frequency, the large number of moving parts and relatively poor reliability.

We have invented an electrometer system which permits all of the necessary characteristics of electrostatic copy material to be measured in a continuous operation. Our electrometer system is adapted to produce an intelligible visual indication of the characteristics of the material. It is readily adaptable to automatically testing a large number of lengths of material. It is simple and inexpensive for the result achieved thereby. Our system incorporates an improved electrometer having good frequency stability, fewer moving parts and greater reliability than the vibrating reed electrometer known in the prior art.

One object of our invention is to provide an electrometer system which tests the characteristics of electrostatic copy material in a simple and expeditious manner.

Another object of our invention is to provide an electrometer system which tests all the significant characteristics of electrostatic copy material in a continuous manner.

A further object of our invention is to provide an electrometer system which produces an intelligible visual indication of the characteristics of electrostatic copy material.

Still another object of our invention is to provide an electrometer system incorporating an electrometer which overcomes the disadvantages of electrometers of the prior art.

Other and further objects of our invention will appear from the following description.

In general our invention contemplates the provision of an electrometer system in which a rotating wheel carrying spaced segments of insulating material moves between a stationary probe and a charged member, such as a length of copy material, carried by a drum to produce an electrical signal which is a measure of the charge on the copy material. We apply the electrometer signal to a device, such as a cathode-ray tube, and provide circuitry for changing the tube sweep rate as the copy material sequentially is charged, permitted to discharge in the dark and is discharged in light to provide an intelligible visible indication of the material characteristics.

In the accompanying drawings which form part of the instant specification and which are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:

FIGURE 1 is a schematic elevation of a portion of our electrometer system for measuring the characteristics of electrostatic copy material.

FIGURE 2 is an elevation of the corona system of our electrometer for measuring the characteristics of electrostatic copy material.

FIGURE 3 is a plan view of a component of our electrometer.

FIGURE 4 is a schematic view of one form of electrical circuitry which we may employ in our electrometer system.

FIGURE 5 is a diagrammatic view illustrating the relationship between copy material charge and time for the various characteristics for which a particular type of copy material is being tested.

FIGURE 6 is a plot of the voltage-time relationship of

the sweep capacitor of the electrical circuit shown in FIGURE 4.

FIGURE 7 is a plot of the display provided by our system for copy material being tested in terms of distance along the display with relation to the material charge.

FIGURE 8 is a plot of the relationship of FIGURE 6 drawn on a nonlinear time scale.

Referring now to FIGURES 1 to 3 of the drawings, the particular form of our apparatus shown therein includes a light shield or housing 10 in which we mount a drum 12 for rotary movement with a shaft 14. The drum 12 is formed of conductive material and is grounded by a conductor 16. Drum 12 is adapted to receive a sheet or length of copy material comprising an insulating base and a photoconductive coating in any suitable manner known to the art. We mount a generally hemicylindrical corona housing 18 grounded by a conductor 20 within the housing adjacent the drum 12. Housing 18 carries a plurality of insulating posts 22 around which a corona wire 24 is strung. Wire 24 extends out to a terminal 26 to which a potential is applied to produce a charge on the material carried by the drum 12. As will be explained in more detail hereinafter, we may apply, for example, a negative potential to the terminal 26.

The electrometer of our system comprises a stationary conductive probe 28 positioned adjacent the surface of drum 12. A shaft 30 carries for rotation therewith a wheel 32 having a plurality of discs or segments 34 of a suitable insulating material held in position around its periphery by a ring 36. Wheel 32 may be formed of any suitable material such, for example, as aluminum, while the discs 34 can be formed of a material such as barium titanate or the like, having a dielectric constant substantially different from unity. We provide a pair of synchronous motors 38 and 40 for driving shafts 14 and 30. With the wheel 32 being driven, whether or not the drum 12 is rotating, movement of the discs 34 between the stationary probe 28 and the surface of the material on the drum 12 produces a signal on conductors 42 and 44 is a measure of the electrical charge on the surface under the stationary probe.

As will be described hereinafter, the drum 12 is driven synchronously with the disc 32 sequentially to perform the desired tests on the material carried by the drum 12. We believe that, assuming the surface charge on the material on drum 12 to be constant, the probe voltage varies owing either to a cyclic variation in effective capacitor plate area or owing to a cyclic variation in dielectric constant between the stationary probe 28 and the charged surface. It is possible that the probe voltage results from a combination of these two factors.

We provide our system with a lamp 46 adapted to be illuminated in a manner to be described to direct light to an optical system comprising lenses 48 and 50 to subject the material on the drum 12 to the influence of light.

In one specific copy material with which our system is adapted to be used, a period of time of approximately 0.4 second may be required for the copy material to acquire a charge of, for example, 240 volts under the action of the corona. This charge may decay about only 10 percent from its initial value in the dark in a period of time of about 6 seconds. Upon exposure to light, the material may substantially lose its charge in only about 0.2 second. We have illustrated the relationship of these characteristics in FIGURE 5. From an examination of that figure, it will readily be apparent that if a picture of the relationship of the characteristics were presented, it would be extremely difficult to determine whether or not the material was within acceptable limits. This is owing to the fact that the slope of the charging portion *a* of the figure and the slope of the light decay portion *b* are extremely steep. At the same time the acceptable dark discharge is so small over a relatively long period of time that it is extremely difficult to measure. Owing to these facts, we have provided a visual representation in which we modify the time base of the display in such a way

as lends greater significance to the various portions of the display with relation to each other.

Referring now to FIGURE 4 of the drawings, the display device of our system indicated generally by the reference character 52 comprises a screen 54 and respective vertical and horizontal input terminals 56 and 58. We feed the output from the stationary probe 28 to an amplifier 60 which is coupled to the input terminal 56 by a resistor 62 and by a variable resistor 64. A normally conductive gating circuit 66 couples the output from buffer amplifier 60 to a storage capacitor 68. When the gating circuit 66 is rendered nonconductive in a manner to be described hereinafter, the output of amplifier 60 and the stored potential on capacitor 68 are compared in a differential amplifier 70, the output of which appears on a resistor 72. This amplified output is connected by a resistor 74 to resistor 64.

The sweep circuit indicated generally by the reference character 76 of our system includes a battery 78 and a capacitor 80 adapted to be selectively connected in series with one of a plurality of resistors 82, 84, and 86 in response to actuation of one of a plurality of respective normally nonconductive gating circuits 88, 90 and 92 to provide a sweep potential at a terminal 94 which is applied to the horizontal deflection input 58 of the display device 52. A normally nonconductive gating circuit 96 is adapted to be rendered conductive in a manner to be described to discharge capacitor 80 at the end of a sweep.

Our system includes a timer 98 adapted to be actuated in response to a signal applied to a reset and start terminal 100 to produce respective output signals on conductors 102, 104, 106, 108 and 110 at various times to be described hereinafter. The signal appearing on conductor 102 at "zero" time is coupled by an OR circuit 112 to the actuating terminal 114 of gate 90 to connect a resistor having a value *R* into the sweep circuit 76 to determine the initial or normal sweep rate of the display device 52. The signal appearing on conductor 104, which also is fed to terminal 114 by circuit 112, is adapted to initiate the measurement of the charge time of the material on the drum 12. Conveniently we select this time to be 0.2 second in a particular example being considered. A conductor 116 applies a signal on conductor 104 to the actuating terminal of a normally nonconductive gating circuit 118 to apply the potential of a battery 120 to a high voltage supply 122 to energize the corona wire 24.

As will be apparent from the discussion advanced hereinabove, the material under consideration, if acceptable, should acquire the desired charge of approximately 240 volts within a period of 0.4 second. We so select the resistance *R* with relation to the capacitance of capacitor 80 as to provide such a normal sweep rate that the rise in potential of the material during the charging time to the desired potential will produce a trace making an angle of about 45° with the horizontal on the screen 54. It will be understood that this trace is for the average acceptable material being tested. The slope of this portion of the trace is selected for ease of interpretation. We have shown such a trace by the portion *d* of the curve in FIGURE 7.

It will readily be appreciated that material being tested may not fall precisely along the line *d* in FIGURE 7 but may require a longer period of time to reach a relatively lower voltage and yet be acceptable. We have indicated the trace produced by such material by the broken line *d'* in FIGURE 7. On the other hand, superior material being tested may acquire a greater charge in a lesser period of time. The trace produced by such material is indicated by the dot-dash line *d''* in FIGURE 7.

From the foregoing, it will be seen that a period of time greater than that required for the normal material to reach the desired charge must be provided to allow for material which is somewhat poorer than normal, though acceptable. For this reason we do not begin our dark

discharge test until a time corresponding to 0.8 second by the appearance of a signal on conductor 106.

At the end of the time during which we measure charging rate, the signal on conductor 104 disappears and a signal appears on conductor 106. Disappearance of the signal on conductor 104 extinguishes the corona and disconnects the resistor R from the sweep circuit. It will be remembered that during the period over which we measure charging time, the output of amplifier 60 was applied to capacitor 68 through gate 66 with the result that capacitor 68 stores the potential to which the paper was charged. When the signal appears on conductor 106 it inhibits gate 66 whereby the output of amplifier 60 which is applied to one terminal of the differential amplifier 70 will be compared with the voltage on capacitor 68 which is applied to the other terminal of the amplifier. The amplified difference between these two signals appears on the output resistor 72.

From the discussion hereinabove, it will be appreciated that the time over which we measure the dark discharge rate should be relatively long as compared with the time for charging the material. For example, we may select a period of time of 0.8 second or twice the time for measuring charging rate. Even having selected such a relatively long time, it will be apparent that no significant result would appear on the screen 54 if the same time base were employed as was used during the charging period. We give significance to this portion of our measurement first by employing the signal on conductor 106 to render gate 88 conductive to connect resistor 82 having a value 2R into the sweep circuit to reduce the sweep rate. Having determined the reduced sweep rate, we so select the gain of amplifier 70 that the normal material will produce a trace having a negative slope of about 45° on the screen 54. Again, this particular slope is selected for ease in interpretation. We have indicated such a trace by the portion *e* of the curve in FIGURE 7. It will readily be understood that we could select a shorter time for this measurement but that would require a higher gain for the differential amplifier. Alternatively, a much longer time could be selected and a corresponding lower gain for the amplifier. It is desirable of course that the test be made in as short a time as possible. With this desideratum in mind, we comprise between the length of time selected and the gain provided for the amplifier to give a normal trace having a negative slope of about 45°.

Of course, the material being tested may produce a trace which does not follow the curve *e* precisely and yet be acceptable. We have illustrated a curve portion *e'* representing a material somewhat poorer than normal owing to the fact that it has a greater dark decay rate than the normal. A superior material having a lower dark decay rate would produce a trace of the type shown at *e''*.

At the end of a measurement of the dark decay rate, the signal on conductor 106 disappears and a signal appears on conductor 108. When the signal on conductor 106 disappears, gate 66 is again conductive and the resistor 2R is out of the sweep circuit. Appearance of a signal on conductor 108 renders gate 124 conductive to illuminate the lamp 46 to expose the material on drum 12 to light. The signal on conductor 108 also connects resistor 86 in the circuit having a value R/4. With gate 66 again conductive, the output of buffer amplifier 60 is applied to the resistor 64 and capacitor 68 merely follows the amplifier output owing to the low output impedance of the latter.

As is pointed out hereinabove, the discharge time with the material in light is extremely short as, for example, 0.1 second. In order to give the display of this decay rate in light some significance, and for ease of interpretation of the trace, we so select the sweep rate as to give the normal material a display having a negative normal slope of 45° as is indicated by the portion *f* of the display as shown in FIGURE 7. A material somewhat poorer than normal in that it had a lower decay rate in light would

produce a trace such as is indicated by *f'* in FIGURE 7. A superior material which lost its charge relatively rapidly would give a trace such as is indicated by *f''*.

At the end of the light discharge rate test, the signal on conductor 108 disappears and a signal appears on conductor 110. This latter signal actuates gate 96 to discharge capacitor 80 to end the sweep. At the same time the signal is applied to a stop portion 126 of the timer 98 to complete the test.

It will be understood that we may, if desired, apply a pattern to the face 54 of the display device to indicate the normal trace, traces indicating the limits of acceptability, or both.

In one specific arrangement which we may employ, capacitor 80 may charge to a voltage V_c of about 10 volts in the course of a sweep. For such a charge we employ a battery 78 having a voltage much greater than 10 volts, such, for example, as 100 volts. FIGURE 6 shows the potential of the sweep capacitor on a linear time basis while FIGURE 8 shows the voltage on a nonlinear time base.

In operation of our system to test electrostatic copy material we first apply a sheet or length of material to the drum 12. Next we energize the motors 38 and 40 to drive the drum 12 and the disc 32 synchronously. We apply a signal to the start section of the timer 98. A signal first appears on conductor 102 and is applied to the gate 90 to connect the resistor 84 in the sweep circuit of the display device 52. At a time corresponding to 0.2 second after the start, a signal appears on conductor 104. This signal also actuates gate 90 to maintain the resistor 84 in the sweep circuit. Conductor 116 applies this signal to the gate 118 to energize the corona wire 24 to apply a charge to the material on the drum 12. As the drum rotates past the stationary probe 28 and as disc 32 rotates, amplifier 60 produces an output signal which is a measure of the charge applied to the material. Within a time of 0.4 second the material should be charged to a predetermined acceptable potential. If the material is normal or standard owing to the output of amplifier 60 applied by resistors 62 and 64 to the terminal 56 of the device 52, there will appear on the screen 54 a line corresponding to the line *d* shown in FIGURE 7. If the material is relatively poor or relatively better, the trace on the face 54 will be similar to the line *d'* or *d''* shown in FIGURE 7.

At a time corresponding to 0.8 second after initiation of the test, the signal on line 104 disappears and a signal appears on conductor 106. When this occurs resistor 82 having a value 2R is connected in the sweep circuit to reduce the sweep rate by about one-half. At the same time gate 66 is inhibited and amplifier 70 compares the potential which had been stored in capacitor 68 with the output of amplifier 60. It will be remembered that when the signal on conductor 104 disappeared the potential was removed from the corona wire 24. Thus we have begun our dark discharge rate test. In the course of this test the normal material produces a trace corresponding to the line *e* in FIGURE 7 while poor and superior materials, respectively, produce traces corresponding to the lines *e'* and *e''*.

At the end of the dark discharge rate test the signal on conductor 106 disappears and a signal appears on conductor 108. Gate 66 is no longer inhibited and the resistor 86, having a value R/4, is connected with the sweep circuit to provide a relatively rapid sweep rate over this portion of the sweep. At the same time gate 124 is rendered conductive to energize the lamp 46 to begin the discharge rate in light test. During this test the amplifier output again is directly applied to terminal 56. A normal material produces a trace corresponding to the line *f* in FIGURE 7, while poor and superior materials, respectively, produce traces corresponding to the lines *f'* and *f''* in FIGURE 7. At the end of the discharge in light test a signal appears on conductor 110 to actuate gate 96 to discharge the sweep capacitor 80. This signal also is ap-

plied to the stop section 126 of the timer. The apparatus is then ready to make another test.

It will be seen that we have accomplished the objects of our invention. We have provided an electrometer system for testing the characteristics of electrostatic copy material in a simple and expeditious manner. Our system permits all significant characteristics of the copy material to be tested in a continuous manner while providing an easily interpreted visual interpretation thereof. The electrometer of our system overcomes the disadvantages of electrometers known in the prior art.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of our claims. It is further obvious that various changes may be made in details within the scope of our claims without departing from the spirit of our invention. It is, therefore, to be understood that our invention is not to be limited to the specific details shown and described.

Having thus described our invention, what we claim is:

1. Apparatus for testing photoconductive copy material including in combination means adapted to be actuated to apply an electrostatic charge to said material, means for measuring the instantaneous charge on said material, means adapted to be actuated to illuminate said material, means for moving copy material adjacent said charging means and said measuring means and said illuminating means, means for actuating said charging means and for deactuating said charging means after a predetermined time, means for actuating said illuminating means, a display device having a variable sweep rate, means responsive to actuation of said charging means for providing a certain sweep rate for said device, means responsive to deactuation of said charging means for providing said device with a sweep rate less than said certain rate and means responsive to actuation of said illuminating means for providing said device with a sweep rate greater than said certain rate.

2. Apparatus as in claim 1 in which said material moving means comprises a first element of conductive material and in which said charge measuring means comprises said first element and a second element mounted in spaced capacitive relation to said first element and movable means for varying the capacitance between said elements at a predetermined rate.

3. An electrometer for measuring the static charge carried by a length of electrostatic copy material including in combination, a stationary probe of conductive material, a conveyor of conductive material for supporting said length of material carrying a static charge, means mounting said conveyor and said probe in spaced relationship with said charge-carrying material between said conveyor and said probe, an element of ferroelectric material having a dielectric constant substantially different from unity, means for moving said element through the space between said conveyor and said probe to vary the capacitance therebetween, means for driving said conveyor to move said charge-carrying material past said stationary probe, and means connected to said conveyor and to said probe for measuring the charge on said material.

4. An electrometer as in claim 3 in which said element is barium titanate.

5. An electrometer as in claim 3 including a plurality of elements of ferroelectric material having a dielectric constant substantially different from unity, said element moving means comprising a disk supporting said elements in spaced relationship around the periphery thereof and means for driving said disk to move the elements through the space between said conveyor and said probe periodically to vary the capacitance between the conveyor and the probe.

6. An electrometer as in claim 5 in which said disk drive means and said conveyor drive means are synchronous.

7. An electrometer for measuring the charge on material carrying a static charge including in combination, a first member of conductive material, a second member of conductive material for supporting said charge-carrying material, means mounting said elements in spaced relationship with said charge-carrying material in the space between said members, an element of ferroelectric material having a dielectric constant substantially different from unity, means for moving said element through the space between said members, and means connected to said members for measuring the charge on said charge-carrying material.

8. An electrometer as in claim 7 including a plurality of said ferroelectric elements, said moving means comprising a disk supporting said elements in spaced relationship around its periphery and means for driving said disk to move said elements successively through said space.

9. Apparatus for testing photoconductive copy material including in combination, first means adapted to be actuated to subject said material to the action of an electrostatic field, second means adapted to be actuated to illuminate said material, timing means for producing a first signal during a first interval and a second signal during a second interval following said first interval after a third interval, means responsive to said first signal for actuating said first means, means responsive to said second signal for actuating said second means and means for measuring the charge on said material during said first and said second and said third intervals.

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RUDOLPH V. ROLINEC, *Primary Examiner*.

C. F. ROBERTS, *Assistant Examiner*.