

March 1, 1955

J. S. SENEY  
MOISTURE INTEGRATOR

2,703,386

Filed Feb. 12, 1952

2 Sheets-Sheet 1

FIG. 1.

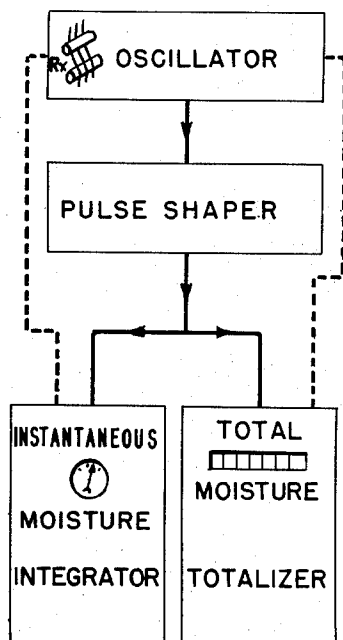


FIG. 2.

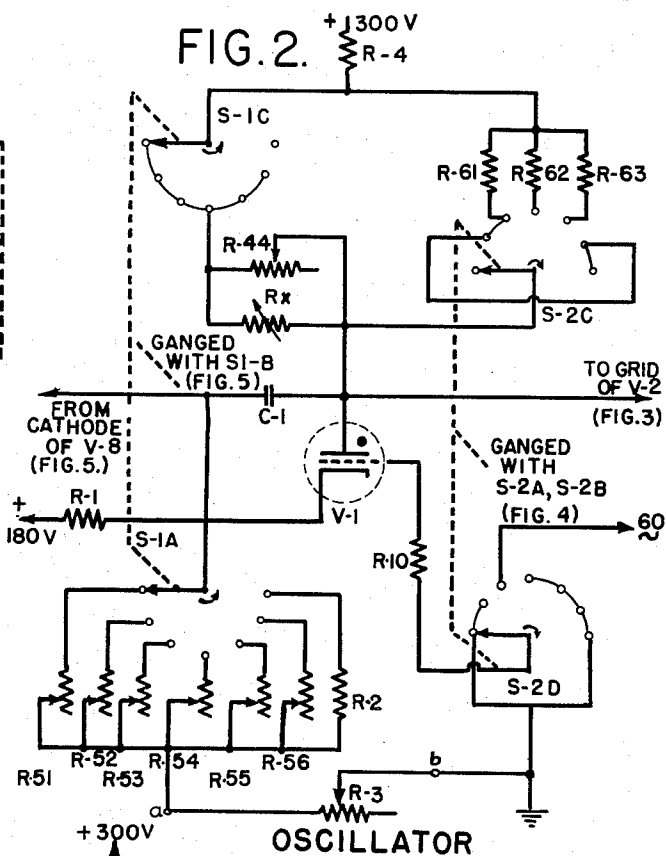
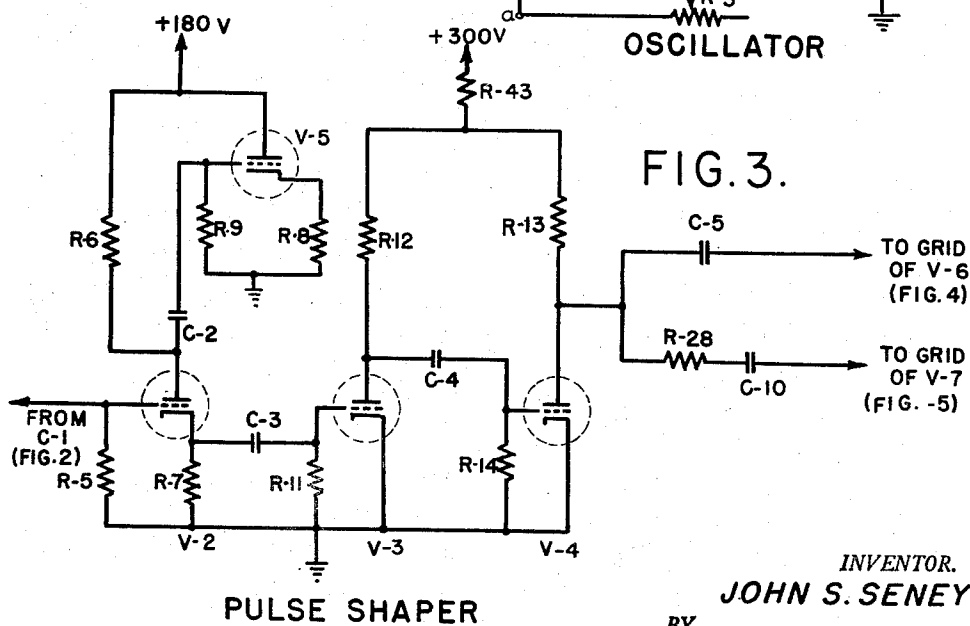


FIG. 3.



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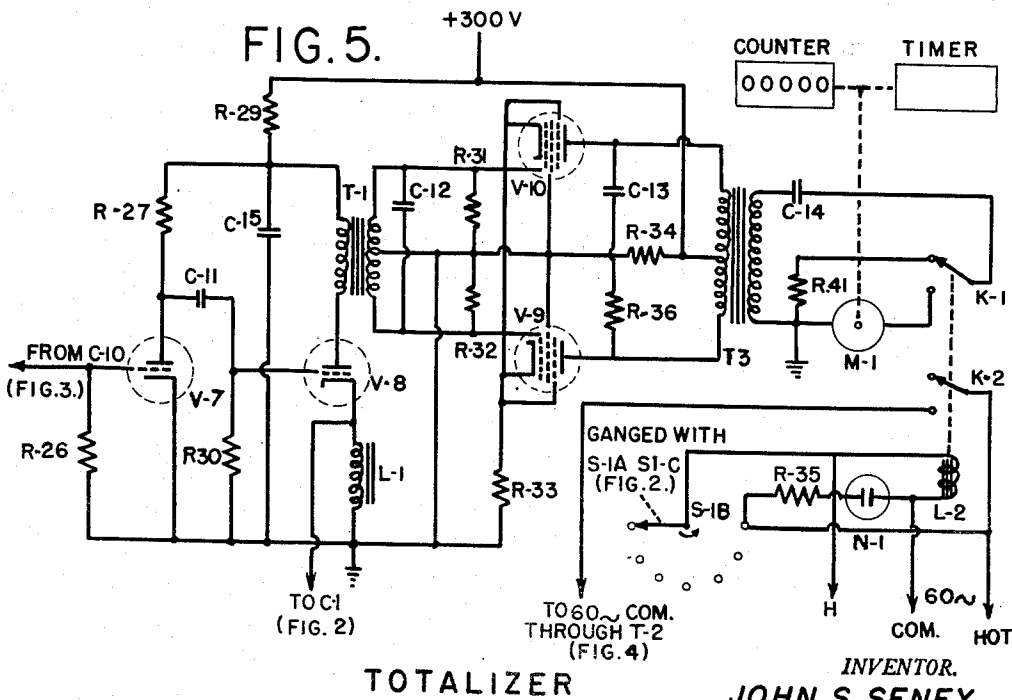
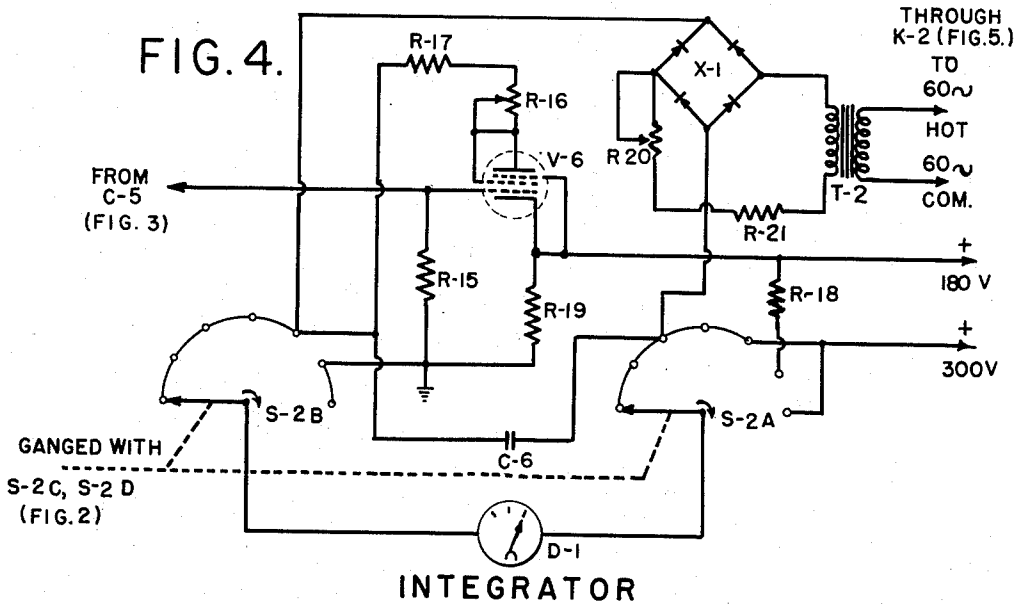
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## MOISTURE INTEGRATOR

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Application February 12, 1952, Serial No. 271,262

6 Claims. (Cl. 324—65)

This invention relates to a moisture indicator for traveling webs. More particularly, it relates to a device for totalling the moisture content of such a web over a predetermined period of time, and for indicating its moisture content at any particular instant. The invention is useful in controlling the moisture content of webs in slashing operations and the like.

An object of the invention is to provide a device of the above type which may be readily installed and operated on commercial slashers or the like.

Another object is to provide an electrical measuring device of the above type which is responsive to the electrical resistance of a web of high-resistance material, such as cellulosic yarns.

Another object is to provide a device of the above type which measures both the instantaneous resistance and the average resistance over a period of time.

Another object is to provide a device of the above type which does not require special operating skill for its use.

A further object is to provide a device of the above type which is responsive to high speed operation.

Various other objects and advantages will be apparent as the nature of the invention is more fully disclosed.

In accordance with the present invention, a continuous measurement is made of the electrical resistance of a portion of a high-resistance web, such as a thread sheet in a slasher, which resistance in turn is a function of its moisture content. For this purpose, the entire thread sheet of the slasher is passed across a pair of stainless steel rolls located behind the last drier can. The rolls are connected in an electrical circuit with a capacitor across which a gas-filled electronic tube is shunted. This capacitor controls the oscillating operation of the gas-filled tube. The capacitor charges sufficiently to fire the tube and then discharges through the low-impedance path within the tube during the ionized period until so low a potential is reached that conduction ceases. Alternating conduction and non-conduction of the oscillator provide an abrupt and cyclical oscillation whose period is a measure of the resistance of the warp sheet and also directly proportional to its moisture content. The oscillator output is amplified and converted electronically into a succession of pulses which actuate two indicator mechanisms one of which, by measuring the average current, indicates instantaneous mean moisture, while the other, by counting the impulses over a period, sums up the moisture content to give an average value. This apparatus represents a decided advance and is an improvement over that disclosed and claimed in my U. S. Patents 2,508,045 and 2,558,392, but it may be similarly adapted to operate only during the time when the web or warp sheet is running, as described therein. The action of the apparatus of the present invention may be more clearly understood by reference to the diagrams, which depict a preferred embodiment in considerable detail.

Figure 1 is a block diagram of the complete apparatus, each block representing a component made up of closely associated elements. To suggest the manner of operation the subject web is shown schematically as resistance  $R_x$  in the oscillator block. As indicated, instantaneous and total moisture values may be shown on direct reading instruments in the integrator and totalizer components.

Figure 2 is the oscillator circuit diagram.

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Figure 3 is the pulse shaper circuit diagram.

Figure 4 is the circuit diagram of the integrator, a component that provides a reading of instantaneous moisture.

Figure 5 is the circuit diagram of the totalizer, a component that provides a record of the moisture summed over a known time interval. Not shown in the diagrams is a power supply from which suitable potentials are obtained for operation of the various components. A person skilled in the art would be familiar with the requisites of power units satisfactory for use with this apparatus.

Four major components make up the block diagram (Figure 1). Solid connecting lines indicate continuity of signal between components, and arrowheads on the lines reveal the direction of flow. Dashed lines stand for mechanical interconnection; here, in both instances, the ganging of switches. Thus, the diagram suggests broadly that an oscillator generates a signal that is modified in some way by a pulse shaper before passing separately to two kinds of measuring components or indicators here called "integrator" and "totalizer." The remaining diagrams present details of these components to show how the indications presented are related to moisture present in material under test.

In the diagram of the oscillator circuit (Figure 2), gas-filled tube V-1 is of the thyatron type. Its plate potential is supplied from the power supply (not shown) through dropping resistor R-4 and switch S-1C in series with the parallel combination of resistor R-44 and resistance  $R_x$ , where  $R_x$  represents the electrical resistance of the material whose moisture is being measured. The reciprocal of  $R_x$  is the mean conductance of the warp sheet. Cathode potential is provided V-1 at the junction of resistor R-1, whose other end connects to the power supply, with the contactor of switch S-1A. In the operating position shown, resistor R-51 leads from S-1A to ground through resistor R-3. Resistor R-10 joins the grid of V-1 to ground through switch S-2D. Capacitor C-1 is located between cathode and plate of V-1. (The heater elements for the cathode of this tube, as well as those for all other tubes, are omitted from the diagrams for the sake of simplicity. They receive appropriate voltages from the power supply.)

Connected in this manner, V-1 acts as a "relaxation oscillator," generating a sawtooth wave at its plate as follows. The grid-to-cathode bias is such that V-1 will not conduct when its plate is below a certain critical potential. Upon the closing of the plate circuit when the instrument is turned on, C-1 is uncharged. As a result of the difference between plate and cathode supply potentials, C-1 rapidly charges, raising the potential of plate with respect to cathode. When the critical ignition potential is reached, current surges through V-1, and the low resistance path through the tube permits C-1 to discharge. As the plate-to-cathode potential across C-1 decreases, conduction continues until a somewhat lower potential than the ignition potential is reached. At this extinction value, the tube ceases firing, and C-1 starts charging again. Cyclic conduction and non-conduction ensue, lowering and raising the plate potential exponentially. The circuit elements are chosen so that the fall in plate potential that occurs when C-1 charges through V-1 is the more rapid portion of the cycle, but the discharging time is also small enough so that both output exponentials are substantially rectilinear. Thus, the wave or series of pulses generated has a serrated or sawtooth form and a repetition frequency characterized by the amount of moisture in the warp sheet. This sawtooth output is applied to the grid of tube V-2 in the pulse shaper (Figure 3). The functions of the other elements of Figure 2 will be explained later.

The pulse shaper, as its name implies, takes the oscillator output and fashions it into forms more suitable for making the instantaneous and total measurements. The input signal appears across resistor R-5 at the grid of V-2, which has resistor R-6 as plate dropping resistor. The output is taken from the cathode of V-2, separated from ground by resistor R-7. Such a cathode follower arrangement is a well known device for preventing succeeding stages from influencing the operation of

a preceding stage. Tube V-5 is present to prevent interaction through the power supply. Its plate is connected directly to the supply source, and it is driven by the signal across resistor R-9 and taken from the plate of the tube through coupling capacitor C-2. Cathode bias is provided V-5 by resistor R-8. Thus, tubes V-2 and V-5 conduct substantially alternately, maintaining a more nearly constant load on the supply source than would be presented if V-5 were not present.

From the cathode of V-2, the sawtooth signal passes to the grid of tube V-3 through coupling capacitor C-3. Resistor R-11 separates this grid from ground. Plate potential is supplied to V-3 through resistors R-43 and R-12. The signal present at the plate of V-3 is trapezoidal, the waveform consisting of a roughly horizontal portion during an appreciable fraction of the rise in the sawtooth grid signal, then falling off gradually as the conduction of V-3 increases progressively at increasing grid potentials. The output from V-3 is sufficient to overdrive V-4, producing a succession of alternating abrupt falls and rises between two fairly definite plate potentials. This type of periodic variation usually is called a square wave. The repetition frequency of this modified signal is the same as the relaxation oscillator frequency. From the plate of V-4, the square wave passes to both remaining components, the integrator and totalizer, separately.

It is the function of the integrator to produce an indication of the instantaneous moisture present in the warp sheet. The square wave output from V-4 is injected at the control grid of remote-cutoff pentode V-6 (Figure 4) through coupling capacitor C-5. Resistor R-15 separates the grid from ground and combines with C-5 to differentiate the square wave, thus forming a series of alternate positive and negative pulses. The suppressor grid of V-6 is connected to the cathode, which has a direct potential applied above biasing resistor R-19, and the screen grid is tied to the plate. In the plate circuit of V-6 are variable and fixed resistors R-16 and R-17, respectively, which lead to the plate supply source through the parallel combination of capacitor C-6 and moisture meter D-1. Switches S-2A and S-2B make the connections between C-6 and D-1, besides serving other functions to be explained later. V-6 clips the negative portion of the input so that its output consists of a series of negative pulses from a moderately positive plate potential. The size of C-6 is chosen with respect to the pulse frequency so that little charge is lost by the capacitor between successive pulses but so that any change in frequency will be reflected quickly in variation of the average potential across it. C-6 thus might be said to "integrate" the signal. As the frequency is an index of the moisture in the material being measured, the meter may be calibrated to read moisture directly. Rectifier X-1, supplied through transformer T-2 and resistors R-20 (variable) and R-21 (fixed), applies an opposing or bucking potential to C-6 so as to expand the useful scale by suppressing the zero moisture end to a convenient extent. This is permissible because zero moisture is not attainable, and low moisture values are found in the warp sheet extremely infrequently.

The square wave produced by V-4 passes through resistor R-28 and coupling capacitor C-10 to appear across resistor R-26 at the grid of tube V-7 in the totalizer component (Figure 5). Plate potential is furnished V-7 through resistors R-27 and R-29. Capacitor C-15 forms a decoupling network with R-29 to prevent reaction of the load variation upon the power supply. The modified square wave output from the plate of V-7 is applied through coupling capacitor C-11 to the grid of tube V-8, which has resistor R-30 as grid resistor. The plate circuit of V-8 contains R-29 and transformer T-1, while the cathode circuit contains choking inductor L-1. The output from V-8 is a roughly symmetrical sawtooth, the plate potential not changing as abruptly as the grid signal because of the inductance present in the plate and cathode circuits. Negative feedback to the grid of V-2, the first amplifier stage, is provided through the lead from the cathode of V-8 in order to prevent oscillation in the amplification system. The secondary of T-1 is center-tapped and grounded; the ends of the winding, bridged by matching capacitor C-12, feeds the grids of tubes V-9 and V-10, which operate as a conventional push-pull amplifier. The respective grid resistors are

R-31 and R-32. Each suppressor grid is connected to its cathode, and the screen grids are supplied with a direct potential through resistor R-34. The pulsating direct-current output is taken off by transformer T-3, whose primary is paralleled capacitor C-13 and resistor R-36 in series. Capacitor C-14 in series with the secondary of T-2 is chosen for maximum power transmission to the motor load.

Except for test purposes, relay coil L-2 is not energized through switch S-1B, which is shown in operating position; instead, the alternating current circuit is completed through lead H, which goes to the hot side of the power line only after passing through another switch (not shown). This omitted switch is closed only while the slasher machinery (with which the measuring apparatus is normally used) is traveling at operating speed. This precaution is necessary to eliminate false readings that otherwise would be made while the slasher is starting or stopping. The magnetic field associated with current through relay coil L-2 actuates contactors K-1 and K-2, connecting synchronous motor M-1 and rectifier transformer T-2 across the line. Rotation of M-1 at a speed determined by the oscillator frequency (which varies from about 35 C. P. S. at 5 percent moisture to 150 C. P. S. at 13 percent) operates a five-dial counter for a full-speed operating time controlled by a timer (details omitted). The timing period is selected large enough to give a good sampling of the yarn wound on any one beam but small enough so that no complete beam will be wound up in a shorter time. At the end of the timed period, the counter reading is an accurate measure of the moisture content of the yarn on the beam. The timer and counter are reset when the operator doffs the beam (mechanism not shown).

As the resistance of a uniform warp sheet varies inversely with the number of yarn ends present, provision has been made for instantly accommodating any of half a dozen different quantities of ends. This is accomplished through switch S-1A (Figure 2) by which the operator selects one of the resistors R-51 to R-56 inclusive as a part of the V-1 cathode resistance, thus adjusting the oscillator frequency to the number of ends in the sheet undergoing measurement. The remaining (seventh) position of S-1A is a test setting, in which fixed resistor R-2 replaces the end-compensating resistor in the cathode circuit. In this test position, switch S-1C breaks the V-1 plate circuit to the warp sheet, and switch S-1B (Figure 5) connects relay coil L-2, completing motor M-1 and rectifier X-1 circuits regardless of slasher speed. By manipulation of ganged switches S-2A through S-2D inclusive, the operator then may easily check the oscillator frequency, moisture meter operation, and power supply potentials.

The only change in operating circuits accomplished by switching to the first position clockwise from that shown for ganged S-2 switches in the diagrams occurs through the action of switch S-2C, which connects resistor R-61 to complete the oscillator plate circuit previously broken when the S-1 switches were put on the test setting. With these connections the oscillator frequency should be the same as the line frequency, here assumed to be 60 C. P. S. Illumination of the rotor of M-1 by neon lamp N-1 reveals stroboscopically whether the oscillator and the motor frequencies are in step. The next (third) position of the S-2 switches changes only the oscillator grid connection by means of S-2D, injecting a 60 C. P. S. signal that positively synchronizes the oscillator frequency to the power line frequency. If the rotor of M-1 appears stationary by the light from N-1, the motor frequency is in accord with the line frequency, indicating proper operation of the motor and the amplifier circuits. The next position returns the grid of V-1 to ground through S-2D and, by the action of S-2C, replaces resistor R-61 by R-62 in the oscillator plate circuit. At this setting, moisture meter D-1 should read at the minimum point on its scale. The next (fifth) position causes S-2C to replace R-62 by a new plate resistor R-63, with which connection D-1 should read full scale. Departure of the meter from either the minimum or maximum position at these respective settings indicates some fault in its operation. The final two (sixth and seventh) settings test the power supply direct potentials; for them, R-61 is restored to the plate circuit, and the operative changes occur in the integrator (Figure 4). In both positions, switch S-2B grounds one end of meter D-1. Switch S-2A in po-

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sition six connects the other end of the meter to the 180 volt lead; in the last position it returns to the 300 volt connection that it assumed for all other positions of S-2A. The meter is provided with special calibration marks on its face corresponding to the two supply potentials.

When controlling the operation of a slasher through which a warp sheet is being passed, as by the moisture-responsive speed control apparatus described in my co-pending application S. N. 271,263, filed February 12, 1952, connection may be made at points *b* and *a* of Figure 2. The short-time average current through resistor R-3 is related to the resistance (and thus to the moisture content) of the warp sheet because the plate load of V-1 includes the warp sheet resistance. As a refinement of the present moisture measuring apparatus, useful to provide automatic compensation for changes in conductivity of sizing solution used in slashers, the circuit between point *b* and ground in Figure 2 may be broken and a conductivity electrode attached to each end of the broken circuit, either with or without an intervening resistor. Connection of the electrodes so that an increase in conductivity of the slasher size, in which the electrodes are immersed, will tend to oppose the potential drop across cathode resistor R-3 may prevent introduction of error that decreased resistance of the warp sheet otherwise would cause in the moisture determination. Suitable electrodes for use with usual textile sizing solutions are described in my co-pending application S. N. 271,263, filed February 12, 1952. Further refinements in the apparatus of this invention will be apparent to those skilled in the art.

What is claimed is:

1. In electrical apparatus for measuring moisture present in a moving web of material having high electrical resistance by determining the electrical resistance of said web and generating a wave frequency-dependent upon said resistance, the improvement comprising totalizing means including a synchronous motor responsive to said wave for summing the number of wave peaks over a period of time corresponding to the period of travel of said web in connection with said apparatus and counter means actuated by said motor for indicating the sum total as moisture content of said web over said period.

2. An electrical moisture-measuring apparatus comprising a gas-filled oscillator tube including in its plate circuit a portion of a moving web and two electrodes spaced in contact therewith so as to render its oscillation frequency dependent upon the electrical resistance of the connected portion of said web; a first indicating circuit responsive to said oscillation frequency for revealing the moisture content of the portion of said web at the time of its connection into said plate circuit, comprising electronic integrator means responsive to said frequency, including a capacitor for integrating the resistance of a portion of said web and shunt meter means for indicating the potential across said capacitor as moisture content of said portion; and a second indicating circuit responsive to the number of oscillations in a time period for summing the absolute amount of moisture in the portions of said web contacted during said period comprising the totalizing means of claim 1.

3. In electrical apparatus for determining the moisture content of a traveling web, the combination of a saw-tooth generator including a gas-filled electronic tube having at least cathode and plate circuits, one of which includes a portion of the web whose moisture content is to be determined, and a grid circuit, said tube having connected between its plate and cathode a capacitor; connected to the plate of the said saw-tooth generator a pulse shaper including a cathode-follower stage and a square-wave generator actuated by the saw-tooth output from said cathode follower; an integrator including a differentiating circuit responsive to the output of said square-wave generator, a clipper stage to remove the negative

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input pulses from the output of the differentiating circuit, having in its plate circuit the parallel combination of a capacitor and an indicator responsive to the short-term average potential established across the capacitor by the output pulses from said clipper stage and thus indicative of the moisture of that portion of the web included in the plate circuit of said gas-filled tube; and a totalizer including at least one shaping stage to convert the output of said square-wave generator to a symmetrical saw-tooth, a power amplifier connected to said shaping stage, a synchronous motor responsive to the output of said power amplifier, and a counter operated by said motor to sum the increments of moisture contained in said web.

4. In an electrical system for measuring the moisture of a traveling web, the steps of charging a capacitor through a circuit including a portion of the web by connection through electrodes spaced in contact with the web and discharging the capacitor through a gas-filled electronic tube fired by application of the potential across said capacitor between conducting elements of said tube, converting the resulting saw-tooth wave present at one of said elements to a square wave of corresponding frequency by passage through at least one electronic tube stage, producing from said square wave a series of alternating positive and negative pulses, clipping one kind of said pulses from said series of pulses, varying the potential across a capacitor by applying to it the remaining pulses, indicating on an indicator connected across said capacitor the short-term average potential between its plates as indicative of the instantaneous moisture content of said portion of the web, also converting said square wave to a symmetrical saw-tooth wave, amplifying said symmetrical saw-tooth, operating a synchronous motor with said symmetrical saw-tooth, and actuating a counter with said motor so as to record the total moisture of all portions of said web successively connected in the said circuit over a selected period of time.

5. The apparatus of claim 2, including also a stroboscope lamp actuable at known frequency and, in adjunct to the oscillator tube, switch means for removing the web from the oscillator plate circuit and inserting a fixed resistor having a resistance of such value as to produce oscillation at the same frequency as the stroboscope frequency, so as to permit detection of abnormal operation by observation of motion of the synchronous motor by the illumination from the stroboscope lamp.

6. The apparatus of claim 5, in which the oscillator tube has a grid element actuated by a signal at the known frequency of the stroboscope to synchronize the frequency of oscillation.

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