Nov. 10, 1953 L. W. ZABEL ET AL 2,659,048

INDICATING AND RECORDING EQUIPMENT

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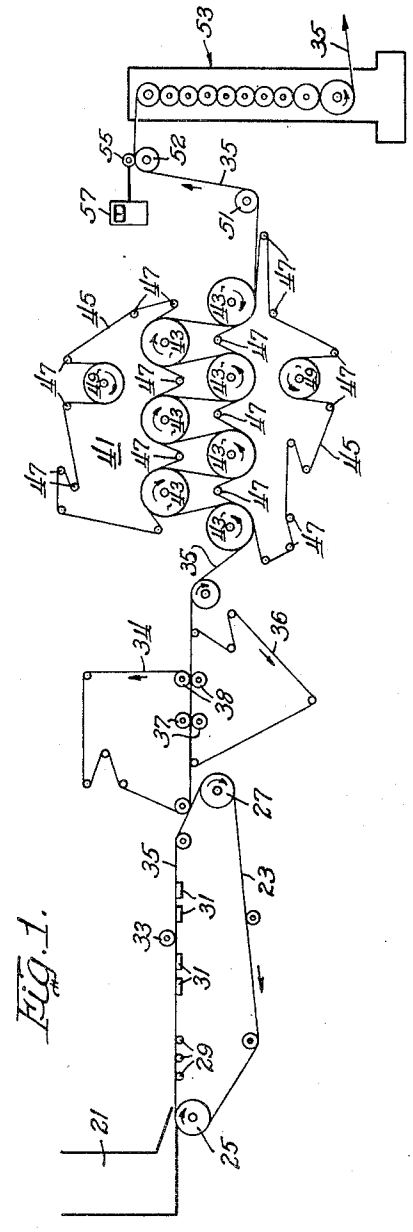


Fig. 1.

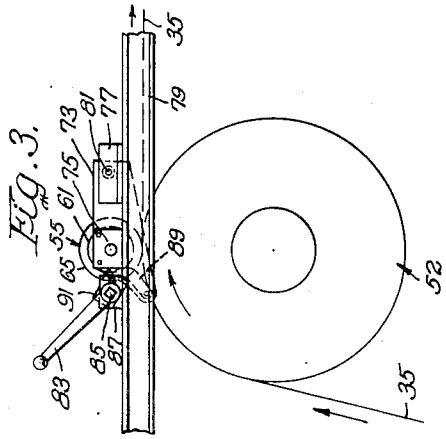


Fig. 3.

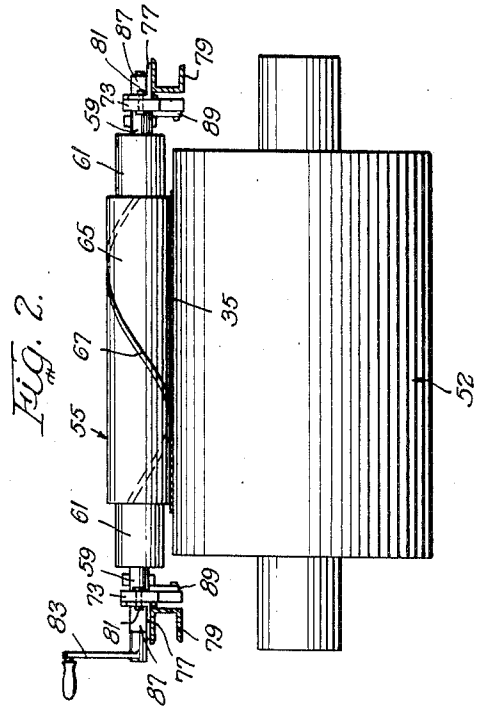


Fig. 2.

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Fig. 4.

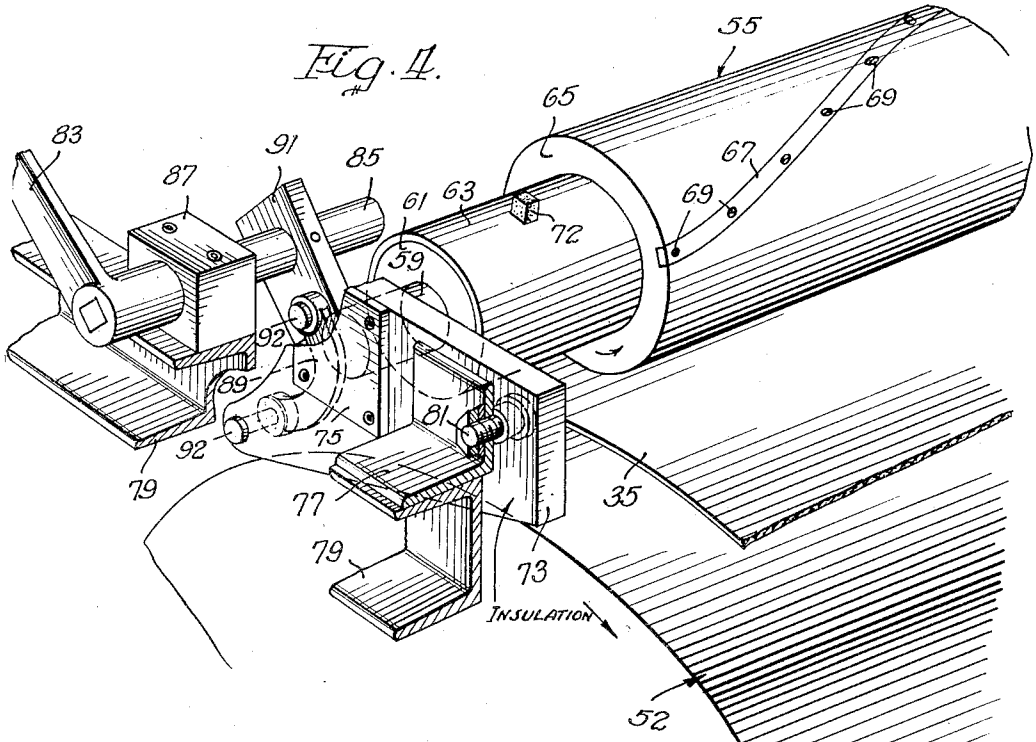


Fig. 5A.

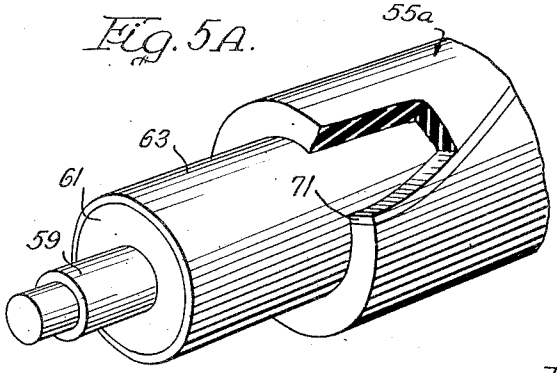
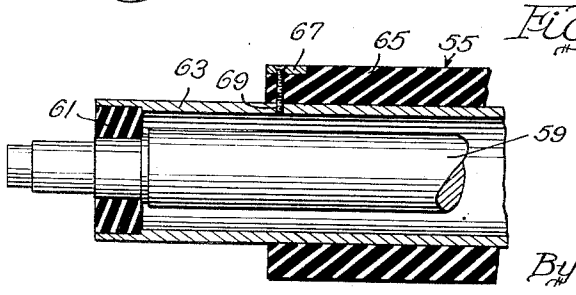


Fig. 5.



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Fig. 6.

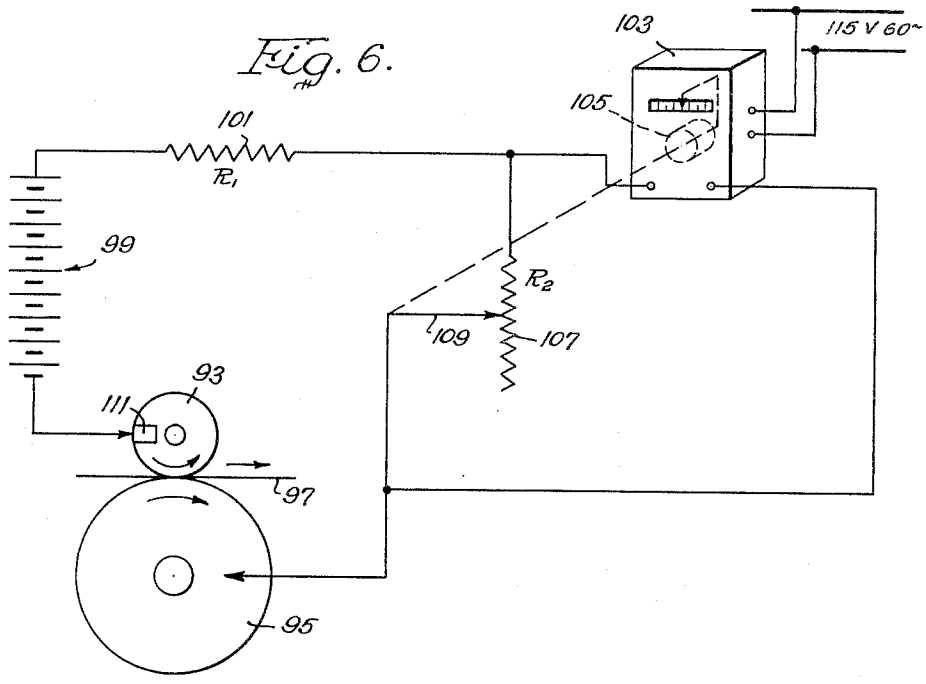
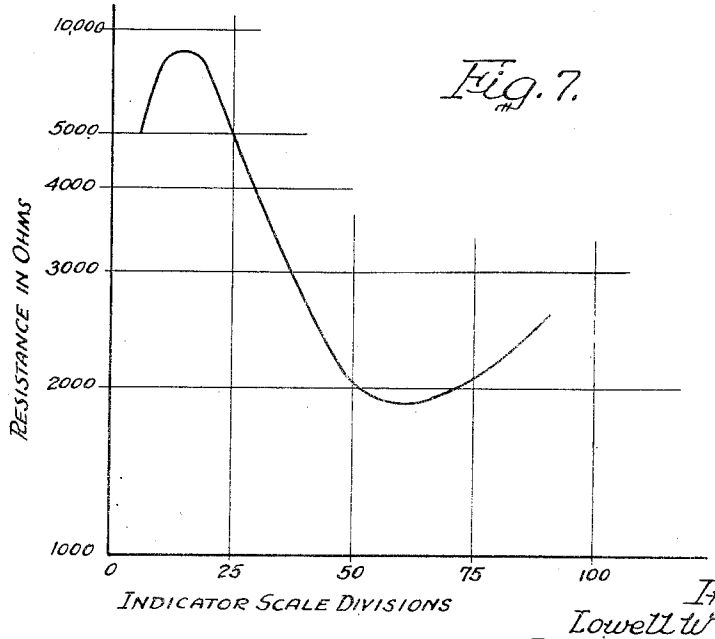


Fig. 7.



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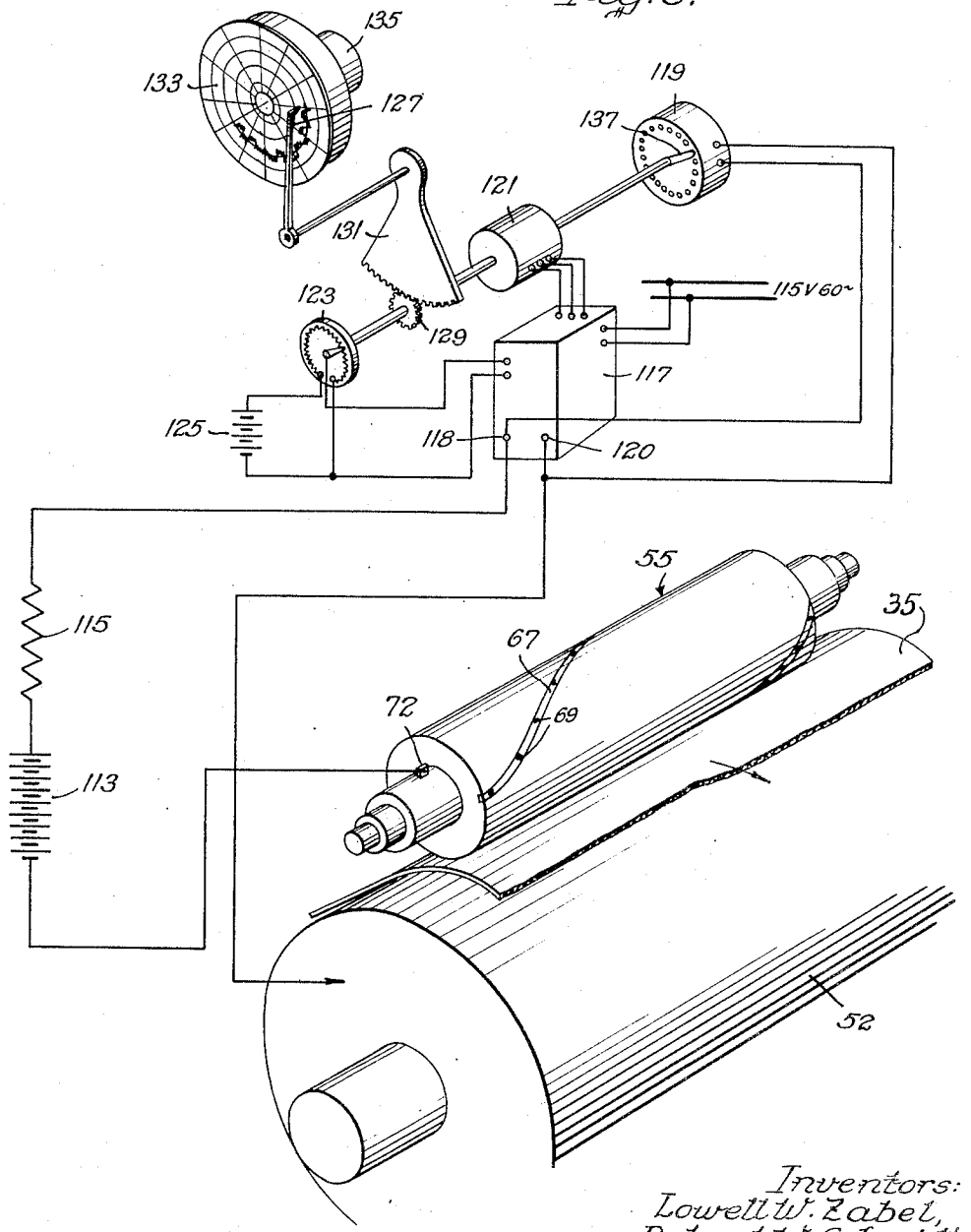
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INDICATING AND RECORDING EQUIPMENT

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Fig. 8.



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Fig. 10.

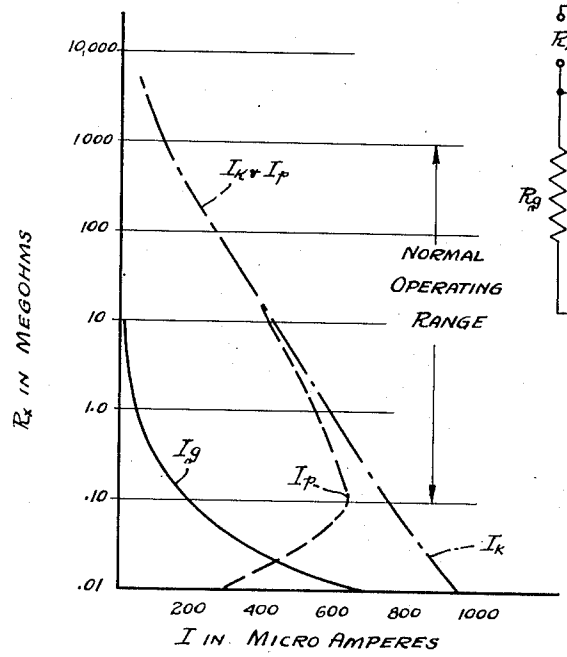


Fig. 9.

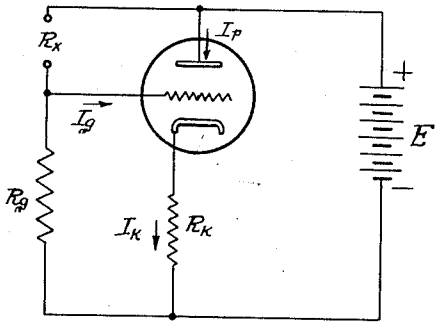


Fig. 12.

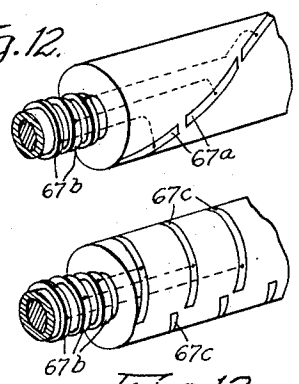
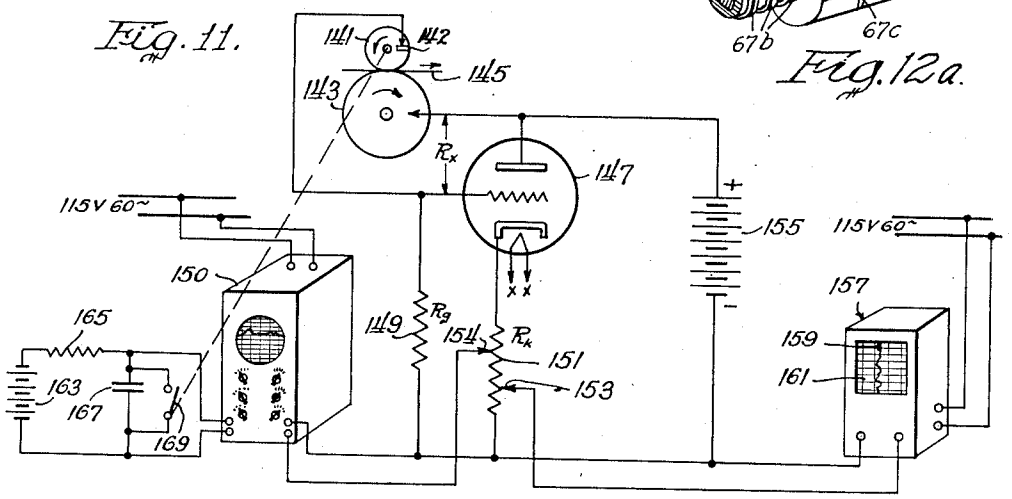


Fig. 12a.

Fig. 11.



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UNITED STATES PATENT OFFICE

2,659,048

INDICATING AND RECORDING EQUIPMENT

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Application February 3, 1948, Serial No. 5,986

9 Claims. (Cl. 324—65)

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The present invention relates particularly to apparatus for measuring the moisture content of a web of paper, either while such web is being manufactured on a papermaking machine, or as a subsequent operation.

In the manufacture and processing of various types and grades of paper, the quality of the paper and the efficiency of the operation are both closely related to the moisture content of the paper web. To obtain the best possible results, it is very desirable that the machine operator be informed at all times regarding the moisture content of the web being manufactured or processed, and it is also desirable that the operator be able to ascertain the moisture content at various positions across the web. As a result, various devices and instruments have been developed for determining the moisture content of paper webs, but the arrangements heretofore available and used in the papermaking art have been of a somewhat makeshift character and have been generally unsatisfactory. Of particular importance in this connection, the results obtainable from the use of the known devices have either been very difficult of interpretation or have been unreliable.

There is, therefore, an existing need in the papermaking art for apparatus which is capable of accurately measuring and indicating the moisture content of a paper web as it is manufactured on a papermaking machine, or as it is passed through a converting or other processing machine, and the provision of improved apparatus for this purpose constitutes the principal object of the present invention.

It is also an object of the invention to provide a simple, efficient means for measuring the average moisture content across the width of a moving web of paper, and for indicating and recording this measurement, all as a continuous operation. Further objects of the invention include the provision of means for determining, continuously, the instantaneous variation in moisture content of a paper web across the width of such web and for making available a continuous indication of this variation during the operation of the papermaking machine.

Other and more detailed objects of the invention include the provision of improved indicating and recording equipment, particularly adapted for use in connection with moisture indicating systems in accordance with the principal object of the invention, and also the provision of a novel scanning or sensing roll, especially useful in connection with the indicating and recording

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equipment of the present invention. Various features of the invention and certain illustrative embodiments thereof will be made more apparent in the following description and the accompanying drawings, wherein,

Fig. 1 is a diagrammatic view of a Fourdrinier papermaking machine equipped with moisture indicating and recording apparatus in accordance with the invention;

Fig. 2 is a front elevational view showing a scanning or sensing roll in accordance with the invention, applied to a papermaking machine of the general type illustrated in Fig. 1;

Fig. 3 is a side elevational view of the mechanism illustrated in Fig. 2;

Fig. 4 is a fragmentary, perspective view illustrating the features of the support and lifting means for the scanning roll illustrated in Figures 2 and 3;

Fig. 5 is a sectional view showing certain of the features of the scanning roll illustrated in Figures 2–4 of the drawings;

Fig. 5*a* is a fragmentary, perspective view of a modified scanning roll of the general type illustrated in Figure 5;

Fig. 6 is a circuit diagram of a moisture content indicating system embodying some of the features of the present invention;

Fig. 7 is a graph illustrating the manner in which one of the resistances shown in the circuit of Figure 6 is varied in order to obtain a linear response characteristic in the indicating instrument;

Fig. 8 is a diagrammatic illustration of a practical embodiment of the circuit illustrated in Figure 6;

Fig. 9 is a circuit diagram of an electronic circuit which is particularly suited for use in a moisture indicating and recording apparatus in accordance with the invention;

Fig. 10 is a graph illustrating the electrical characteristics of the electronic tube circuit illustrated in Figure 9;

Fig. 11 is a diagrammatic illustration, generally similar to Figure 8, showing the features of a moisture indicating and recording system employing the electronic circuit of Figure 9;

Figure 12 is a fragmentary perspective view of another modified form of scanning roll; and

Figure 12*a* is a fragmentary perspective view of still another modified form of scanning roll.

It is a known physical fact that the variation of the electrical resistance of a web (or sheet) of paper constitutes an accurate measure of the variation in moisture content of that web. For

any particular grade or type of paper, the electrical resistance of the web changes approximately logarithmically with linear change in moisture content for a wide range of moisture contents, and this inherent characteristic of paper is utilized in practicing the present invention.

Generally stated, the apparatus of the present invention includes means for continuously measuring and indicating, and for recording, if desired, the electrical resistance of a moving web of paper. The measuring and indicating means of the invention provides an approximately linear indication in response to variation in the moisture content of the web with which it is used. This obviates many of the difficulties experienced with the non-linear indicating means of the prior art and greatly facilitates the interpretation of the readings obtained. The apparatus of the invention includes a novel scanning or sensing means whereby it becomes possible to determine both instantaneous and average variations in moisture content across the width of the web. The feature of the invention makes possible the practical utilization of cathode ray oscilloscopes for obtaining a continuous, instantaneous indication of moisture content variation across the width of the web.

In Figure 1 of the drawings there is illustrated, in generally diagrammatic form, a Fourdrinier papermaking machine of conventional type. This machine includes a head box 21, or other means, for delivering the stock to the wire, a Fourdrinier wire 23 which is supported at its ends by the usual breast and couch rolls, 25 and 27, and which may be supported intermediate its length by suitable table rolls, three of which are illustrated at 29. Suction boxes and like means for facilitating the drainage of the web are indicated at 31, and a dandy roll is shown at 33. The formed paper web 35 is removed from the wire 23 and is conducted through press rolls, two pairs of which are indicated at 37 and 38 by means of suitable felts 34 and 36. After leaving the press rolls, the web 35 is conducted through the one or more drier sections, an illustrative unit of which is shown at 41.

The drier section 41 is of conventional design and includes a series of heated drier rolls 43, and a pair of felts 45 which are arranged to press the paper web 35 into contact with the drier rolls. Each of the felts 45 is supported by suitable guide and tightening rolls 47, and the apparatus may include one or more pony driers, as illustrated at 49. As previously noted, a plurality of drier sections, similar to the drier section 41, may be used in accordance with conventional paper manufacturing practice. In the illustrated apparatus, the dried web 35, after leaving the drier 41, is conducted over suitable guide rolls 51 and 52 to a calender stack, illustrated at 53. The calender stack 53 is of conventional design and after passage therethrough, the now dried and calendered web 35 is conducted to suitable reeling mechanism, not shown.

It will be understood that the disclosure in the drawings of a multiple cylinder type drier is merely illustrative. Should the machine be manufacturing a thin, creped, cellulosic sheet, a Yankee type drier would be used, and for the purposes of this invention, the particular drier used is not important.

Moisture indicating and recording apparatus in accordance with the present invention is embodied in the papermaking machine illustrated in Figure 1. This apparatus includes a scanning or sensing roll, illustrated diagrammatically at 55, and a moisture recording and indicating instrument, illustrated diagrammatically at 57.

The features of the scanning or sensing roll 55 are shown particularly in Figures 2 through 5. The function of this roll is to provide a scanning electrode or contact which, in effect, moves across the web of paper as it is manufactured on the machine, thereby providing means for continuously determining the electrical resistance and the moisture content across the moving web. The scanning roll 55 includes a central core 59 of steel shafting or other suitable rigid metal. An insulating ring 61 is disposed at either end of the central shaft 59, and these rings 61 serve to support a metallic tube 63, which in turn serves as the support for an insulating sleeve 65 which provides the roll surface.

The insulating sleeve 65 should be manufactured of material having very high insulation resistance, such as rubber, a reinforced phenol-formaldehyde resin of known type, or any other suitable material, and in the illustrated embodiment of the invention, a strip 67 of conducting metal, such as brass or copper, which is bent in a generally spiral form, is attached to, and recessed in, this sleeve, as illustrated. The spiral metallic strip 67 makes one complete turn about the surface of the scanning or sensing roll 55, and it is anchored in place and electrically connected to the inner sleeve 63 by means of a plurality of spaced screws or studs 69, as shown. Desirably, the surface of the insulating sleeve 65 and the spiral electrode 67 are ground smooth and flush with each other to provide a proper roll surface. In one practical embodiment of the invention, the scanning roll 55 had an overall length of about 46 inches, and a maximum external diameter of 5½ inches. The insulating sleeve 65 in this roll had a width of 28 inches and a uniform thickness of ¾ inch, and was fabricated of a moderately soft rubber compound. This roll was designed for use with a papermaking machine manufacturing a web 30 inches wide. Generally, the width of at least the scanning electrode should be less than the width of the web with which it is used.

In certain instances, a strip of conducting rubber compound can be substituted for the metallic electrode strip 67 described above. Also, as illustrated in Figure 12, the electrode strip can be divided into sections 67*a*, each of which is connected to a collector ring or to a commutator segment 67*b* at one end of the roll. This construction makes it possible to obtain a series of sensings from a particular section or sections of the web. Alternatively, as illustrated in Figure 12*a*, a series of short 360° spiral sections 67*c* can be used to advantage in certain instances.

A further modified construction of the scanning or sensing roll is shown at 55*a* in the fragmentary view Figure 5*a*. In this construction, the conducting electrode in the surface of the roll is provided by a solid, generally radially extending fin 71, of brass or bronze or other conducting material, which is welded or otherwise affixed to the conducting sleeve portion 63 of the roll in a manner similar to the flight of an auger conveyor. The electrode 71 is thus in the form of an up-ended strip and is shaped so as to provide one spiral turn around the roll surface. The insulating sleeve or roll cover 65 is applied to the tubular portion 63 with the conducting strip 71 in place, and as in the previous described construction, this portion of the roll should be manufactured of a material having high insulation

value. After the roll covering operation, the surface of the roll should be turned down and ground to provide the proper smooth surface.

During use, the scanning or sensing roll is supported parallel to, and adjacent one of the driers or some other roll in the paper machine, and the web of paper which is to be subjected to a moisture determination test is passed through the nip formed between the scanning roll and this cooperating roll. Electrical contact to the spiral electrode is conveniently made by a brush contact 72 which contacts the sleeve portion 63 of the scanning roll, as illustrated in Fig. 4. In the paper machine illustrated in the drawings, the scanning roll 55 is supported directly above one of the guide rolls 52, preceding the calender 53. It will be understood that the scanning roll 55 can be disposed in cooperative relation with one of the drying cylinders 43, with one of the metallic rolls in the calender stack 53, or in any other location where moisture content determination might be desired. The essential feature is merely that the strip of paper to be tested shall be passed through a nip provided by the scanning or sensing roll and a cooperating roll which has a conductive surface.

To obtain fully reliable, reproducible results, it has been found necessary to maintain moderate pressure along the line of engagement of the scanning roll and the roll which cooperates therewith to provide a sensing region for the paper web. Generally, a linear pressure at the nip of these rolls of the order of about five pounds per linear inch is satisfactory. Also, in order to permit convenient threading of the machine, it is desirable that the scanning roll shall be movable out of engagement with its cooperating support or drier roll.

In the illustrated apparatus, the support means for the scanning roll 55 includes a pair of support members 73, which have the general outline illustrated in Figures 3 and 4. The support arms 73 are manufactured of insulating material and each is provided with a bearing support 75 for receiving one end of the scanning roll shaft 59. Each of the support members 73 is pivoted to an angle bracket 77 attached to the main frame 79 of the paper machine by a suitable pin 81. In order to move the support members 73, and with them the scanning or sensing roll 55, there is provided a crank 83 having a shaft 85 which extends transversely of the machine and which is supported upon suitable bearings 87 attached to the machine frame 79. The shaft 85 and the crank 83 are operatively connected to the unpivoted end of each of the roll support members 73 by means of two bell crank levers 89, two short cranks 91, each of which is keyed to the cross shaft 85, and suitable pins 92 (Fig. 4).

It will be evident that rotation of the main crank 83 and the shaft 85 will raise or lower the unpivoted end of the roll support members 73, and thereby raise and lower the scanning rolls 55 relative to the cooperating support roll 52, as desired. The weight of the scanning roll 52 is usually sufficient to produce the desired nip pressure, under normal operating conditions, but if additional pressure is required, this can be accomplished by applying a suitable torque to the cross shaft 85.

In Figure 6 of the drawings, there is illustrated, diagrammatically, a circuit which can be used in conjunction with a scanning roll as above described for the purpose of measuring the moisture content of a moving web of paper. In this diagram, a scanning roll 93, which may be similar to the roll 55, is illustrated in contact with a cooperating roll 95, which may be of somewhat larger diameter than the scanning roll and which is of conducting material, at least on the surface thereof. A web of paper 97 is shown as passing between the nip of the rolls 93 and 95. The spiral contact or electrode 111, constituting a part of the scanning or sensing rolls 93 is electrically connected to one end of a battery 99 or other source of direct current potential; the other end of the battery 99 is connected through a protective resistance 101 to one side of an indicating and recording instrument 103, which includes a galvanometer type response element and a motor-driven pen mechanism, indicated at 105, which is powered from a 115 volt, 60 cycle source, as illustrated, and which is controlled by the galvanometer element. This same terminal of the indicating and recording instrument 103 is also connected to one side of a variable resistor 107 having a movable contact 109, which is adapted to be moved in response to movement of the motor-driven mechanism 105 for the recording pen. The other terminal of the recording instrument 103 is connected to the movable contact 109 of the variable resistor 107 and also to the cooperating roll 95.

The circuit of Figure 6 is operable to measure the resistance of the segment of paper which is between the spiral electrode 111 and the surface of the cooperating roll 95 at any particular instant, and it will be apparent that the segment of paper under test moves progressively across the web surface during each revolution of the scanning or sensing roll 93. Of course, if measurement across the width of the web is not desired, the sensing electrode can comprise a simple narrow disc or roller which contacts the web at a fixed point; the circuit will operate with any type sensing means. Excluding the sensing means, the circuit illustrated in Figure 6 differs from known resistance-type ohmmeter circuits by the use of a variable shunt resistance, such as resistance 107, which is arranged to be varied in response to movement of the motor driven operating means for the indicating and recording pen of the instrument 103. Ordinary series resistance ohmmeter circuits have a substantially logarithmic response in the mid-portion of the scale, and in instances where the moisture and resistance variations in the paper are very slight, it is conceivable that it might be possible to measure and record the resistance of such paper continuously by the use of an ordinary series instrument. However, under practical operating conditions, the resistance of a paper web may vary over a ratio of 10,000 to 1, or even greater, resistance values from .10 megohm to 1000 megohms being commonly encountered in the operation of the average paper machine. This variation is obviously far beyond the range of even approximate logarithmic response in ordinary series resistance ohmmeters, and as part of this invention, we have provided a resistance-type ohmmeter of novel design which is capable of a substantially logarithmic response for very large variations in resistance. Such an instrument makes possible a substantially linear indication over the entire range of moisture contents consistent with the resistance range given above, and thereby overcomes many of the difficulties of the prior art equipment.

More specifically, we have discovered that if a series resistance type ohmmeter is provided

with a shunt-resistance across the galvanometer indicating element or the galvanometer control for the indicating element, which resistance is varied continuously in response to movement of the instrument indicating means, the desired logarithmic response over a very wide ratio of resistance values can be obtained. In the circuit, as illustrated in Figure 6, where the resistance R_1 or 101 is a protective resistance in series with the galvanometer element, and the variable resistance R_2 or 107 is connected in shunt of the galvanometer element, it can be shown that the instrument 103 will respond logarithmically for wide variations in resistance across the test electrodes, whether provided by the rolls 93 and 95 or otherwise, if the shunt resistance R_2 is varied in accordance with the following formula:

$$R_2=\frac{(R_1+R_x)\ (\log R_x-b)}{mE-\log R_x-b}$$

where b and m are constants, depending on the slope and intercepts of the desired curve and the voltage range of the measuring instrument, E is the battery voltage, and R_x is the resistance of the paper or other material under test.

It is desired that the indication of the instrument shall be directly proportional to the logarithm of the resistance of the paper. Since the instrument actually measures a voltage, e, this linear relationship may be represented by $\log R_x=me+b$, where R_x is the paper resistance and m and b are constants. If we decide to let a voltage e_1, near the lower end of the instrument scale represent a value R_{x1}, at the upper end of the desired range of R_x and if we decide to let a voltage e_2 near the upper range of the measuring instrument corresponding to a value R_{x2} near the lower end of the desired range of R_x then we may write:

$$m=\frac{\log R_{x1}-\log R_{x2}}{e_1-e_2}$$

$$b=\frac{e_1 \log R_{x2}-e_2 \log R_{x1}}{e_1-e_2}$$

The graph, Figure 7, shows a curve derived by the use of the above formula for a particular instrument in which the variation in the resistance R_2 was between a low value of about 1900 ohms and a high of around 9000 ohms. Since it is inconvenient to provide a slide wire resistance which is capable of varying in accordance with a curve such as is illustrated in Figure 7, it will be found most convenient to use a tapped point resistor, so arranged that an approximation of the curve will be obtained. Normally, about 40 points will be found sufficient to produce a substantially uniform response in the instrument. It will also be understood that response characteristics other than logarithmic can be accomplished by suitable variation in the shunt resistance. So long as the slope of the desired response curve is positive, almost any reasonable response characteristic can be obtained.

It will be apparent that the operation of a circuit as shown in Figure 6 (where the shunt resistance R_2 is caused to vary in accordance with the curve shown in Figure 7, in response to movement of the instrument indicating means) will make possible substantially linear indication of the moisture content of a web of paper which is passed between the test electrodes provided by the scanning roll 93 and the support roll 95, and a complete system of this character is shown in somewhat more detail in Figure 8. In that figure, the scanning or sensing roll 55, previously described, is illustrated in cooperative relation with the support roll 52, and the web of paper 35 which is to be tested is shown as passing between the nip provided by these rolls. One side of a battery or other source of direct current potential 113 is electrically connected to the spiral test electrode 67 in the surface of the scanning roll 55, this latter connection being made by the brush 72, although other arrangements can be used. The other side of the battery 113 is connected to one end of a series protective resistor 115. The other end of the protective resistor 115 is connected to one of the input terminals 118, of a sensitive, motor control unit 117, which constitutes a part of the indicating and recording instrument. A multipoint variable resistor 119 is connected across the input terminals 118 and 120 of the motor control unit 117, so as to place the variable resistor 119 in shunt with that unit.

The terminal 120 is also connected to the support roll 52 by suitable means (not specifically shown). The motor control unit 117 may be of known type and may include a sensitive galvanometer control, or a balance unit, and switching means which is operable upon the application of a signal potential to the input terminals 118 and 120 to effect energization of a reversible motor, 121, in a direction which is determined by the direction of the signal potential. The motor 121 is arranged to operate a balancing potentiometer 123, energized from a suitable potential source 125, and this potentiometer is used to provide a potential for balancing the signal potential. Whenever the galvanometer unit 117 is thrown out of balance, the motor 121 is operated and continues to operate until the potentiometer 123 brings the galvanometer into balance. Since the motor 121 is also geared to a combination indicator and recording pen mechanism 127 through a suitable pinion 129 and a segmental gear 131, operation of the motor to balance the galvanometer also actuates the indicating and recording means. The indicator and recording pen 127 coacts with a circular record chart 133 which is driven by a time clock 135.

In accomplishing the indicating and recording function by the use of a balancing, motor actuated potentiometer, the apparatus is in accord with prior practices. However, the equipment illustrated in Figure 8 also includes the multipoint variable resistor 119 which is connected across the input terminals of the galvanometer control unit, and the reversible motor 121 is mechanically connected to operate the moving contact 137 of this resistor in unison with the balancing potentiometer 123 and the indicating and recording pen 127. The resistance 119, similar to the resistance R_2 in Figure 6, is designed to effect variation in the shunt resistance in accordance with the curve shown in Figure 7, and as a result the response of the instrument becomes linear with response to moisture content. During actual operation of the apparatus, movement of the sheet of paper 35 under test between the rolls 52 and 55 effects rotation of the scanning roll 55, and a signal potential which is determined by the constants of the circuit and the resistance of the particular segment of the paper web which is between the spiral electrode 67 and the conducting surface of the cooperating roll 52 in each particular instance is transmitted to the sensitive, galvanometer type, motor control

unit 117 of the instrument. By suitable dampening of the motor control and the indicating and recording means, with reference to the speed of rotation of the scanning electrode 67, the instrument can be operated to provide an indication which is a very close approximation of the integrated variation in moisture content across the web under test.

Galvanometer-type motor control units capable of producing full scale response of the indicating means with an applied potential of about 200 millivolts have been used successfully for paper moisture measurements in circuits, as described above, having a battery potential of about 105 volts in the test electrode circuit. The protective resistance 115 in this circuit had a resistance of 1,000,000 ohms, and the shunt resistance 119 varied from 1430 ohms to 9520 ohms during operation.

The variable shunt resistance unit 119, as above described, makes possible the practical operation of a shunt-type ohmmeter to provide a substantially logarithmic response for resistance changes which vary in the ratio of 10,000 to 1, or even higher. As above noted, it is also possible by further variation and modification of the shunt resistance characteristics to produce other types of response in the indicating portion of the instrument. The arrangement, however, requires a substantial amount of equipment and is subject to certain minor operational difficulties. For these reasons, it is desirable, in certain instances, to utilize an electronically controlled indicating and recording mechanism in place of the electromechanical structure previously described. In Figure 9, there is illustrated an electronic circuit which can be used for the measurement of resistance and which, when properly designed, is capable of providing a substantially linear current or voltage output in response to logarithmic variation in a resistance connected in the position R_x of the circuit. This response characteristic of the circuit pertains for resistance values which may vary in a ratio of as much as 100,000 to 1, and the circuit is therefore particularly suitable for use in the determination of the moisture content of paper webs. Preferably, the circuit of Figure 9 utilizes a high amplification factor triode, such as the tube manufactured and sold under the designation 12F5, although other triodes and triode connected multiple grid tubes can also be used. When the circuit is being used for the determination of moisture content in a paper web, where resistance values from the order of .10 megohm to 1000 megohms, or even higher, are normally encountered and a 12F5 triode is employed, it will be found desirable to use a voltage E of the order of about 75 volts with a resistance in the grid circuit, the resistance R_g of about 2500 megohms and a cathode resistance R_k of the order of about .500 megohm.

The graph, Figure 10, illustrates the current variation in the several branches of the Figure 9 circuit for various values of resistance in the R_x position. In this graph the resistance R_x is plotted on a logarithmic scale whereas the current values are plotted on a linear scale. It will be noted that the cathode current I_k varies as a substantially linear function, inversely with the logarithm of the resistance R_x. The cathode current I_k, and hence the voltage drop across the cathode resistor R_k, is determined by the sum of the plate current I_p and the grid current I_g. For values of R_x below about 10 megohms, the grid current becomes increasingly important as determinative of the total cathode current, whereas for values of R_x over 10 megohms, the grid current becomes almost negligible. The grid potential is determined by the series relationship of R_x and R_g, the two resistors acting as a voltage divider.

It will be seen that the cathode current I_k approaches a limiting minimum value as R_x is increased, and it can be shown that the rate of approach of I_k to the minimum value is determined, to a large extent, by the ratio of the grid resistance R_g to the resistance R_x. The higher the value of the grid resistance the more slowly the curve approaches the limiting value. Thus, the grid resistor R_g serves the primary function of aiding in straightening the R_x vs. cathode current calibration curve in the range of R_x values above about 100 megohms. The grid resistor for available high mu triodes should have a value within the range of from about 500 to 20,000 megohms, although values as low as 100 megohms can sometimes be used.

The cathode resistor R_k introduces degeneration into the circuit so that normal variations in tube characteristics and supply voltages have little effect on the operation of the circuit. This resistor may have any reasonable value, provided that it is high compared to the plate resistance of the tube being used. Generally, resistors having values between .1 and 1.0 megohm are for available high mu triodes.

It will be understood that the relatively high resistance values which this circuit may be called upon to measure necessitate very careful insulating of the test electrodes and all other parts of the circuit, since even with relatively high values of leakage resistance the accuracy of the instrument may be seriously affected. The magnitude of the plate potential is usually not particularly critical and may be of the order of 40 to 100 volts. Alternating current plate voltage may be used, since the tube is conductive in only one direction, but greater stability will be encountered when a direct current plate supply is provided.

Figure 11 is a diagrammatic view illustrating the manner in which an electronic circuit of the type illustrated in Figure 9 can be used in conjunction with indicating and recording apparatus of various types for measuring and recording the moisture content of a paper web. The circuit illustrated in Figure 11 utilizes a scanning or sensing roll 141 which has a spiral electrode 142, similar to the roll 55, and a paper support roll 143 as the test electrodes (i. e. as the connections to the R_x resistance in the Figure 9 circuit); but it will be understood that any other suitable type of test electrodes or sensing means can be used. The paper web under test passes between the nip of the rolls 141 and 143, as indicated at 145, and the segment of paper between the surface of the support roll 143 and the spiral scanning roll contact 142 is connected across the plate and grid of the triode 147, which, as previously noted, may be a 12F5 or other high mu triode. The grid resistance 149 (R_g) in this arrangement has a value of 2500 megohms and the cathode resistance 151 (R_k) a value of 500,000 ohms. One side of the cathode resistance 151 is connected directly to the cathode of the triode 147, and the other side of that resistance is connected to one side of the grid resistor 149, to the negative terminal of the plate supply battery 155, and to one terminal of a conventional, galvanometer-type, indicating and recording instrument 157.

Two adjustable taps 153 and 154 are provided on the cathode resistance 151, and one of these, the tap 153, is connected to the other terminal of the recording instrument 157. This instrument should be capable of giving full scale deflection with a current of about one milliampere or less and a supply potential of about 40 volts or less. Galvanometer-type indicating and recording instruments having these operating characteristics are available commercially from both Esterline Angus and the Bristol Company. In operation, a recording pen 159, which is directly connected to a galvanometer and which also serves as an indicator means, is arranged to move across a recording tape 161 which is progressively advanced by a clockwork or electrical timing mechanism. The instrument thus yields a trace showing the variation in the potential which is applied thereto over any desired period of time. By regulation of the sensitivity and dampening of the galvanometer, the instrument may be operated to yield an integrated reading.

In a circuit as illustrated in Figure 11, utilizing the resistance values noted above, and a direct current plate supply voltage of about 75 volts, the cathode tap 153 can be conveniently adjusted to give full scale deflection (100 scale divisions) of the instrument 157 at a potential of about .20 volt when the plate and grid of the tube 147 are shorted, i. e. when the resistance across the test electrodes, the resistance R_x, is zero. When the resistance R_x increases to 1000 megohms, the voltage applied to the galvanometer actuating element of the instrument 157 will drop to about .06 volt with corresponding movement of the indicator pen 157 to about 30 scale divisions.

The voltage developed across the cathode resistor 151 may also be used to control a power-driven instrument of the general type illustrated schematically in Figure 8. In general, a power-actuated instrument is almost required with the variable shunt-resistance circuit of Figure 8, due to relatively low output of that circuit under some operating conditions, but, as noted above, the increased output of the electronic tube circuit illustrated in Figure 11 makes possible the use of direct reading instruments as well. Whether or not a circular or linear chart is used for recording is, of course, an optional consideration.

The electronic circuit of Figure 11 has a further very important advantage in that it makes possible the continuous indication of variations in moisture content across a moving web by the use of a cathode ray oscilloscope. The resistance type mechanism is not adapted for use with instruments of this character, due to the fact that there is a substantial time lag in the operation of the mechanism which practically precludes cathode ray operation. The variation in the cathode current in the electronic tube apparatus is subject to no such limitations, however, and to obtain continuous indications of moisture content, it becomes necessary merely to apply a potential obtained from the cathode resistor 151 to the vertical deflection plates of a cathode ray oscilloscope, as illustrated at 150, and to provide a suitable sweep voltage to the horizontal deflection plates in synchronism with the scanning or other sensing means used in conjunction with the apparatus. A suitable circuit for generating such a sweep voltage is shown in Figure 11, and as there illustrated, this circuit consists of a source 163 of direct current potential, which should have a magnitude of from 3 to 10 times the voltage required for complete horizontal deflection of the cathode ray beam, and a series connected resistor 165 and condenser 167, as shown. The time constants of the R-C circuit should be such that the condenser will charge to within from ⅓ to $\frac{1}{10}$ of the battery voltage in the time required for the scanning roll to make one revolution. Under these conditions the voltage rise across the condenser is sufficiently linear for practical purposes. In an actual embodiment of the apparatus, using a 175A DuMont oscilloscope wherein an applied voltage of about 1.0 volt applied to the horizontal amplifier was required to produce a 4 inch horizontal deflection of the cathode ray beam and wherein the scanning roll turned at a rate of 200 R. P. M., the voltage of the battery 163 equalled 22½ volts, the resistance 165 had a value of 20 megohms, and the capacitance 167 was ½ microfarad. With a sweep voltage generator, as above described, it becomes necessary merely to provide a condenser discharge switch 169 which is operable to short circuit the condenser 167 for an instant during each revolution of the scanning roll 141.

It will usually be found necessary to amplify the voltage which is applied to the vertical deflection plates of the oscilloscope. Standard oscilloscopes utilizing 5 inch cathode ray tubes, for example, are usually designed to give a vertical deflection of about one inch for applied voltages of the order of from 20 to 35 volts. The voltage obtainable across the cathode resistor 151 in the circuit of Figure 11 is normally not much more than about 60 volts, and accordingly, movement of the oscilloscope beam would be seriously limited without amplification. The built-in amplifier forming a part of the usual cathode ray oscilloscope will, however, usually provide adequate amplification for this purpose.

During operation of the system illustrated in Figure 11, it will be evident that there is available not only an integrated recording of the variation in moisture content crosswise of the paper web, but also there is available a continuous visual indication showing the exact instantaneous variation in moisture content across the web of paper as it is being manufactured or processed. This latter is a most important and most valuable feature of the invention, and is something which has heretofore been unavailable in the papermaking art. In actual tests of the equipment on a papermaking machine, the use of this continuous, crosswise indication of moisture content has made it possible for the machine operator to detect immediately the conditions resulting in formation of excess moisture content streaks, which show up on the finished paper, and to correct and overcome this difficulty with a minimum of delay. Important savings accompanied by increased paper quality thereby result.

The scanning or sensing roll is a most important part of the invention. It will be understood, however, that both the novel resistance type ohmmeter indicating and recording system and the novel electronic indicating and recording system of the invention can be used in conjunction with sensing means of other types. For example, as previously described, the sensing roll might comprise a series of insulated discs which are individually connected to a commutator and a brush contact can be employed to contact successively each of these contact discs with resultant progressive sensing across the surface of the

web. Other arrangements will suggest themselves to those skilled in the art.

Also, the novel indicating and recording apparatus disclosed in the foregoing need not be utilized in conjunction with a sensing means operable to determine continuously the variation in moisture content across the face of the web. A single, narrow contact may be disposed in cooperative relation with a dried or other roll, and the resistance of this particular section of the web may be all that is measured. However, the circuit arrangements and structural combinations described above can be used to great advantage to provide linear, continuous indications of the variation in moisture content across the width of a moving web and to provide linear recordings of such variation. It is anticipated that the invention, in at least certain of its aspects, may find application in other fields, for example, the textile and printing industries, where continuous indications, based upon resistance values subject to non-linear variation, may be encountered.

The features of the invention believed to be new are expressly set forth in the appended claims.

We claim:

1. In apparatus which is operable to provide a continuous indication of variations in resistance across the width of a moving web or sheet; electrode means which moves progressively across the web or sheet under test in repetitive, cyclic manner during the use of said apparatus, while in contact with a segment of said web or sheet; resistance responsive means connected to said electrode means and operable to provide a voltage which varies with variation in the resistance of the segment of the web or sheet which is contacted by said electrode means at any particular instant during the use of said apparatus; a cathode ray oscilloscope having one pair of deflection plates connected to be energized in response to said voltage, and a second pair of deflection plates disposed at right angles to said first mentioned pair; and a sweep voltage generator, which operates in synchronism with the repetitive cycle of said electrode means, connected to said second pair of deflection plates.

2. In apparatus which is operable to provide a continuous indication of variations in resistance across the width of a moving web of paper; electrode means which moves progressively across the web under test in repetitive, cyclic manner during use of said apparatus, while in contact with a segment of said web; a resistance responsive circuit which includes a source of potential, a thermionic tube unit having a plate connected to one side of said source of potential, a cathode connected to the other side of said source of potential through a cathode resistor, and a grid connected to said cathode resistor through a grid resistance, the plate and grid of said tube being connected to said electrode means, and said resistance responsive circuit being operable to produce a voltage across said cathode resistor which varies in response to variations in the resistance of the segment of the web between said electrodes at any particular instant during the use of said apparatus; a cathode ray oscilloscope having one pair of deflection plates connected to be energized in response to the voltages produced across said cathode resistance and a second pair of deflection plates disposed at right angles to said first mentioned pair; and a sweep voltage generator, which operates in synchronism with the repetitive cycle of said electrode means, connected to said second pair of deflection plates.

3. In apparatus which is operable to provide a continuous indication of variations in resistance across the width of a moving web of paper; electrode means which moves progressively across the web under test in repetitive cyclic manner during the use of said apparatus, to contact successive segmental areas across said web width; said electrode means comprising a conducting surface over which the web may be moved and a rotatable member supported adjacent said conducting surface; the web under test passing between said conducting surface and said rotatable member, and said rotatable member having an electrode in the surface thereof; resistance responsive means connected to said electrode means, said resistance responsive means being operable to provide a voltage which varies substantially linearly in response to logarithmic variation in the resistance of the segment of the paper web which is between said conducting surface and said electrode at any particular instant during the use of said apparatus; a cathode ray oscilloscope having one pair of deflection plates connected to be energized in response to said voltage, and a second pair of deflection plates disposed at right angles to said first mentioned pair; and a sweep voltage generator, which operates in synchronism with the repetitive cycle of said electrode means, connected to said second pair of deflection electrodes, whereby a continuous indication of the variation in moisture content across the width of said web is obtained on the screen of said cathode ray oscilloscope.

4. In apparatus particularly adapted for determining variations in moisture content across a moving web of paper; a pair of electrodes, one of said electrodes comprising a roll having a conducting surface, and the other of said electrodes comprising a roll having an insulating surface and a narrow, ribbon-like, spirally shaped contact supported in said insulating surface; said electrode contact making one complete turn about the axis of said roll; said rolls being supported adjacent each other to provide a nip and the web of paper under test being passed through the nip formed between said rolls whereby the said electrodes contact a small segment of paper, which segment moves progressively across the web of paper as said web moves through said rolls.

5. In apparatus particularly adapted for determining variations in moisture constant across a moving web of paper; a pair of electrodes, one of said electrodes comprising a roll having a conducting surface, and the other of said electrodes comprising a roll having an insulating surface and a narrow, ribbon-like contact supported in and extending spirally around said insulating surface; said rolls being supported adjacent each other to provide a nip and the web of paper under test being passed through the nip formed between said rolls whereby the said electrodes contact a small segment of paper, which segment moves across the web of paper as the web moves through said rolls.

6. In an apparatus for determining variations in resistance across a moving web or sheet; a pair of electrodes, one of which comprises a roll having a conducting surface over which the web or sheet under test may be moved, and the other of which comprises a rotatable member supported adjacent said conducting surface; said rotatable member comprising a roll having an insulating surface and at least one spirally shaped contact

supported in said insulating surface, the web or sheet under test passing through the nip formed between said rolls whereby said electrodes contact a small segment of web, which segment moves across the web in a cyclic, repetitive manner as the web moves through said rolls, and means for measuring the resistance connected to said electrodes whereby the resistance over a small, segmental area at different points across the width of said web may be independently and continuously measured in a cyclic, repetitive manner.

7. In apparatus which is operable to provide a continuous indication of variations in resistance across the width of a moving web or sheet; electrode means which moves progressively across the web or sheet under test in repetitive, cyclic manner during the use of said apparatus, while in contact with a segment of said web or sheet; resistance responsive means connected to said electrode means and operable to provide a voltage which varies with variation in the resistance of the segment of the web or sheet which is contacted by said electrode means at any particular instant during the use of said apparatus; and an indicating means connected in voltage responsive relationship with said resistance responsive means, said indicating means operating in synchronism with the repetitive cycle of said electrode means and providing both a continuous indication of the segment of the web which is contacted by said electrode means and of the resistance of said contacted web segment.

8. In apparatus which is operable to provide a continuous indication of variations in resistance across the width of a moving web of paper; electrode means which moves progressively across the web under test in repetitive cyclic manner during the use of said apparatus to contact successive segmental areas across said web width, said electrode means comprising a conducting surface over which the web may be moved and a rotatable member supported adjacent said conducting surface; the web under test passing between said conducting surface and said rotatable member, and said rotatable member having an electrode in the surface thereof; resistance responsive means connected to said electrode means, said resistance responsive means being operable to provide a voltage which varies with variation in the resistance of the segment of the paper web which is between said conducting surface and said electrode at any particular instant during the use of said apparatus; and an indicating means, connected in voltage responsive relationship with said resistance responsive means, said indicating means operating in synchronism with the repetitive cycle of said electrode means so as to give a continuous indication of both the position of said electrode on the web and the resistance of the web underneath said electrode.

9. In apparatus which is operable to provide a continuous indication of variations in resistance across the width of a moving web of paper; electrode means which moves progressively across the web under test in repetitive cyclic manner during the use of said apparatus to contact successive segmental areas across said web width, said electrode means comprising a conducting surface over which the web may be moved and a rotatable member supported adjacent said conducting surface; the web under test passing between said conducting surfaces and said rotatable member, and said rotatable member having an electrode in the surface thereof; resistance responsive means connected to said electrode means, said resistance responsive means being operable to provide a voltage which varies substantially linearly in response to logarithmic variation in the resistance of the segment of the paper web which is between said conducting surface and said electrode at any particular instant during the use of said apparatus; and an indicating means, connected in voltage responsive relationship with said resistance responsive means, said indicating means operating in synchronism with the repetitive cycle of said electrode means so as to give a continuous indication of both the position of said electrode on the web and the resistance of the web underneath said electrode.

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