Aug. 29, 1967 W. D. PERRY 3,339,137

MOISTURE DETERMINING APPARATUS HAVING ADJACENT ELECTRODE PAIRS DRIVEN OUT-OF-PHASE

Filed July 3, 1964 2 Sheets-Sheet 1

Fig. 1.

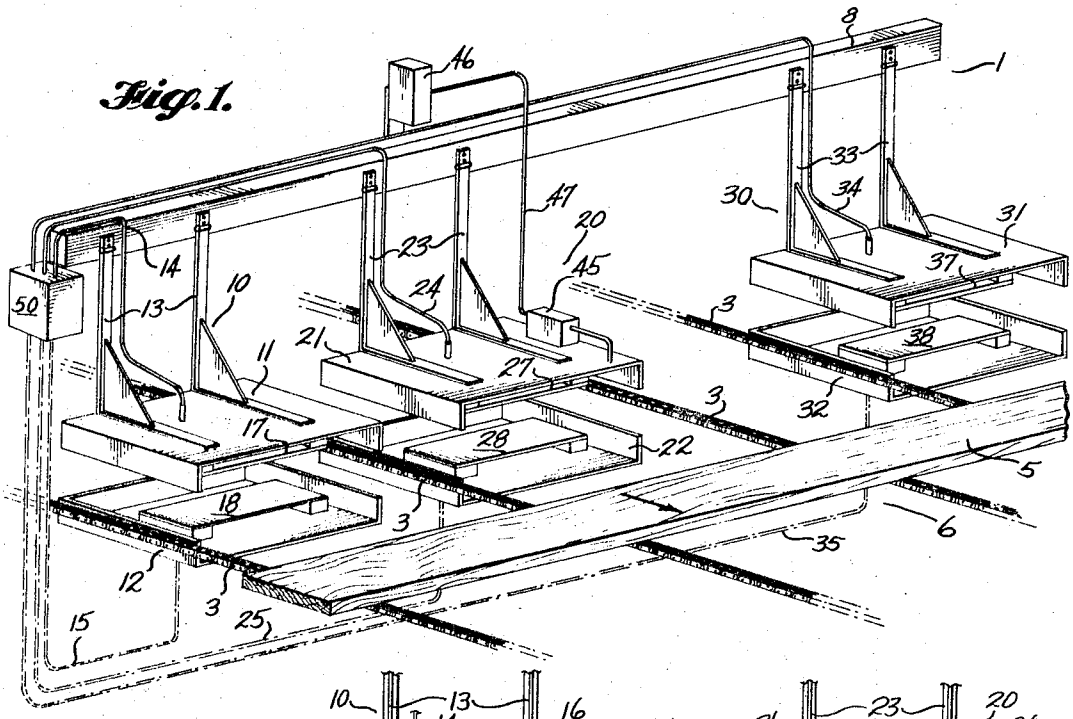


Fig. 2.

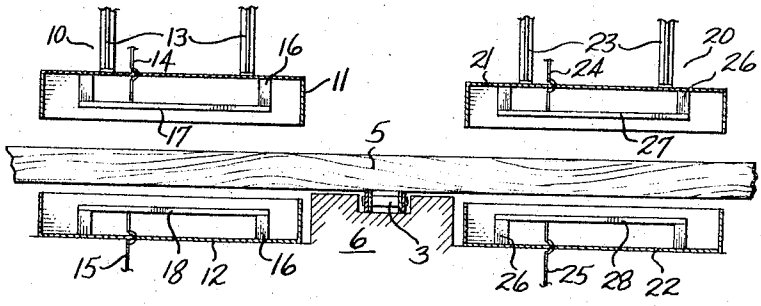


Fig. 3.

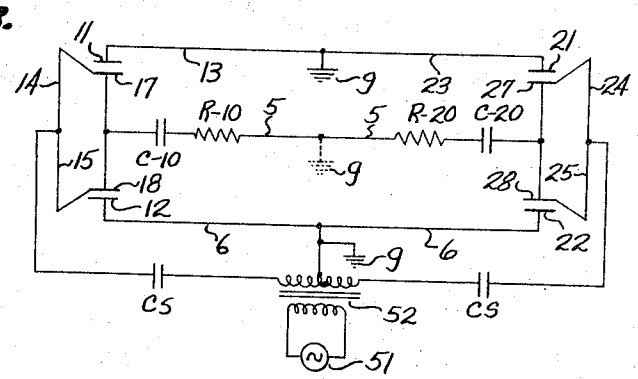
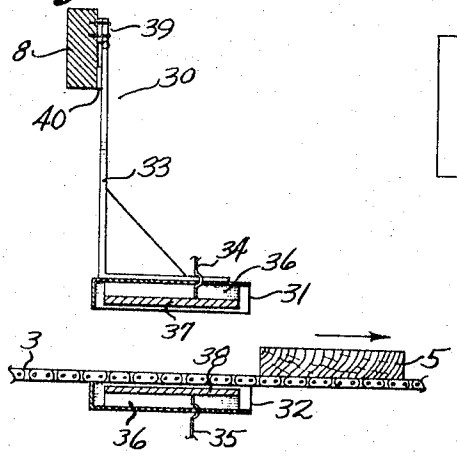


Fig. 4.



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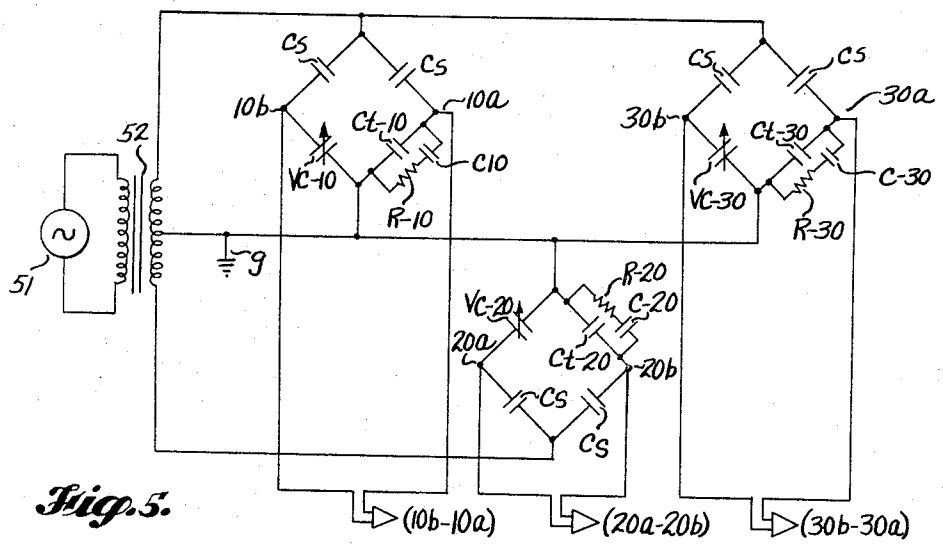
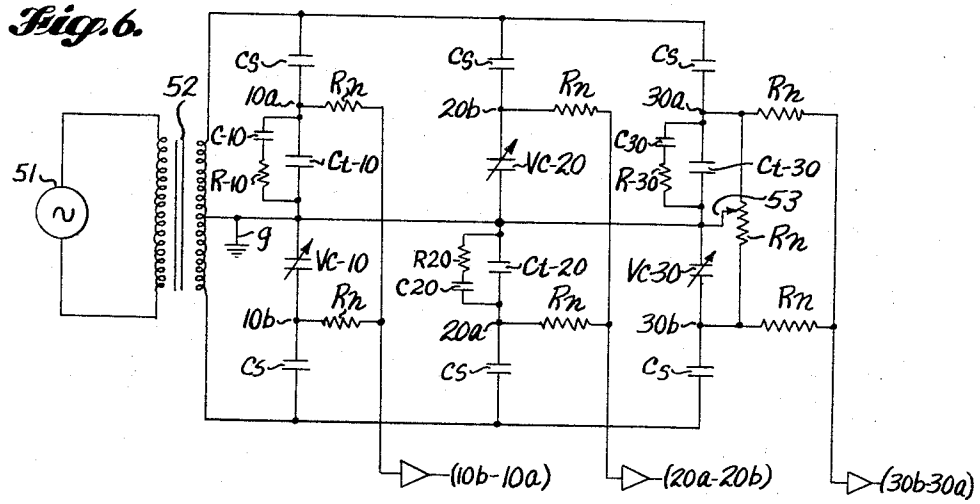


Fig. 5.

Fig. 6.



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MOISTURE DETERMINING APPARATUS HAVING ADJACENT ELECTRODE PAIRS DRIVEN OUT-OF-PHASE

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4 Claims. (Cl. 324—61)

This invention relates to an apparatus for measuring the moisture content of materials and particularly relates to electrical means for inducing an electrical impulse into wood products and measuring the internal resistance which is related to the moisture content of the material through which the impulse flows.

In the production of wood products there is often a requirement for ascertaining the moisture content of the product. This requirement has often been partially satisfied by means of meters which measure the resistance, power loss or dielectric constant of the product. Such meters measure the electrical conductivity and/or dielectric constant which in turn depend upon the moisture content of the product.

In order that production cost and time requirements are maintained at a low value, the metering of moisture content of the product must be rapid, accurate and non-destructive. Thus, resistance type meters which consist of probes driven into the wood are not acceptable since they are slow and leave holes in the product. Likewise, power loss type meters, which consist of electrodes which upon contact with the wood surface set up an electrical field which is metered, are unacceptable since these meters are sensitive to the degree of contact and their accuracy is decreased as the product's thickness is increased. Previously known capacitance meters, which consist of two electrodes either in contact with, or at a fixed distance from the wood, are intended to measure the increase in capacitance due to the presence of a dielectric other than air adjacent to the electrodes. Such meters are not fully satisfactory in performance since they are dependent upon wood density and thickness and are consequently quite sensitive to the distance between the wood surface and the electrodes. Thus these meters may not detect wet pockets in the middle of a two-inch thick sample of wood, and the accuracy is of a lower order whenever the electrode to wood distance varies as is the case with rough sawn lumber.

In my copending application, U.S. Ser. No. 248,573 filed Dec. 31, 1962, I have disclosed an improved capacitance type moisture meter in which a pair of electrodes of the same potential is placed above and below the wood so that the wood itself acts as an electrode or semi-grounded plate rather than a dielectric material. The capacitance depends upon the area of the wood between the electrodes and the distance from the wood to the electrodes. However, since the electrodes are spaced with a fixed separation between them, the motion of the wood toward one electrode requires motion of the wood away from the other electrode, balancing the signal.

In my copending application, U.S. Ser. No. 319,191 filed Oct. 28, 1963, I have disclosed a portable capacitance type moisture meter wherein two electrodes are driven electrically 180° out of phase and placed a fixed distance from the same surface of the wood.

The capacitance type moisture meters described in my copending applications referred to above are used to measure the moisture in lumber traveling longitudinally through the meters or in only one portion of the lumber traveling laterally through the meter. The present invention provides an improvement by expanding the meter to

two or more pairs of shielded electrodes mounted a fixed distance apart with the wood passing between each pair. The use of two or more electrode pairs allows moisture to be detected in two or more portions of the lumber passing laterally through them. The adjacent pairs of electrodes must be driven electrically 180° out of phase to guarantee the presence of an electrical ground plane in the wood between electrode pairs.

It is, therefore, the object of this invention to provide an apparatus for measuring the moisture content of materials which permits the materials to pass in a direction normal to the alignment of the electrode pairs to one another.

It is a further object of this invention to provide a rugged and reliable moisture meter which can continuously meter a moving line of lumber for moisture content in the range from 12% to 25% and indicate which pieces of lumber are either above or below points within this moisture content range.

It is a further object of this invention to provide an apparatus which can be used to measure the moisture content in one or more portions of a piece of lumber and to indicate, by combining the signals from the measurement of each portion, either the average or maximum moisture content measured in these wood portions.

It is still a further object of this invention to provide a moisture meter apparatus which is sensitive to non-uniform moisture distribution resulting from water concentrations within the body of the material being metered.

It is still a further object of this invention to provide a moisture metering apparatus which allows for rapid measurement without physical contact with the material being metered.

It is still a further object of this invention to provide electrical circuit means for providing power to multiple electrode capacitance type moisture meters and to measure the output of such electrodes.

In the practice of this invention the moisture metering apparatus consists of two or more sensing heads which are mounted in a line normal to the direction of lumber is being conveyed past them. Each sensing head consists of a pair of shielded electrodes mounted a fixed distance apart such that the wood sample to be metered passes between them without touching them. These electrodes are connected to any electrical circuit which allows the internal resistance which indicates the presence of water in the wood to be indicated as an output voltage. The two shielded electrodes making up each sensing head are connected together electrically so that the volume between them is essentially a field-free region. Thus, as the wood containing water is moved into this volume, an electrical charge is induced into the wood with the amount of the charge induced depending upon the conductivity, and hence, the moisture content of the wood. Each of the sensing heads is connected to the same power supply which drives adjacent heads 180° out of phase. This out-of-phase drive forces the wood to a ground potential midway between the heads. The output signals from each head can be combined to indicate either the average or maximum moisture content in the portions of the wood adjacent to each head.

Further objects and advantages of the invention will become more readily apparent from the following description and annexed drawings, in which:

FIGURE 1 is a perspective view showing a typical installation of this invention.

FIGURE 2 is a side elevation view of adjacent meter heads constructed in accordance with this invention.

FIGURE 3 is a schematic electrical diagram of the elements shown in FIGURE 2.

FIGURE 4 is an end elevation view of one moisture metering head made in accordance with this invention.

FIGURE 5 is a schematic diagram of a conventional electrical circuit which can be used in the operation of a moisture meter made in accordance with this invention.

FIGURE 6 is a schematic diagram of a modified electrical circuit which may be used in controlling the moisture meter installation as taught by this invention.

Referring in more detail to the drawings, FIGURE 1 shows a typical multiple head moisture meter installation **1** used for metering lumber as it is conveyed from one station to another in a lumber mill.

In a typical installation **1**, a suitable conveying means **3** causes the lumber **5** to be transported across the lower frame **6**. An upper frame **8** is supported above the path of the lumber **5** and aligned perpendicular to the direction that the lumber is conveyed. Aligned with the upper frames **8** are a number of moisture sensing head units **10**, **20** and **30**.

The first moisture sensing unit **10** comprises an upper electrode shield **11** and a lower electrode shield **12** with the upper electrode shield **11** being suspended from the upper frame **8** by means of support rods **13**. The lower electrode shield **12** is supported by the lower frame **6**. The first moisture sensing head unit **10** is electrically connected to the control unit **50** by means of upper electrode lead **14** and lower electrode lead **15**, shown in dotted lines since it is below the lower frame **6**.

Also electrically connected to the control unit **50** may be a spray unit **45** which is supplied by a marking fluid container **46** through hose **47**. As shown in FIGURE 1, the spray unit **45** can be mounted on an extension of either of the upper electrode shields **11** or **21** or the second moisture sensing head unit **20** and the container **46** may be supported by the upper frame **8**.

Referring now to FIGURE 2, there is shown a side elevation view of two adjacent moisture sensing head units **10** and **20**. The second moisture sensing head unit **20** has similar structural elements to those in the first moisture sensing unit **10**. For example, the upper electrode shield **21** is suspended by means of support rods **23**, which are, in turn, connected to the upper frame **8**. The lower electrode shield **22** is supported by the lower frame **6**. The upper electrode **27** is separated from the upper electrode shield **21** by means of insulation spacers **26**, and is electrically connected to the control unit **50** by means of the upper electrode lead **24**. In a similar manner, lower electrode **28** is separated by means of spacers **26** from the lower electrode shield **22** and electrically connected to a control unit **50** by means of lower electrode lead **25**. The lumber **5** is conveyed by means of conveying means **3** through the air gap between the first moisture sensing unit's upper and lower electrodes **17** and **18** and the second moisture sensing unit's upper and lower electrodes **27** and **28**. It should be noted that there is no actual connection between the electrodes and the lumber.

Referring now to FIGURES 2 and 3 together, it is seen that the upper electrode shields **11** and **21** are grounded as are the lower electrode shields **12** and **22**. It is also seen that in the first moisture sensing unit head **10**, the upper and lower electrodes **17** and **18** are commonly connected to an electrical power source and thus the air gap between the electrodes **17** and **18** becomes a field-free region. In a similar manner, the pair of electrodes **27** and **28** in the second moisture sensing head unit **20** are electrically connected and a field-free region exists in the air gap between these electrodes. It should also be noted that the A.C. power supply **51** through the transformer **52** provides a phase relationship between the adjacent moisture sensing units **10** and **20** such that the paired electrodes **17** and **18** are 180° out of phase with the paired electrodes **27** and **28**. This out-of-phase drive forces the wood **5** to a ground potential midway between the heads **10** and **20**. This is schematically shown by means of a capacitance C–**10** and a resistance R–**10** as a connection between the paired electrodes **17** and **18** and the ground *g*. C–**10** represents the capacitance between the electrodes **17**, **18** and the wood **5**. R–**10** represents the internal resistance of the volume of wood between the field of electrodes **17**, **18** and the ground *g*. Similarly, in the portion of the wood between the ground *g* and the effective field of the second unit's paired electrodes **27** and **28** there is shown resistance R–**20** and a capacitance C–**20**. As the wood **5** containing water is moved into the air volume between paired electrodes **17** and **18** and **27** and **28**, an electrical charge is induced into wood **5**. The amount of the charge induced depends on the conductivity, and hence the moisture content of the wood.

With this arrangement, the moisture content of the lumber **5** can be measured regardless of whether the lumber **5** is rough or surfaced lumber. Since the electrodes **17** and **18** have the same electrical potential, the moisture sensing unit is relatively insensitive to the wood's position in the space between these electrodes. This installation is especially sensitive to nonuniform moisture distributions resulting in water concentrations inside of a piece of lumber, and allows rapid measurement without physical contact with the lumber's surface. The use of two or more electrode pairs, such as in units **10** and **20**, allows the moisture to be detected in two or more portions of the lumber passing through them. The adjacent pairs of electrodes **17** and **18** and **27** and **28** being driven out of phase guarantees the presence of an electrical ground plane in the wood between the electrode pairs and erroneous signals due to local interference are eliminated by this positive ground.

FIGURE 4 shows an end elevation view of the third moisture sensing unit head **30**. The upper electrode shield **31** is suspended by means of support rods **33** and physically separated and insulated from the upper electrode **37** by means of spacers **36**. The upper electrode **37** is connected to the control unit **50** by means of the upper electrode lead **34**. The lower electrode shield **32** is supported by the lower frame **6** and is electrically insulated from the lower electrode **38**, which is electrically connected to the control unit **50** by means of lower electrode lead **35**. In many installations it is possible for the lumber **5** to become jammed in the space between the upper and lower electrodes **37** and **38** and, to eliminate any damage and delay in the conveying process, the upper support rods can be attached to the upper frame by means of hinges **39**. A cushion **40** may be interposed between the upper frame **8** and the support rods **33** to absorb the shock when the support rods **33** return to the normal position after being deflected.

In FIGURE 5 there is shown an electrical diagram of some of the control components which may be used to control the moisture sensing installation **1**. As shown, the AC power source **51** through the transformer **52** drives each of the adjacent control bridges which corresponds to the adjacent moisture sensing unit heads **10**, **20** and **30**, 180° out of phase. A typical bridge is composed of a series connection between a ground *g* and a point **10***b*, having within it a variable capacitor VC–**10**. From point **10***b* to the high potential is a standard capacitor C*s*. Continuing around the bridge from the high potential is an identical standard capacitor C*s* which connects the high potential to another pick-off point **10***a*. Between the point **10***a* and the ground *g* is the capacitance between the paired electrodes **17** and **18** and their shields **11**, **12**, indicated as C*t*–**10**, which is a metering capacitor connected in parallel through the air gap with the portion of the lumber **5** electrically shown as the capacitor C–**10** and resistor R–**10** in series. Whenever the gap between the pair of electrodes **17** and **18** is occupied by a material containing moisture, an electrical current is transmitted from the electrodes **17** and **18** through capacitor C–**10** and through the material R–**10** to ground *g*. Depending upon the moisture content in the material, the resistance R–**10** will be high or low such that, the higher is the resistance, the lower is the moisture content. If the moisture content is

above 12% the effect of the resistance R–10 is significant in the bridge and the potential between the point 10*b* and 10*a* is no longer identical. This change in potential can be amplified by suitable amplifier, shown as 10*b*–10*a*. This then is the output signal of the control for the first moisture sensing unit head 10. A similar signal will be generated by the other two moisture sensing units 20 and 30, and the output signals can be combined or averaged in any desired manner to affect the spray unit 45 if desired, which may mark the lumber 5 if it is too moist. The sensitivity of the control is dependent upon the settings in the amplifier such that the output signals can be used to energize the spray unit 45, if any one signal goes over a maximum amount allowed or if all three signals combined go over a maximum amount allowed or any combination of such signals. These signals could be used to ring a bell, open a conveyor pocket, or any other desired way to indicate the presence of a wet board.

In reference now to FIGURE 6, there is shown an equivalent control circuit to that shown in FIGURE 5, with similar units being designated by the same identifying symbols. The novel feature of this particular circuit lies in the fact that it is a straight line bridge running from the high potential through the first standard capacitor C*s*, through the point 10*a*, through the meter capacitance C*t*–10 to the ground *g* and continuing through a variable capacitor VC–10 to point 10*b*, through the standard capacitor C*s* to the low potential. The difference between the potential 10*a* and 10*b* is transmitted through the nominal resistances R*n* to a preamplifier giving the signal difference 10*b*–10*a*.

If desired, the bridge output side may be modified as shown in the bridge circuit for the third moisture sensing unit head 30. Addition of a potentiometer 53 can provide a resistance balance between the points 30*a* and 30*b* on the output side of the circuit to the preamplifier 30*b*–30*a*.

The novel feature or advantage of the equivalent circuit shown in FIGURE 6 is that standard electronic components, rather than higher cost specialty items, can be used throughout this circuit. Specifically, the amplifiers used in the circuit shown in FIGURE 6 may be simple AC amplifiers, whereas the amplifiers required in the circuit shown in FIGURE 5 must be differential amplifiers.

By this invention there has been provided an apparatus for measuring the moisture content of lumber while the lumber is being conveyed without contacting the lumber and without being affected in its accuracy by the exact positioning of the lumber, the surface condition of the lumber, or by the variations in thickness of the lumber. This installation is sensitive to nonuniform moisture distribution within a portion of the lumber, is rugged in design, reliable, accurate, and flexible in use. It can be used to measure the average moisture content within one portion of lumber or the maximum moisture content in all of the portions, or any one portion of the lumber metered. The electrical control is likewise flexible and easily maintained.

Various changes may be made in the form, size and materials used in the moisture meter installation above disclosed, and certain features such as the spray unit and the particular control circuit may or may not be used with other features. All such modifications are intended to be within the scope of the appended claims. Having now described my invention, in what manner the same may be used, what I claim is new and desire to protect by Letters Patent is:

I claim:

1. A moisture meter apparatus comprising in combination:

first pair of electrodes,

second pair of electrodes adjacent to said first electrodes electrical power source means having first and second leads, said first lead connected to said first pair of electrodes, said second lead connected to said second pair of electrodes,

conveyor means for conveying material to and from said first and second pair of electrodes,

said first and second pair of electrodes having opposite electrodes of each pair being displaced one from another a distance to establish a field-free region between each other through which the material being metered passes,

each of said pairs of electrodes being electrically driven, by said power source 180° out of phase from the adjacent pair of electrodes,

control means electrically connected to each of said pairs of electrodes and responsive to electrical currents from said electrodes to indicate the moisture content of said material passing between said adjacent electrode pairs.

2. The moisture meter of claim 1 wherein:

said adjacent pair of electrodes is aligned on an axis normal to the direction in which said material being metered passes said electrodes.

3. The moisture meter of claim 1 including:

additional pairs of electrodes adjacent to said second pair of electrodes with each of said pairs of electrodes being electrically driven, by said power source, 180° out of phase from the adjacent pair of electrodes and electrically connected to said control means.

4. The moisture meter of claim 1 wherein:

said power means includes an alternating current source providing, through said first and second leads, for a high potential, a low potential connection, and, through a ground lead, a ground connection,

said pairs of electrodes are included in a capacitor voltage divider means, said capacitor voltage divider means includes at least two capacitor voltage dividers,

one of said dividers includes in series from said high potential lead a standard capacitor and a first capacitor and in series from said ground lead a variable capacitor and another standard capacitor to said low potential lead, said first capacitor having one plate formed by one of said pairs of electrodes and another plate formed by a first grounded shield means for said one of said electrode pairs,

a second divider adjacent said one divider includes in series from said high potential lead a standard capacitor and a variable capacitor to said ground lead and in series from said ground lead a second capacitor and another standard capacitor to said low potential lead, said second capacitor having one plate formed by said adjacent pair of electrodes and another plate formed by a second grounded shield means for said adjacent pair of electrodes,

said control means includes an output means having at least one amplifier which is electrically connected through nominal resistances to one of said dividers at one point between said electrode capacitor and one of said standard capacitors and at a second point between said variable capacitor and another of said standard capacitors.

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