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GASEOUS-DISCHARGE METHOD AND SYSTEM

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2 Sheets-Sheet 1

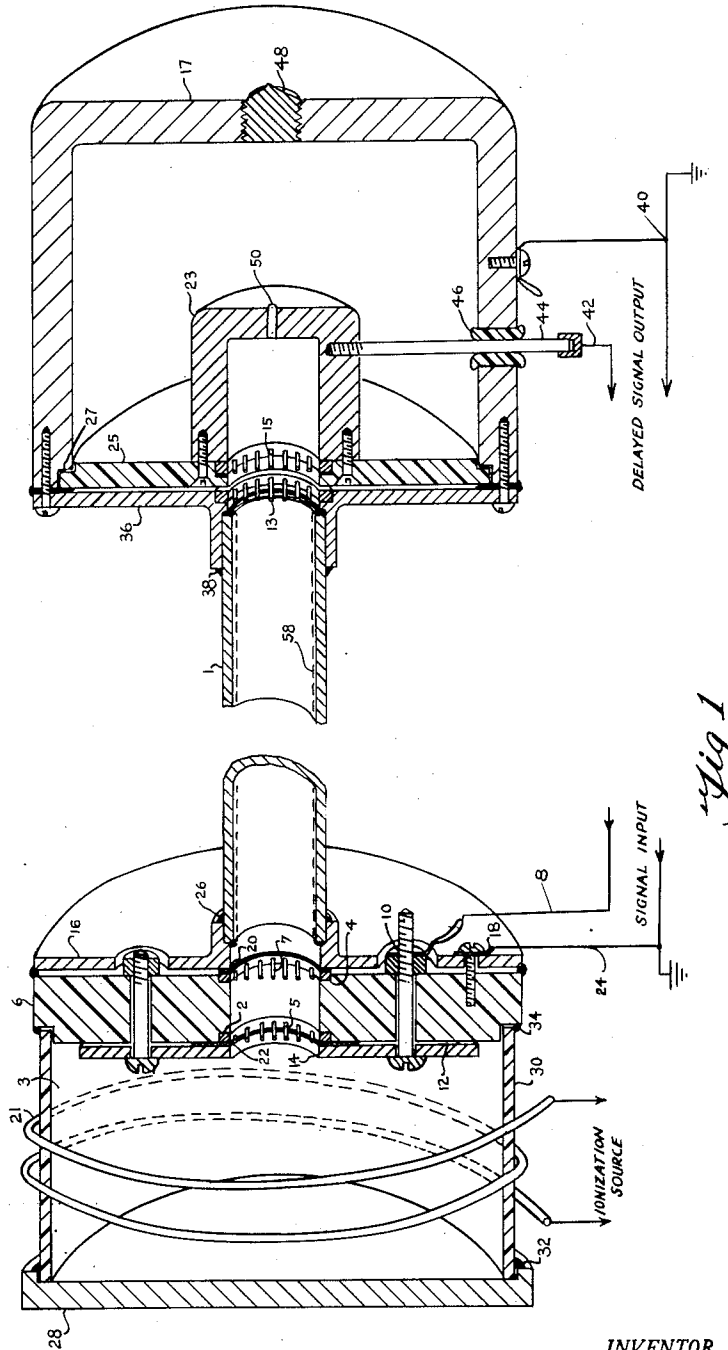


Fig 1

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2 Sheets-Sheet 2

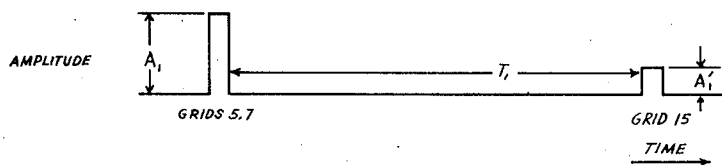


Fig. 2

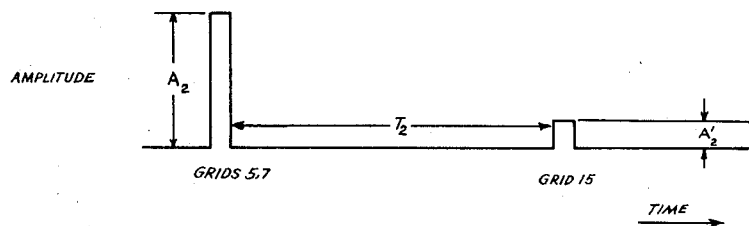


Fig. 3

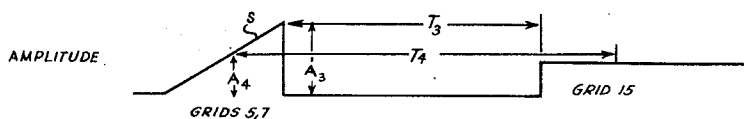


Fig. 4



Fig. 5

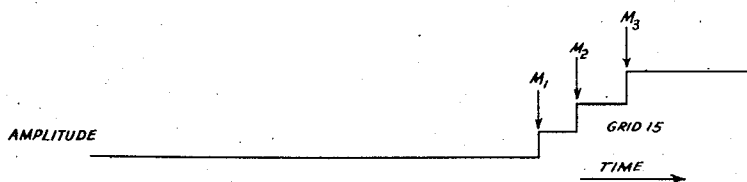


Fig. 6

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GASEOUS-DISCHARGE METHOD AND SYSTEM

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16 Claims. (Cl. 313—63)

The present invention relates to electric discharge systems and more particularly to systems utilizing the flow of gaseous ions.

Various types of electrical delay lines have heretofore been evolved. Electrical networks and transmission lines, for example, have been utilized to cause a pulse applied at the input to travel to the output in a predetermined time interval, thereby to produce at the output a pulse that is delayed in time, from the time of occurrence of the input pulse, the said predetermined time interval. Such delayed pulse systems are of great importance in radar systems, computing systems and similar apparatus. Networks and transmission lines, however, have decided disadvantages. In the case of transmission lines, the lines must be of considerable length in order to introduce delays of the order of magnitude required in radar, computing and similar circuits. The delay produced by these systems, furthermore, is inherently fixed and cannot be varied at will. In the case of networks or artificial transmission lines, the frequency-response characteristics are limited by the physical components utilized therein, so that a high degree of resolution of the pulse output is not obtainable. As an illustration, it is usually not feasible with such techniques to produce a delayed pulse with resolution better than about one-tenth of the delay time itself. If, for example, a hundred-microsecond delay were desired, the resolution of the output delayed signal would not be better than about ten microseconds. Other types of delay devices, such as magnetic-tape or drum delay devices, have also been proposed, but these have the serious drawback that their frequency-reproducing range is limited. Such magnetic-tape delay devices can not resolve signals better than approximately ten microseconds, and even this degree of signal resolution is quite difficult to obtain with such devices. Still other forms of delay apparatus have embodied acoustic transmission paths, such as, for example, glass, fused quartz or liquid paths through which ultrasonic or other elastic vibrations may be propagated. Such acoustic delay lines also have serious drawbacks including their complexity, the difficulty of their manufacture, and their inherent fixed time-delay nature. Other signal-delay devices have also been proposed such as cathode-ray storage members, but these are quite costly and intricate, and have other limitations.

An object of the present invention is to provide a new and improved system for producing time-delayed voltage signals that shall not be subject to any of the above-described disadvantages. In accordance with the present invention, time-delayed signals are produced by controlling the flow of gas ions through an un-ionized gaseous medium.

A further object is to provide a new and improved delay system having far greater resolution than is obtainable with the above-mentioned prior-art delay devices.

Still an additional object is to provide a delay system that is adapted to produce, at will, any desired variable delay period.

Another object is to provide a delay system that is adapted to provide a continuously variable delay of a

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nature which, again, can not be attained with the prior-art delay devices.

An additional object is to provide a system of the character described that may also be employed for mass spectrometry.

Other and further objects will be explained hereinafter, and will be more particularly pointed out in the appended claims.

The invention will now be described in connection with the accompanying drawings, Fig. 1 of which is a longitudinal cross-section of apparatus constructed in accordance with a preferred embodiment of the invention; and Figures 2 to 6 are explanatory diagrams:

Referring to Fig. 1, an elongated gas-containing envelope 1, such as a glass tube, is provided with a region 3 at one end, shown at the left, separated therefrom by a pair of grid electrodes 5 and 7 which may take the form of wire-screen discs. The grids 5 and 7, for example, may be constructed of nickel wire two thousandths of an inch in diameter with a spacing between adjacent wire elements of about eight thousandths of an inch. The separation of the grids 5 and 7 may be about 1 centimeter, more or less. The grids 5 and 7 may be mounted within recesses 2 and 4 in an insulating block 6 disposed in line with the envelope 1. Electrical connection to the grid 5 through conductor 3 is achieved through a binding post 10 that clamps a conductive plate 12 to the left-hand face of the block 6, contacting the grid 5 at 22. The plate 12 is provided with an aperture 14 in line with the grid 5. A similar apertured conductive plate 16 is held against the right-hand face of the block 6, as by binding posts 18, to establish an electrical connection with the grid 7, as at 20. The other input conductor 24 is connected to the binding post 18. The left-hand end of the envelope 1 is received in a recessed collar 26 extending from the plate 16.

The before-mentioned region 3 is bounded to the right by the plate 12, and to the left by a conductive cap 23. The region is enclosed by a glass or other cylindrical wall 30. Gas-tight seals are provided as by cementing the edges of the wall 30 at 32 and 34. Similar seals are provided at 26 so that the passage from the envelope 1 through the space between the grids 7 and 5 into the region 3 is gas-tight.

At the other or right-hand end of the envelope 1 there is preferably provided a pair of similar collector grid electrodes 13 and 15. The grid 15 may be seated adjacent and hence in electrical connection with a conductive cap 23. The cap 23, in turn, is mounted by an insulating plate 25 within a Faraday shield can 17. The insulating plate 25 bears against a recessed rim 27 of the Faraday shield, being held there-against by an apertured conductive plate 36 that is similar to the plate 16. The conductive plate 36 also establishes electrical connection with the grid 13 and is sealed at 38 to the right-hand end of the envelope 1. The grid 13, the plate 36 and the Faraday shield 17 are thus all at the same potential, which may be ground, as shown at 40. Electrical connection to the grid 15 is established by the plug 44 extending from the cap 23 through a gas-tight insulation-sealed aperture 46 in the Faraday shield 17. The output conductor 42 may easily be connected with the plug 44, as shown.

The gas for the system may be introduced at the inlet 48 in the Faraday shield, which inlet may then be sealed off as shown. The gas enters at 50 into the region between the electrodes 13 and 15, into the envelope 1, into the region between the electrodes 7 and 5 and into the region 3.

In accordance with the present invention, the region 3 is provided with a mechanism for ionizing the gas in that region only. This mechanism is preferably in the form of a radio-frequency coil 21 for producing a radio-frequency carrier wave, since ionization produced by radio-

frequency energy is inherently sharply confined to the region of the radio-frequency field. In addition, the ionization source may be easily modulated in accordance with any desired signal should such be desired, as will be later explained. The gas contained in the envelope 1 may be of any desired gas such as hydrogen, krypton, xenon, and, indeed, where the device is to be used as a mass spectrometer, as hereinafter discussed, it may be any desired combination of gases at any desired pressures. In actual practice, however, there are restrictions on the gas pressure that will later be explained.

Upon ionization of the gas in the limited region 3, which may be termed the ionization chamber, gas ions and electrons are produced. If a voltage is applied to the electrodes 5 and 7 through the input conductors 8 and 24, respectively, such that the electrode 7 is positive with respect to the electrode 5, ions from the ionized region 3, assumed to be positively charged for the purposes of illustration, will be repelled back toward the ionization chamber 3. The ions in the region of the grid electrode 5 will therefore have substantially zero velocity. When, however, a voltage signal, such as a voltage pulse, is applied to the input conductors 8 and 24 so that the grid 5 goes positive with respect to the grid 7, ions will travel through the space between the electrodes 5 and 7 into the envelope 1 in which the gas is un-ionized. The velocity imparted to the ions is determined by the magnitude of the voltage pulse. The ions are permitted to travel freely through the un-ionized gaseous region of the envelope 1, passing through the grid 13 and impinging upon the grid 15, and the cap 23, where they may be taken off as an output signal by the conductor 42. If desired, an accelerating potential may be placed upon the electrode 13 but this is not essential in all cases.

The significance of the gas pressure will now be evident inasmuch as the path length between the grid 7 and the grid 13 should preferably be of such length that the probability of a substantial number of collisions of the traveling ions with un-ionized gas molecules in the envelope 1 is not too great, as otherwise, the ion current ultimately reaching the electrodes 15, 23 will be greatly reduced. For practical purposes, the length of the space between the grids 7 and 13 should be adjusted so that it is preferably less than about two times the mean free path of the gas. For optimum results, this path length should be less than the mean free path of the gas. Trapping of those ions that do collide and scatter or disperse in the medium 1 is preferably effected by such means as a carbon or aquadag electrode coating 58 within the inner walls of the envelope 1 between the grids 7 and 13, which coating is preferably grounded through contact with the grounded plates 16 and 36. Positive scattered ions therefore find an easy path to ground and do not appear at the collector electrode 15, 23.

If, therefore, a positive voltage impulse, such as a rectangular pulse A_1 of Fig. 2, is applied by the conductors 8 and 24 to the grids 5 and 7 in polarity such that the grid 5 is positive with respect to the grid 7, ions will be accelerated from substantially zero velocity in response to the gating action of this voltage pulse signal, through the grids 5 and 7 along the medium within the tube 1 toward the grids 13 and 15. As the freely traveling ions approach the collector grid 15, the electric field that they set up is prevented from influencing the grid 15 by virtue of the Faraday shield 17 associated with the closely spaced collector grid 13, as a result of the isolating action of the shield. Thus, only upon the actual arrival of the traveling gas ions at the grid 15 is current available in the output conductor 42. This insures the maintaining of a steep envelope in the pulse voltage signal reproduced at the conductor 42 after the lapse of time taken for the travel of the ions to the grid 15. The resolution is thus extremely high because the ion flow can be very sharply gated. If such steepness is not desired,

the shield 17 may be omitted and an ordinary collector electrode provided.

By controlling the magnitude or amplitude of the voltage signal, the time delay T_1 , Fig. 2, between the reproduced signal A_1 at the output conductors 40, 42 and the input voltage signal A_1 originally applied to the grids 5 and 7, may be varied. This is because the velocity imparted to the ions in passing from the grid 5 to the more negative grid 7 determines the transit time of the ions traveling through the medium of the envelope 1 to the collector grid 15. Thus, for example, a rectangular input-voltage pulse A_1 of 50 volts amplitude, with a hydrogen-gas medium of about one-tenth micron pressure, will produce an output pulse A_1 delayed by three microseconds, over a path between the grid 7 and the grid 13 of about twenty centimeters. With a pulse of one hundred volts, A_2 , Fig. 3, a shorter time delay T_2 , for the production of the output pulse A_2 , of about 2.1 microseconds will be produced. Thus it is evident, that by varying the amplitude of the voltage signal applied to the grids 5 and 7, the transit time may be varied. Different gases, moreover, have different transit times since their masses are different. With xenon, for example, about forty microseconds delay is produced in the same apparatus.

This phenomenon enables the present invention to be utilized where other delay devices cannot be used, since it provides for easily varying the delay time merely by controlling the input voltage. If the signal input were of saw-tooth form S, Fig. 4, or of any other desired changing-amplitude configuration, the ion velocity at successive instants of time imparted to the ions passing between the grids 5 and 7 will be successively varied and thus successively variable time delays T_3 , T_4 , etc., corresponding to input signal amplitudes A_3 , A_4 , etc., in the transit time of the successively transmitted ions will be produced. This would be useful for purposes of comparing the input signal with the output signal. This is, moreover, a method of converting amplitude modulation into time or frequency modulation. This sweeping or continually varying delay may be utilized in connection, moreover, with a modulated ionization carrier signal. This might be useful, also, for such purposes as detecting voltage information that is occurring in a background of noise voltages. This has application, for example, in trying to locate moving targets represented by successively received pulses in moving-target radar systems where there is considerable background noise.

If, as before stated, the device is to be utilized as a mass spectrometer with a mixture of a plurality of different gases, it is merely necessary to supply a step-function voltage signal F, Fig. 5, to the gating grids 5 and 7 so that the resulting output signals at the collector 15, 23 will take the form of successive steps of voltage signals M_1 , M_2 , M_3 , etc., Fig. 6. The first such step M_1 will be produced as gas ions of the lightest mass arrive at the collector 15, 23 with the shortest time delay; the second step M_2 indicates the arrival of the next heavier mass ions; and so on. The amplitude of each such step, moreover, is related to the quantity of that type of gas in the mixture. The gas mixture is preferably continually passed from an aperture, not shown, in the cap 28 through the apparatus and out of the aperture 48, for such spectrometry operation.

While the invention has been described in connection with a particular apparatus that has been found, by laboratory tests, to operate as described, it will be evident that many other types of apparatus may be similarly utilized in accordance with the invention. The regions 1, 3, 23, for example, may all be formed as a single unit; other ionization devices than the radio-frequency coil 21 may similarly be employed; different types of screen or other grid electrodes may be utilized; and so on. The invention may also be used for other purposes than those before described. Where voltage information is to be

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stored, in a computer, for example, it is applied to the input and is thus stored for the period of the time delay. The storage period may be varied from a short to a long period merely through control of the amplitude of the voltage information.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the present invention as defined in the appended claims.

What is claimed is:

1. An electric system having, in combination, a gaseous medium, means for ionizing a limited region only of the gaseous medium, electrode means disposed in the neighborhood of the said region and adapted to permit the travel of gas ions from the said region past the same, means for first applying a voltage to the electrode means in such polarity as to repel gas ions traveling towards the electrode means, means for thereupon applying a voltage signal of reverse polarity to the electrode means to cause gas ions to travel from the ionized region past the electrode means into another region of the medium, and means disposed at a distance substantially equal to or less than twice the mean free path of the gas from the electrode means for collecting the travelling gas ions in the said another region of the medium, the collecting means comprising a pair of closely spaced electrodes with the electrode of the pair that is closer to the first-named electrode means shielding the other electrode of the pair.

2. An electric system as claimed in claim 1 and in which a further electrode means is disposed along the said other region of the medium between the collecting means and the electrode means to trap ions scattered during their travel through the said other region.

3. An electric system as claimed in claim 1 and in which the said shielding electrode and the other electrode of the pair of electrodes comprise substantially parallel-wire grids.

4. An electric system as claimed in claim 1 and in which means is provided for varying the magnitude of the voltage signal correspondingly to vary the time of collection of the gas ions.

5. An electric system as claimed in claim 1 and in which the voltage signal is of pulse form and the electrode means comprises a pair of grids between which the pulse voltage signal is applied, the collected ions producing a further pulse voltage occurring at a time after the application of the first-named pulse voltage signal dependent upon the magnitude of the first-named voltage signal.

6. An electric system as claimed in claim 1 and in which the gaseous medium comprises a plurality of different types of gases whereby the time of collection of the gas ions of each different type of gas after the application of the voltage signal differs in accordance with the mass of the gas ions and the number of collected gas ions of each different type of gas differs in accordance with the quantity of each different type of gas in the gaseous medium.

7. An electric system as claimed in claim 1 and in which the voltage signal is of successively changing magnitude whereby the time of collection of the ions successively correspondingly changes.

8. An electric system as claimed in claim 1 and in which the said distance is substantially equal to or less than the said mean free path.

9. An electric system as claimed in claim 1 and in which the said pair of electrodes comprises a pair of substantially parallel-wire grids, and the said closer electrode of the pair is connected with a Faraday shield.

10. An electric system as claimed in claim 9 and in which the said other of the said pair of electrodes is connected to a signal output conductor extending through and insulated from the said Faraday shield.

11. An electric system as claimed in claim 1 and in

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which the ionizing means comprises modulated radio-frequency energy.

12. An electric system having, in combination, a gaseous medium, means for applying a radio-frequency carrier-wave to a limited region only of the gaseous medium to ionize the same in the said limited region only, electrode means disposed in the neighborhood of the said region and adapted to permit the travel of gas ions from the said region past the same, means for applying a voltage to the electrode means in such polarity as to repel gas ions traveling toward the electrode means, means for thereupon applying a voltage signal of reverse polarity to the electrode means to cause gas ions to travel from the ionized region past the electrode means into another region of the medium, and means disposed at a distance substantially equal to or less than the mean free path of the gas from the electrode means for collecting the traveling gas ions in the said another region of the medium, the collecting means comprising a pair of closely spaced electrodes with the electrode of the pair that is closer to the first-named electrode means shielding the other electrode of the pair.

13. An electric system having, in combination, a gaseous medium, means for applying a radio-frequency carrier-wave to a limited region only of the gaseous medium to ionize the same in the said limited region only, electrode means disposed in the neighborhood of the said region and adapted to permit the travel of gas ions from the said region past the same, means for applying a voltage to the electrode means in such polarity as to repel gas ions traveling toward the electrode means, means for thereupon applying a voltage signal of reverse polarity to the electrode means to cause gas ions to travel from the ionized region past the electrode means into another region of the medium, and means disposed at a distance substantially equal to or less than substantially twice the mean free path of the gas from the electrode means for collecting the traveling gas ions in the said another region of the medium, the collecting means comprising a pair of closely spaced electrodes with the electrode of the pair that is closer to the first-named electrode means shielding the other electrode of the pair.

14. An electric system having, in combination, a gaseous medium, means for applying a radio-frequency carrier-wave to a limited region only of the gaseous medium to ionize the same in the said limited region only, electrode means disposed in the neighborhood of the said region and adapted to permit the travel of gas ions from the said region past the same, means for applying a voltage to the electrode means in such polarity as to repel gas ions traveling toward the electrode means, means for thereupon applying a voltage signal of reverse polarity to the electrode means to cause gas ions to travel from the ionized region past the electrode means into another region of the medium, means disposed at a distance substantially equal to or less than substantially twice the mean free path of the gas from the electrode means for collecting the traveling gas ions in the said another region of the medium, the collecting means comprising a pair of closely spaced electrodes with the electrode of the pair that is closer to the first-named electrode means shielding the other electrode of the pair, and further electrode means disposed between the first-named electrode means and the collecting means to trap ions scattered during their travel through said another region.

15. An electric system having, in combination, a gaseous medium, means for applying a radio-frequency carrier-wave to a limited region only of the gaseous medium to ionize the same in the said limited region only, electrode means disposed in the neighborhood of the said region and adapted to permit the travel of gas ions from the said region past the same, means for applying a voltage signal of such polarity to the electrode means to cause gas ions to travel from the ionized region past the electrode means into another and un-ionized

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region of the medium, and means disposed at a distance substantially equal to or less than the mean free path of the gas from the electrode means for collecting the traveling gas ions in the said another un-ionized region of the medium, thereby to produce a time or frequency-modulated signal corresponding to the amplitude of the voltage signal, the collecting means comprising a pair of closely spaced electrodes with the electrode of the pair that is closer to the first-named electrode means shielding the other electrode of the pair.

16. An electric time-delay system having, in combination, a mono-gaseous medium, means for ionizing a limited region only of the mono-gaseous medium, electrode means disposed in the neighborhood of the said region and adapted to permit the travel of gas ions from the said region past the same, means for applying a voltage to the electrode means in such polarity as to repel gas ions traveling toward the electrode means, means for thereupon applying a voltage signal that is to be delayed to the electrode means in reverse polarity to cause gas ions to travel from the ionized region past the electrode means into another and un-ionized region of the

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medium, and means disposed at a distance substantially equal to or less than twice the mean free path of the gas from the electrode means for collecting the traveling gas ions in the said un-ionized region of the medium to produce a further voltage signal corresponding to the first-named voltage signal but delayed therefrom a period of time corresponding to the transit time of the mono-gas ions from the electrode means to the collecting means, the collecting means comprising a pair of closely spaced electrodes with the electrode of the pair that is closer to the first-named electrode means shielding the other electrode of the pair.

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