No 2.

"Electrokinetic Apparatus"

Docket No. 8309

Thomas Townsend Brown

N°2

"ELECTROKINETIC APPARATUS"

Thomas Townsend Brown
1236 Chestnut Street
San Francisco, California 94109

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COMMENTS:

Reference: A) U.S. Patent No. 2,949,550 - "Electrokinetic Apparatus"
B) U.S. Patent No. 3,018,394 - "Electrokinetic Transducer"

1) This patent application covers another method and means for producing movement of dielectric fluid, and to electrically control the flow thereof. It differs from the applicant's previous devices in that moving electrodes are employed. It may be said that the device combines electrokinetic and ~~aero~~ fluid dynamic principles. The device is superior in performance to the applicant's previous devices in that more energetic flow is obtained, the kinetic energy being supplied largely from the moving electrode(s). The present device has the disadvantage of employing moving parts, but this disadvantage may be offset by the more energetic flow, higher output pressure and greater pumping capacity.

2) Devices built along these lines may serve as pumps for dielectric fluids such as air and various gases, cryogenic fluids, oils and other non-conducting liquids. When the flow rate is electrically modulated, the device may be uses as a transducer or loudspeaker. The important advantage is the increase in effluent velocity and the relatively high pressure differential which can be produced.

3) In (A) movement is imparted to the fluid dielectric in the direction of the divergence of the electrostatic field (from the fine-wire electrode toward the large plate electrodes) by forces derived entirely from the electric field.

In (B) the electric field is modulated so as to produce corresponding variations in the pressure or rate of flow in the medium acted upon by the electric field.

In the present invention, applicant combines the electric field with one or more electrodes which are moving rapidly. The fluid medium in contact with said moving electrodes is subject to skin friction and the motion of the fluid which results is a combination of that provided by skin friction ~~with~~ and the applied electric field. Motion of the fluid can be modulated, with almost instantaneous response, by varying the electric field.

In the present invention, further advantage is derived by the change in viscosity of the fluid medium which is subjected to an electric field. This "hardening" of the fluid increases the skin friction with respect to the moving electrode so that additional kinetic energy is conveyed from the moving surface to the fluid flow. This change in viscosity in ferroelectric fluids is virtually instantaneous.

SUGGESTED SPECIFICATIONS:

1) This invention relates to electrokinetic apparatus for converting electrical energy into kinetic energy.

2) This invention relates to fluid flow-control devices whereby a varying electric input is made to control or regulate output pressure or flow of a dielectric fluid.

3) This invention relates to flow-control devices whereby relatively small electrical energy triggers or controls relatively large energy of fluid flow.

4) This invention relates to electrokinetic amplifiers.

5) This invention relates to electro-acoustic transducers, loudspeakers or the like, whereby an electric signal produces sound without the aid of a diaphragm.

1) This invention features a fluid-control system the response of which is practically instantaneous.

2) This invention features a pump which is relatively quiet.

3) This invention features a loudspeaker which operates with unusually high signal efficiency by reason of the fact that it is an electro-kinetic amplifier. This loudspeaker has no diaphragm and virtually no inertial or Doppler distortion.

4) This invention features a loudspeaker which has especially good low-frequency response, free from resonance peaks or mechanical distortion.

5) This invention features a dielectric pump whereby the energy of a moving impeller electrode is translated to fluid flow using electrically-created viscosity changes as the coupling mechanism.

Referring to the attached drawings:

Fig. 1 is a circuit diagram setting forth the simplest aspect of the invention by which the flow of a dielectric fluid is created and/or controlled.

Fig. 2 is a diagram showing an alternative arrangement including counter-rotating electrodes with electric field therebetween to cause fluid flow.

Fig. 3 is a diagram of the invention (similar to Fig. 1) showing a single rotating electrode and ionizer wire in perspective.

Fig. 4 is a diagram illustrating the manner in which the direction of fluid flow may be controlled.

Fig. 5 is a diagram showing the essential circuit of the device used to produce flow pulses from a signal input.

Fig. 6 is a similar diagram showing the application of a triode for amplifying the signal input to the modulating system.

Fig. 7 is a circuit diagram illustrating a multiplicity of counter-rotating electrodes together with associated high voltage power supply and vacuum tubes for the purpose of creating "push-pull" action on the fluid dielectric in which the electrodes are immersed. This diagram describes the means of operation of a multi-electrode loudspeaker for "push-pull" operation.

Referring in more detail to the attached drawings:

Fig. 1 illustrates the simple circuit of the invention. It is a diagram showing revolving electrode 1, being a rod or cylinder maintained in a state of continuous rotation by a motor or the like (not shown). A second electrode 2, being an emitting point, is held in fixed spaced relationship near the moving surface of electrode 1.

These electrodes are energized by high voltage power supply 3 and controlled by switch 4. The power supply 3 may produce an output of either direct or alternating current, but direct current is preferred in most instances. It is found that the voltage, depending upon the emissivity of point 2, should exceed 7,500 volts and normally ranges to 25 or 30 KV for practical purposes.

When switch (4) is closed and emitting electrode 2 becomes highly charged, a divergent electrostatic field is created between electrode 2 and the larger surface of electrode 1. Ions created near electrode 2 flow in the direction of electrode 1 and transfer their momentum to the host medium (air, oil or similar dielectric fluid) and increase the fluid pressure against the moving surface of electrode 1.

Since this surface is in rapid motion skin friction causes the medium in contact therewith to circulate along the rotation of the electrode. An impinging flow, normal to the direction of flow produced by skin friction, causes a resultant flow outward and away from the rotating electrode in the direction shown by the arrow. This outward flow is observed to vary with the amount of potential applied to electrode 2. The magnitude of the flow is such as to indicate that the kinetic energy is derived from the rotating electrode rather than from the electrical field between the electrodes.

In the above description of the operation of the device, the action has been attributed largely to the migration of ions and the transfer of momentum from the ions to the host medium, hence to create an aerodynamic pressure upon the face of the rapidly spinning electrode. This pressure in turn affects the fluid movement resulting from skin friction, so that a net outward flow is produced as indicated.

However, it must be understood that another physical principle is at work also. This second effect is produced by the action of the electrical field upon ferroelectric fluids and is practically instantaneous. The electric field changes the viscosity of the fluid and is a function of electrical permittivity (dielectric constant). It is analogous to the change in viscosity of oils which are loaded with iron powder (having high magnetic permeability). This principle (so far as it relates to ferromagnetic fluids) is used and well-known in the magnetic clutch art.

As stated above, the change in viscosity of the fluid with the application of the electric field is immediate. This change is sensed as increased surface friction at the face of the rotating electrode where the electric field is greatest (nearest electrode 2) and this, in turn, produces tangential flow. In the case of air, this latter effect is somewhat dependent upon ionization, and this dependence arises from the fact that ionization increases the dielectric constant of air.

Fig. 2 illustrates the thrusting action caused by a pair of differently-charged counter-rotating electrodes upon a ferroelectric ~~field~~ fluid in the region between said electrodes. As stated earlier, the electric field established between the charged electrodes causes any ferroelectric fluid (embracing most dielectric fluids) to undergo a change in viscosity. This "hardening" of the fluid increases the skin friction at the surface of the moving electrodes, hence conveying increased kinetic energy or thrust to the flow. Electrodes 1 and 1a, usually in the form of counter-rotating cylinders, are insulated from each other and connected to a driving motor (not shown). When switch 4 is closed, so as to apply a high potential between said cylinders, the electric field therebetween increases the fluid viscosity, causing the increased flow as indicated by the arrow.

A variation in the potential difference applied to counter-rotating electrodes causes instantaneous and corresponding variations in the pressure or rate of flow.

Fig. 3 is a circuit diagram (similar to Fig. 1) but showing the electrodes in perspective. This structure is also adapted for creating flow pulses or sound waves. Revolving electrically-conductive cylinder 1 is maintained in continuous high speed rotation (as indicated by arrow) by motor 6 which is powered from an independent source. Filaform electrode 2 consisting of a fine stainless steel wire or the like .0015" to .0025" in diameter is positioned to one side of electrode 1 with a fixed distance of separation normally between ½ to 1 ". High voltage power supply 3 supplies DC potential so that electrode 1 is the cathode and electrode 2 is the anode. Reverse polarity is operative but not as satisfactory in most instances.

Transformer 5 steps up a low voltage input signal to corresponding high voltage output so as to vary the potential supplied to the electrode structure. As in Fig. 1, when electrode 2 acquires a high potential, an electric field is created between the electrodes so as to cause increased flow as indicated by the arrow. When the device is operated in air, as a loudspeaker, the electrode structure serves as a transducer to generate sound waves from the signal input to transformer 5. It is to be understood that the energy represented by the sound waves is derived, in the main, from the kinetic energy of the rotating cylinder 1 and the power feeding the electric motor driving the cylinder. In this respect, the signal input merely supplies the control current in the production of the flow pulses or sound waves. As such, the system may be also defined as an electrokinetic amplifier.

Fig. 4 is a circuit diagram showing counter-rotating electrodes 1 and 1 a (driving motor not shown) and emitting electrode 2 which is energized from the slider of rheostat 7 connected to a source of high voltage 3. When slider is in position "B" fluid is driven outward from the counter-rotating electrodes in the general direction of B'. When slider is shifted to position "A" airflow is deflected in the direction of A'. Similarly when slider is in "C" position, airflow is deflected in direction of C'. This form of the invention illustrates the manner in which the resultant fluid flow may be shifted. This shifting is virtually instantaneous and does not depend on a moving vane to alter the direction of flow.

Fig. 5 shows a system of counter-rotating cylinders for the production of flow pulses (as in the earlier figure), counter-rotating electrodes 1 and 1a are in close proximity, with electrode 2 midway (and slightly to one side of center) between them, power supply 8 and step-up transformer 9 supply positive potential to electrode 2 according to signal input to transformer 9.

Flow pulses or sound waves are generated in the region between the counter-rotating electrodes 1 and 1a by rapid changes in the potential of electrode 2.

Fig. 6 is a circuit diagram similar to the above but using vacuum tube triode 11 in place of transformer 9 to modulate the potential applied to electrode 2. Resistor 10 supplies plate potential to triode 11 and, at the same time, permits the plate of the triode to engage in voltage swings as the result of a signal input to grid of triode 11.

This system for modulating is to be preferred over that illustrated in Fig. 5 and is the basic circuit for a bass-response loudspeaker.

Fig. 7 is a suggested circuit for a multiplicity of counter-rotating electrodes especially adapted as a bass-response loudspeaker. Cylindrical electrodes 1, 1 b and 1 d are adapted to rotate in the same direction. Cylindrical electrodes 1 a, 1 c and 1 e are adapted to rotate in the opposite direction. Both sets of electrodes are kept in continuous rotation by motor 6.

Both sets of rotating electrodes, including the driving shaft of the motor, may be electrically grounded along with the negative output side of the high voltage power supply 8.

Fig. 7 (continued)

Emitting anodes 2, 2 b and 2 d are electrically connected together to the plate of triode 12 and to resister 16, thence to the positive side of the output of power supply 8.

Emitting anodes 2 a and 2 c are connected to the plate of triode 13 and to resistor 17, thence to the positive side of the output of the high voltage power supply 8.

Signal input is applied to the primary of transformer 14, the secondary of which provides "push-pull" signals to the grids of tubes 12 and 13 respectively. Bias supply 15 is shown in connection.

In operation, the input signal provides "push-pull" operation to the emitting electrodes so that pressure pulses are created between the rotating electrodes first in one direction then the other. This "push-pull" operation generates sound outward from the electrode structure and normal to the plane of the electrodes.

In electrode structures, where the degree of ionization is important, it may be advantageous to increase the emissivity of the electrodes, i.e., the anodes for the emission of positive ions and the cathodes for the emission of negative ions. Coating electrodes with such materials as cesium or barium chloride, thorium oxide or certain radioactive materials may be resorted to whenever indicated.

In certain special cases, operation is improved by heating the ionizing wires to provide thermal ionization and the emission of thermions. Toward this end, the fine-wire anode may be heated by including the same in a resistance-heating electrical circuit. Since this is an obvious arrangement it is not shown specifically in the drawings.

Where very high voltages are used or when inter-electrode spacing is small, it is found desirable in some cases to use rotating electrodes of poorly conducting material. The reason for this is to prevent damaging electrical break-down across the air gap between the electrodes. When said rotating electrodes are fabricated of a material (such as a plastic loaded with carbon powder) so as to have a resistivity in the range from 10^6 to 10^{10} ohms per cubic centimeter, the possibility of damaging spark breakdown to the surface of the rotating electrodes is virtually eliminated. The use of a high resistance coating on rotating metallic tubes or rods may serve the same purpose. The low conductivity prevents localization of an intense electric field which must precede spark breakdown.

There may be many variations in the form of the rotating electrodes or the manner of rotating the same, or the form of the ionizer electrode or its relative position in the system, without departing from the spirit of the invention as set forth in the following claims:

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CLAIMS:

1) Method for creating flow of dielectric fluid consisting in immersing a pair of counter-rotating electrodes in said fluid, applying a high voltage between said electrodes and utilizing the ferroelectric change in viscosity to effect a pumping action.

2) Method for controlling flow of dielectric fluid through a valving system consisting in directing said flow between rotatable electrodes, maintaining said electrodes forcibly in counter-rotation by an external motor, applying a variable electrical potential difference to and between said electrodes to effect control of flow.

3) A valving system for dielectric fluid comprising a pair of electrodes maintained in counter-rotation by a motor, means for applying an electrical potential difference to said electrodes and means for varying said potential for the purpose of controlling flow of the fluid engaged between said electrodes.

4) Means for pumping dielectric fluid comprising counter-rotating electrodes, means for applying electrical potential difference between said electrodes and means to utilize the fluid flow generated in the region between said electrodes.

5) A pump for dielectric fluid comprising a rotating impeller and means for maintaining an electric field around said impeller.

6) Means for increasing the capability of a pump for dielectric fluid comprising establishing an intense electric field around the impeller thereof.

7) Means for varying the output pressure of a pump for dielectric fluid by varying the electric field around the impeller thereof.

8) An electrokinetic loudspeaker comprising rotating electrodes and means for supplying a varying electrostatic field between said electrodes to generate sound waves in said field.

9) Apparatus for generating sound waves comprising a pair of counter-rotating cylindrical electrodes together with means for differently-charging said electrodes with an input signal.

10) Apparatus for pumping dielectric fluid comprising a multiplicity of pumping stages in accordance with claim 4.

11) Method for creating flow of ionizable dielectric fluid consisting in immersing a rotatable electrode in said fluid, arranging in close proximity to said rotatable electrode an ionizing electrode, forcibly rotating said rotatable electrode by an external motor, supplying potential to said ionizing electrode and utilizing the resultant interaction to create flow tangentially from the surface of said rotating electrode.

CLAIMS (Continued)

12) A valving system for ionizable dielectric fluid comprising a pair of electrodes maintained in counter-revolution by a motor, an ionizing electrode positioned between said rotating electrodes and means to supply a variable potential to said ionizing electrode.

13) A multiplicity of rotating electrodes and ionizing electrodes in accordance with claim 12 for increasing the capacity of said valving system.

14) In a system according to claim 12, the use of coatings applied to the electrodes thereof to improve the emissivity of said electrodes.

15) In a system according to claim 12, the use of partially-conducting materials in the electrodes thereof to prevent electrical breakdown between said electrodes.

16) In a system according to claim 3, the use of vacuum tubes in combination therewith to modulate the electrical potential applied to the said electrodes.

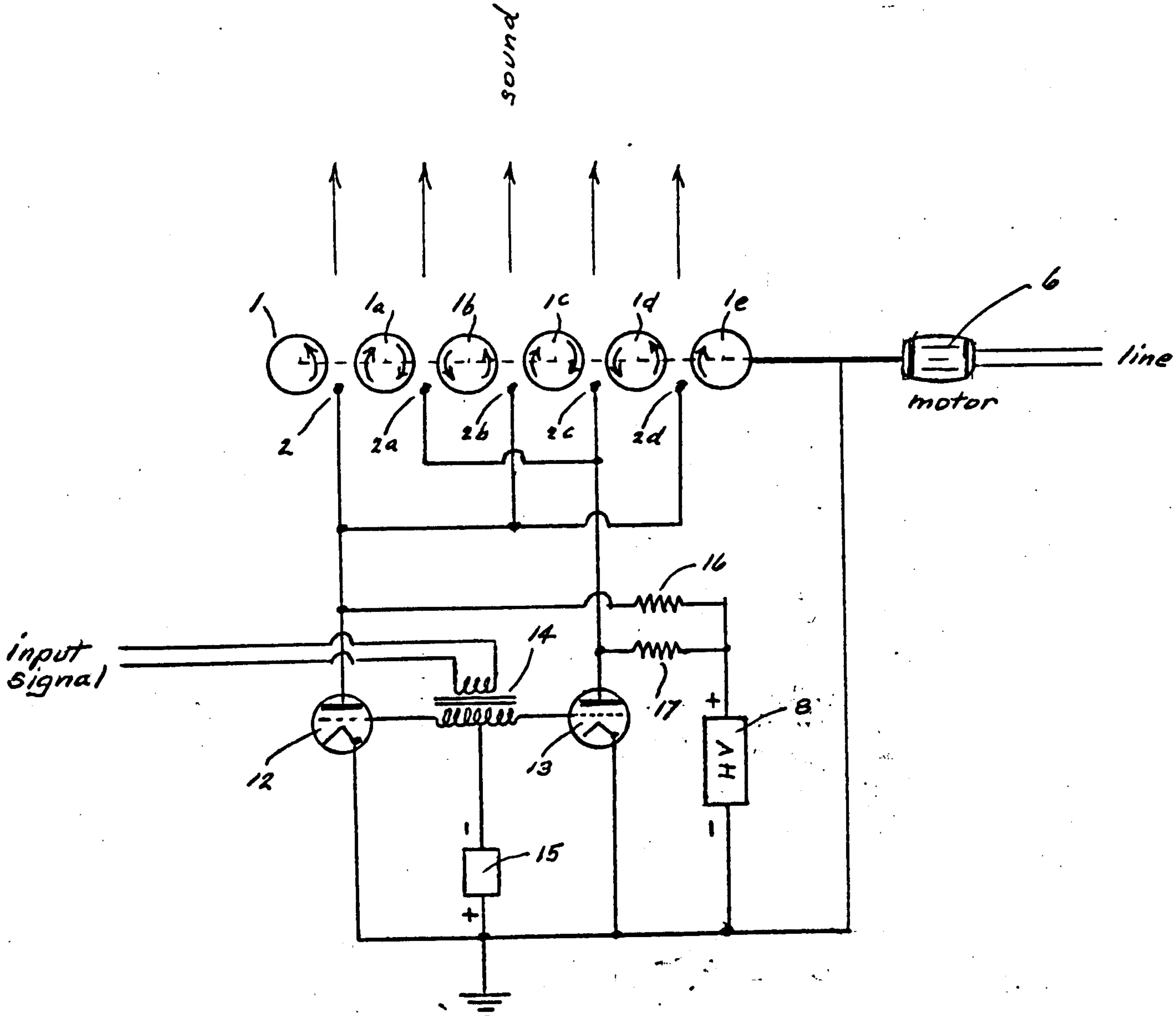
17) In a system according to claim 12, the use of vacuum tubes in combination therewith to modulate the electrical potential applied to said ionizing electrode.

18) A loudspeaker including a multiplicity of rotating electrodes and ionizing electrodes in planar array to enlarge the wave front of the emitted sound.

19) A loudspeaker utilizing a multiplicity of rotating electrodes and ionizing electrodes in push-pull electrical relationship to improve and intensify the sound emission.

20) Electrokinetic apparatus to control the flow of dielectric fluid between the electrodes thereof consisting of a multiplicity of electrically-grounded rotating electrodes and highly-charged ionizing electrodes in close proximity thereto to which a varying control potential is applied.

Thomas Townsend Brown
San Francisco, California
June 8, 1967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motor
2
2a
2b
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signal
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17
8
+
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12
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Fig. 7.

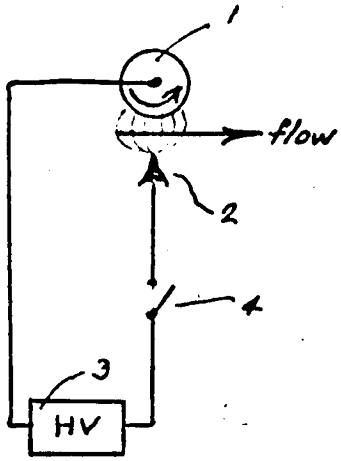

Fig. 1

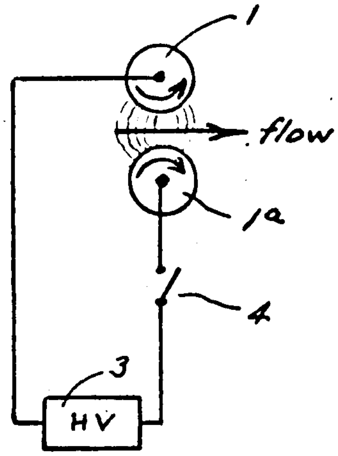

Fig. 2

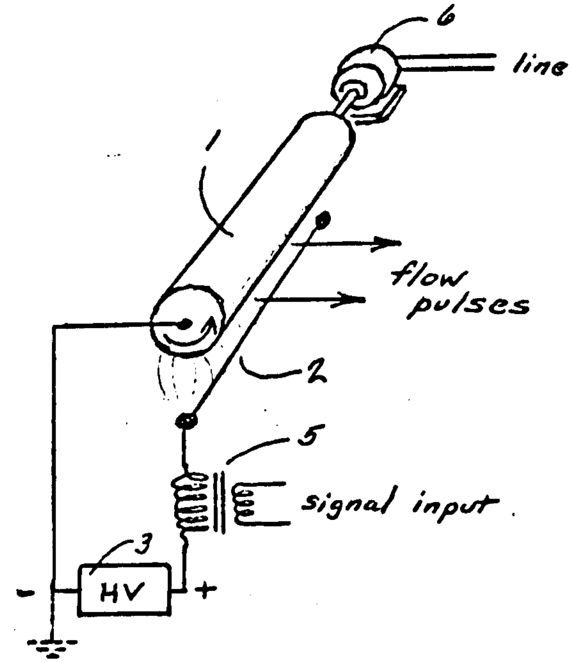

Fig. 3

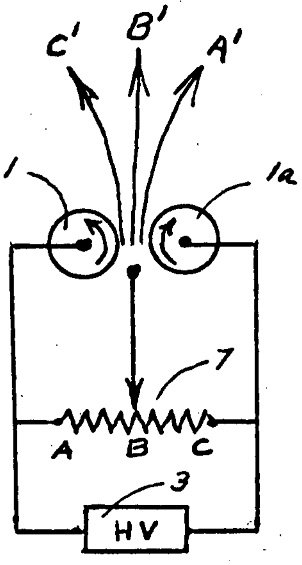

Fig. 4.

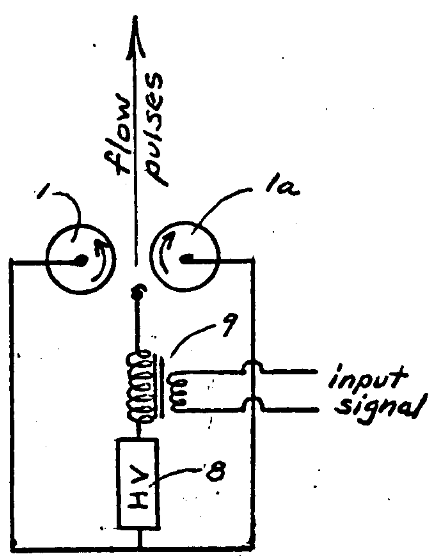

Fig. 5.

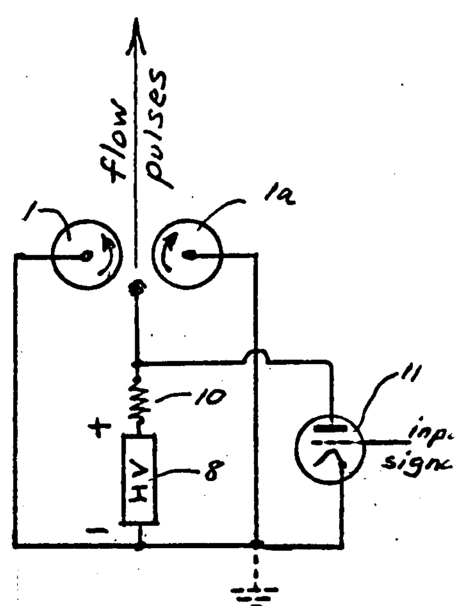

Fig. 6