Nov. 4, 1941. H. M. STROBEL 2,261,507

MAGNETICALLY CONTROLLED DISCHARGE DEVICE

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Fig. 1.

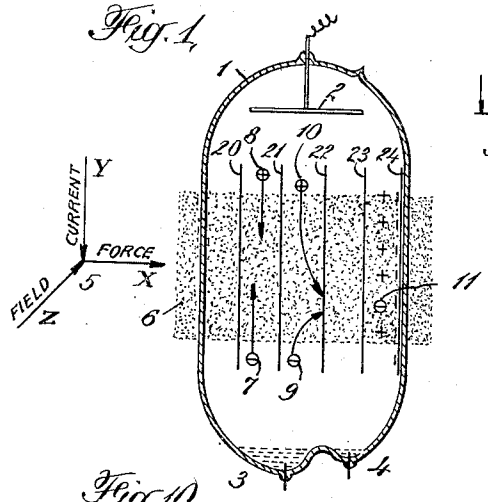


Fig. 5.

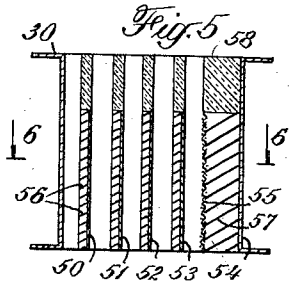


Fig. 6.

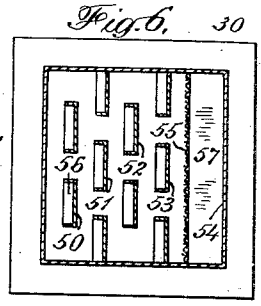


Fig. 8.

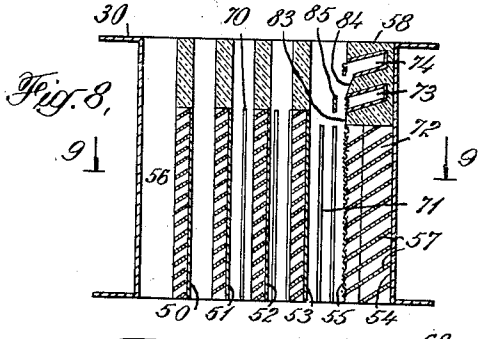


Fig. 10.

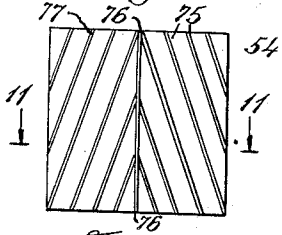


Fig. 11.

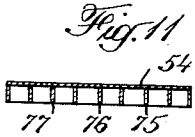


Fig. 3.

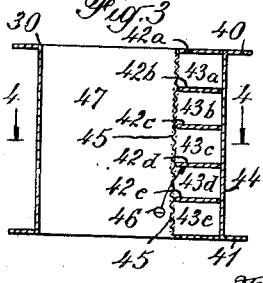


Fig. 4.

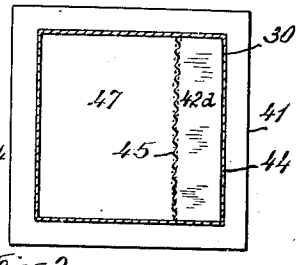


Fig. 9.

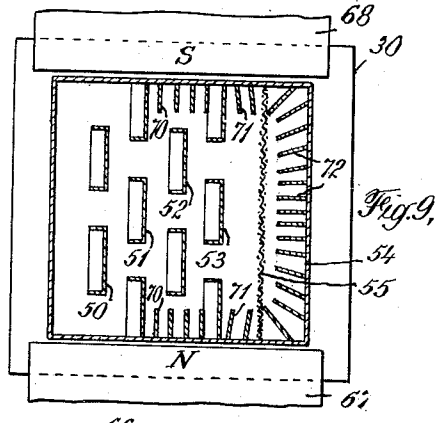


Fig. 2.

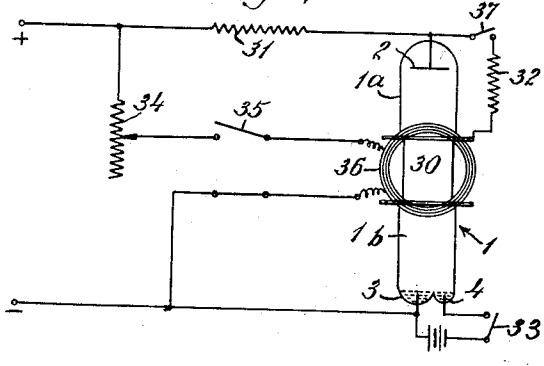
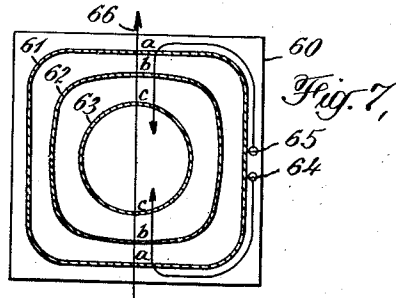


Fig. 7.



INVENTOR
Howard M. Strobel
BY
Marshall & Hawley
ATTORNEYS

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Fig. 12.

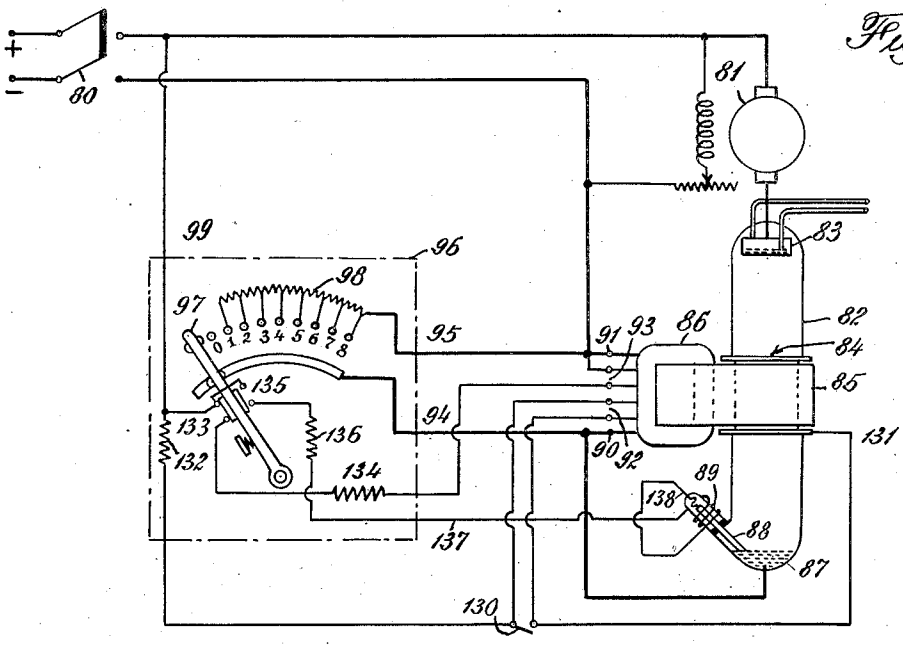
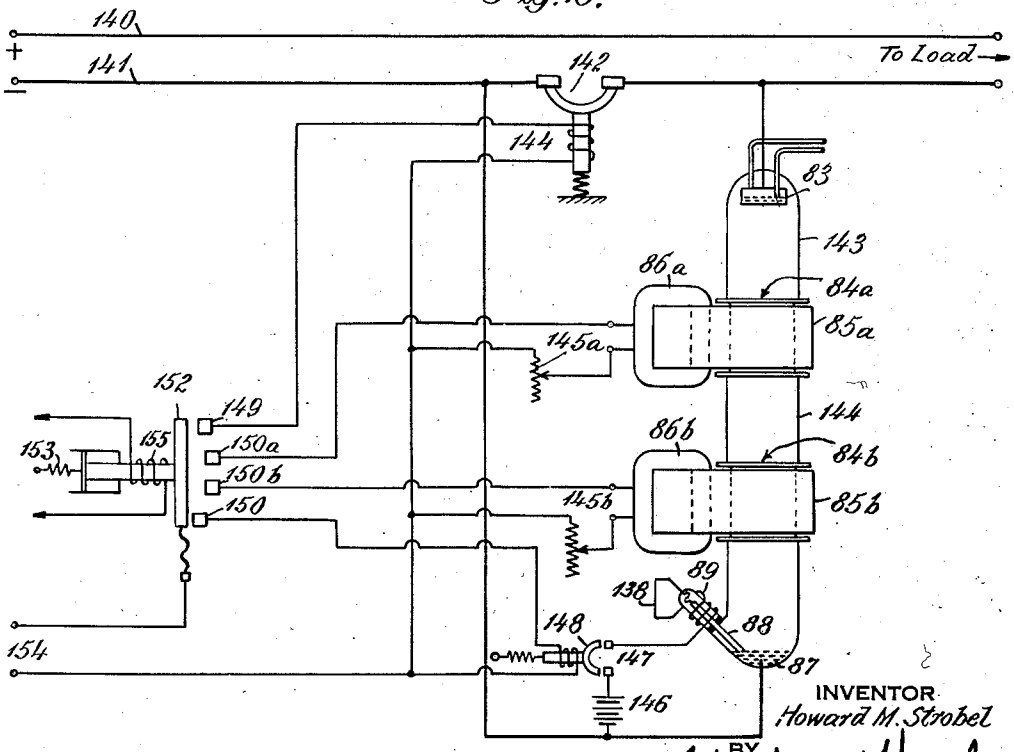


Fig. 13.



INVENTOR
Howard M. Strobel
BY
Marshall & Hawley
ATTORNEYS

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MAGNETICALLY CONTROLLED DISCHARGE DEVICE

Howard M. Strobel, Allegany, N. Y.

Application February 3, 1940, Serial No. 317,133

16 Claims. (Cl. 250—27.5)

This invention relates to improvements in a magnetically controlled discharge device and particularly to devices in which an electric current is carried between two electrodes by conduction of gaseous ions and in which the current is modified or controlled by the use of a magnetic field deflecting the discharge within the confines of a specially constructed third member or deionization chamber interposed between the two electrodes and substantially surrounding said discharge.

It is the object of the invention to provide apparatus capable of breaking a direct current of substantial strength as to current and voltage, without the direct use of solid contacts or switches.

It is well known that a pure electronic current may be maintained between an electron emitting cathode and an anode at a higher potential, and that if an ionizable medium, such as a gas, is present the initial primary electrons will render the gas conductive by a process of accumulative ionization, and produce thereby an electrical discharge containing both electrons and positive ions. Controlling these primary electrons, either by electrostatic or magnetic means, affords an easy method of timing the instant of initiation of the ionized discharge in devices utilizing ionizable mediums for current carrying purposes. Once the ionized discharge starts, however, the positive ions therein prevent the re-establishing of control either by electrostatic or magnetic deflection action, since neither of these methods alone provide a deionizing action capable of disrupting the discharge. Control in such devices is re-established by removing the anode potential or, as in alternating current practice, by making the anode negative (as by reversing the anode potential).

Disrupting a discharge through an ionized medium, containing both positive and negative charges, by magnetic means has met with but limited success. Increasing the length and thereby the resistance of the discharge path by magnetic deflection has been proposed, but the low voltage drop of arc path per unit length requires excessive distension of the discharge path if anode voltages other than those that are critically adjusted to be just slightly above the minimum required ionizing potential of the ionized medium are to be disrupted. "Crushing" the ionized discharge against a surface or collector plate by the application of increasingly stronger magnetic fields has also been proposed, but it has been overlooked that resulting electrostatic forces of attraction, due to the positive space charge layer, and of repulsion, due to the negative charge created on the stopping surface, oppose or balance the magnetically derived deflecting forces exerted upon the moving electrons, and that since these electrostatic forces increase substantially in direct proportion as the applied magnetic field, no appreciable gain in disruptive capacity is obtained.

It is the purpose of this invention to provide improved means for deionizing, and hence disrupting an electrical discharge through an ionizable medium by the use of a transverse magnetic field in conjunction with a deionizing and trapping member which is so designed in its structural form as to overcome those difficulties that previously limited the effectiveness of magnetic control. Surface elements of the deionizing member against which the moving charges are magnetically deflected are provided with small fin-like surfaces projecting therefrom to reduce the chances of the glancing angle of impacts which favor the emission of secondary electrons. Concerning the resultant electrostatic forces which oppose the magnetic deflecting forces, the effectiveness of the repulsive component is decreased by placing a shielding screen or member a short distance in front of the stopping plate so that once the electrons pass the shielding screen they are partially shielded from the repulsion effects of the negative charge on the stopping plate, while the effectiveness of the attractive component is decreased by providing conductive plates or members substantially parallel to the line of magnetic deflection of the moving charges, so that the attractive force between the positive space charge layer and the deflected electrons is greatly reduced. Application of the above two methods for aiding the deionizing action of the magnetic field results in a stopping surface comprising a plurality of shielded pockets wherein the electric charges may be more easily trapped by the applied magnetic field. Since the applied transverse magnetic field can only deflect charges moving across or transverse to the magnetic flux lines, a re-distribution of space charges may take place within the deionizing or trapping member tending to distort the electrostatic field so as to favor the movement of the charges parallel to the magnetic flux lines. According to my invention, flux-line leakage of this type is restricted by channelizing the confining surfaces in directions at right angles to the anticipated flux-line leakage flow.

More particularly the invention consists in a

novel construction and combination of parts, certain embodiments of which are illustrated in the accompanying drawings and described in the following specification and its novel features are defined in the claims appended hereto, it being understood that various changes in form, proportion and size and minor details of construction within the scope of the claims may be resorted to without departing from the spirit or sacrificing any of the advantages of the invention.

For a clearer comprehension of the invention reference is directed to the accompanying drawings which illustrate a preferred embodiment thereof, wherein:

Figure 1 shows the general arrangement of a deionizing chamber and other elements of a device which embodies my invention.

Figure 2 is a schematic diagram showing how such a device may be connected up for operation.

Figure 3 shows a side view of a simple form of a deionizing chamber and Figure 4 is a sectional plan view of the device in Figure 3.

Figure 5 is a side view and Figure 6 a sectional plan view of a modified form of deionizing chamber.

Figure 7 is a sectional plan view diagrammatically illustrating the deionizing chamber indicating the relative positions and shape of equipotential surfaces and the direction of the magnetic lines of force as indicated by an arrow.

Figure 8 is a sectional side elevation of another modified form of deionizing chamber, in which provision is made to limit leakage of charges along parallel electro-static and magnetic flux lines.

Figure 9 is a sectional plan view of the device shown in Figure 8 taken through the plane indicated by the lines 9—9; also the position of the magnet pole faces with respect to the deionization chamber is shown in this figure.

Figures 10 and 11 show in elevation and sectional plan view respectively an alternative arrangement for the vertical fins used in Figure 8 for the right hand side stopping plate.

Figure 12 is a diagrammatic illustration of one application of the device as a variable resistor and current limiter for motor operation.

Figure 13 is a similar representation of the devices for interrupting current at high voltage.

In Figure 1 the numeral 1 designates a tube or envelope within which is an anode electrode 2 with external connection, and mercury pool cathodes 3 and 4 each with external connections. In the central region of the tube between the cathodes 3 and 4 and the anode 2 is arranged a plurality of non-magnetic conducting plates 20, 21, 22, 23 and 24 spaced substantially parallel with one another. If mercury vapor is used in the tube, the metal for the plates should be such as not to amalgamate therewith. An electromagnet is provided external to the tube capable of producing a magnetic field transverse to the vertical axis of the tube and parallel to the plates throughout the indicated region 6. Such a magnet is shown in Figure 9. The relative directions of the current, magnetic field, and resulting deflecting force is illustrated graphically at 5. The three axes at 5 are perpendicular to each other. The vertical axis Y indicates the direction of current flow (of positive charges) through the tube; the perpendicular axis Z indicates the direction of the applied magnetic field; and the axis X indicates the direction of the deflecting force upon the current carrying discharge. In this and subsequent discussion the choice of direction of the magnetic field will be assumed such as to always cause deflection of the discharge toward the right or X-direction.

In Figure 2 is shown schematically the external circuits by which the tube may be operated. The tube 1 is shown in Figure 2 in a more practical embodiment, in which the parallel central plates are located in the conductive non-magnetic central member, or deionizing chamber 30, and the separate anode and cathode ends of the envelope 1a and 1b sealed to the member 30. The external connection of the anode 2 is connected through a suitable load resistor 31 to the positive end of the direct current line, while the external connection of the cathode mercury pool 3 is connected to the negative side of the line. Across the main cathode 3 and the auxiliary cathode mercury pool 4 is a low voltage source controlled by the switch 33. The magnetic field is applied across the deionizing chamber 30 by the coil 36 when it is energized by the line voltage acting through limiting resistor 34 and the control switch 35. For ease in starting the anode discharge deionizing chamber 30 may be connected to the anode 2 through a high limiting resistance 32 controlled by a switch 37.

To start the discharge, the switch 33 is closed causing a current to flow in the auxiliary circuit through the mercury pools 3 and 4. By tipping the tube the mercury pools in 3 and 4 can be made to separate, which causes a spark or arc to form. This acts as a source of electrons which are attracted toward the chamber 30 when the switch 37 is closed, and initiates a discharge to 30. Due to the high resistor 32, however, the potential of 30 is lowered and the discharge immediately strikes through 30 to the anode 2. Once the discharge is started, switches 33 and 37 may be opened if desired. In order to apply a transverse magnetic field across the member 30 it is then merely necessary to close switch 35.

Referring back to Figure 1, let it be assumed that a discharge is taking place through the tube from the anode 2 to the cathode 3 and that the transverse magnetic field is zero. Under these conditions a positive ion at point 8 would travel downward from anode 2 to cathode 3 as indicated by its arrow. Similarly, a negative ion or electron at 7 would travel upward from cathode 3 to anode 2 as indicated by its arrow. If now the magnetic field were applied, a positive ion at 10 and an electron at 9 would be deflected substantially as indicated by their respective arrows into the plate 22. If the electron 9 were moving at a high velocity when it strikes the plate 22 it may knock secondary electrons out of the plate which would tend to contribute toward maintaining the discharge. This type of secondary emission can be reduced by constructing the plates out of a material having a very high "work function," where "work function" may be defined as the amount of energy that must be expended to force an electron out of an atom of the plate material. Secondary emission can also be reduced by so shaping the plates as to reduce the chances of glancing blows which favor it, or by causing the striking to take place in a region where any ejected secondary electrons can be trapped, as will be more fully described in connection with Figures 3 and 5.

If we assume that Figure 1 has but one con-

ducting plate 24 and the discharge is magnetically deflected into it, the preponderance of electrons in the discharge will cause the plate to become negative and tend by repulsion to balance the magnetic deflecting force acting on the electron indicated at 11. Further, a positive ion space charge will build up in the space in front of the plate, and will tend to maintain an electrostatic attractive force to the left which partially balances the magnetically derived deflecting force to the right. If another plate 23 is placed in front of the stopping plate 24 and conductively connected thereto, the negative charge will be distributed between the two plates and the electro-static repulsive forces acting on electron 11 between them will balance out. In a similar manner, the lines of electro-static force extending out from the layer of positive ion space charges indicated by + will be partially diverted by and through the plate 23. Thus the plurality of connected conductive plates 20, 21, 22, 23 and 24 tend to redistribute the concentration of electric charge caused by the magnetic deflection of the discharge, and so reduce the building up of electro-static forces which would otherwise prevent the magnetic field from acting effectively. It will be noted that merely increasing the magnetic field itself without end or limit is no solution, since the opposing electro-static forces build up in direct proportion.

Using a plurality of plates 20, 21, 22, 23 and 24 as in Figure 1 is an advantage in that each plate acts as the stopping plate for the deflected ions in the ionized channel to the left of it thus more quickly deionizing the discharge. In actual practice, however, as soon as the magnetic field is applied, the discharge is cleared from all but one channel in which the discharge tends to concentrate or "hang." By arranging connecting openings or slots through each of the central plates so as to give some ion conduction between channels, the final deionizing action of the discharge will invariably occur at the extreme right stopping plate 24. Since the final action of deionizing occurs at the right hand major stopping plate, the other minor plates need not be made as elaborate as it. This type of construction is shown in the improved arrangement within the deionizing chamber 30 shown in Figures 5 and 6.

In Figure 3 is shown a vertical section of one form of construction within the trapping member or deionizing chamber 30. The metal within the chamber 30 is preferably non-magnetic and non-amalgamated by mercury. Aluminum is satisfactory in these respects. The deionizing chamber 30 is provided with a top sealing flange 40 and a bottom sealing flange 41, which facilitates attaching the anode end 1a and the cathode end 1b of the envelope, in the manner depicted in Figure 2.

The side 44 of the deionizing chamber 30, serves as the stopping plate. Joined to the stopping plate 44 are a plurality of trapping plates 42a, 42b, 42c etc., arranged substantially perpendicular to the longitudinal axis of the deionizing chamber and spaced so as to form trapping pockets 43a, 43b etc. The front of the pockets 43a, 43b etc., are closed with a wire mesh screen or grid 45 joined or welded to the inner edges of the trapping plates 42a etc. The aforesaid parts are all joined conductively to the chamber element 30.

When the tube is in operation and with a discharge flowing through the channel 47 of the deionizing chamber 30 in Figures 3 and 4, an electron at point 46 would be deflected into the trapping plate 42d as indicated by the arrow. By thus striking the trapping plate 42d substantially perpendicular to its line of travel, the electron 46 has less chance to eject secondary electrons from the metal than if it were to hit the plate a glancing blow. Further, if secondary electrons were ejected, they would be inside the pocket 43d, and hence electro-statically shielded from electro-static forces existing in the channel 47 outside the pockets 43a etc. The wire mesh screen or grid 45 aids in more effectively shielding the pockets from the electro-static forces existing in the channel region 47 of the gaseous discharge.

Figure 5 shows a modified form of construction for the arrangement within the trapping member or deionizing chamber 30. A plurality of stopping plates 50, 51, 52, 53 and 54 are positioned parallel to the longitudinal axis of the deionizing chamber and substantially perpendicular to the direction of magnetic deflection of the discharge. On each of the stopping plates 50, 51, 52, 53 and 54 are mounted a plurality of parallel trapping plates or fins 56, 57, these trapping fins being inclined somewhat to the horizontal cross-section plane of the chamber 30. Inclining the trapping fins downward aids in trapping the electrons and in preventing the accumulation of metallic mercury inside the pockets. The anode ends of the stopping plates 50, 51, 52, 53 and 54 are covered over with insulative material as at 58. As is evident from Figure 6, each of the stopping plates 50, 51 52 and 53 is provided with vertical slots or openings which join adjacent channels. The slots made in adjacent stopping plates, as 50 and 51, are staggered, so that the maximum width of any channel in the direction of magnetic deflection of the discharge is maintained at a minimum. The pockets formed by the plurality of trapping fins 57 on stopping plate 54 are covered with a wire mesh screen 55.

Referring to Figures 5 and 6, when the discharge is flowing normally through the tube and deionizing chamber 30, it pervades the whole of the available channels provided. On application of the magnetic field each of the minor stopping plates 50, 51, 52 and 53 aids in quickly clearing their respectively adjacent channels of ionized charges, and the major part of the discharge is brought up against the major stopping plate 54, where the final deionizing and disrupting of the discharge takes place. The vertical slots or openings staggered in adjacent minor stopping plates provide means of connection between channels and so prevent the concentrating action of the magnetic field upon the discharge from "hanging" it in one of the minor channels. In this manner, the final deionizing action of the discharge occurs at the last major stopping plate 54, which is therefore more elaborately constructed. The insulative material which protects the anode end of the stopping plates is used to decrease the possibility of positive ion bombardment of the plates causing secondary emission thereon and thus forming hot spots at the anode end of the chamber 30.

In Figure 7 the drawings represent a top view of a horizontal cross-section taken through a deionizing chamber 60, to show theoretically the arrangement of equipotential surfaces 61, 62 and 63, within the deionizing chamber 60. In operation, when the magnetic field is applied, the volt-

age drop across the deionizing chamber **60** tends to rise; that is to say, the number of equipotential surfaces through the region tends to increase and crowd together. Since the metallic deionizing chamber **60** can be grounded to the cathode without effecting the tube's operation, the casing **60** can be assumed an equipotential surface at ground potential. Since the discharge is still maintained through the chamber **60**, the more positive equipotential surfaces **61**, **62** and **63** must extend themselves like columns or fingers down through the openings in the deionizing chamber toward the cathode. This distortion of the equipotential surfaces is due to the realignment of the positive ion space charges in the ionized vapor which form positive ion sheaths that in effect act like a flexible column or extension of the anode itself. The arrow **66** represents the direction of the applied magnetic field across the deionizing chamber **60**. The arrow **66** or magnetic lines of force parallel to it pass through the equipotential surfaces **61**, **62** and **63** at the points indicated as *a*, *b* and *c* respectively. Remembering that the electro-static lines of force are always perpendicular to the equipotential surfaces, it will be seen that they are thus parallel to the magnetic lines of force at the points *a*, *b* and *c*. The magnetic field will tend to concentrate the moving electrons in the region **64**, **65**, from which they will tend to migrate along the indicated arrow paths **64**—*a*—*b*—*c* and **65**—*a*—*b*—*c*. To prevent this sidewise migration of charges when the magnetic field is applied, baffle fins may be placed along the walls of the deionizing chamber which are so oriented as to restrict this type of charge migration, as is illustrated in Figures 8 and 9.

Figures 8 and 9 are similar to Figures 5 and 6 respectively, and have identical parts numbered the same, but are provided with other features, which will be described. Referring to Figures 8 and 9, it will be seen that along the sides of the chamber **30**, a plurality of narrow metallic fins **70** and **71** are attached vertically and substantially perpendicular to the side walls of the chamber **30**. The vertical fins **71** have their surfaces inclined towards the stopping plate **54**, in order to avoid having a continuous vertical surface perpendicular to the direction of magnetic deflection of the discharge, since this would favor concentrating the discharge on said surface. The major stopping plate **54** has similar vertical narrow fins **72** substantially perpendicular thereto. If the vertical fins **72** are made just as wide as the horizontal trapping plates **57**, the stopping plate **54** will have a cellular appearance formed by the rectangular pockets.

The insulative material **58** topping the stopping plate **54** is provided with pockets **73** and **74** which are lined with conductive material and screened at the fronts to provide shielded pockets. The pockets **73** and **74** are recessed into the insulative material **58** so that a non-conductive surface **83** and **84** is directly below the opening to each pocket **73** and **74** respectively. The surface **84** is inclined slightly inward so that any electrons moving along its surface will be directed toward the interior of the shielded pocket **74**. In operation, when the magnetic field is applied, repelling charges build up on the insulative surfaces **83** and **84** which result in electro-static forces that balance the magnetic deflective forces derived from the motional energy that the electrons acquire in being accelerated along the said surfaces **83** and **84** by the electro-static field applied between cathode and anode. When the speeding electrons pass beyond the surfaces **83** and **84** they are in front of the openings of pockets **73** and **74** where the electro-static repelling forces no longer exist and then the still active magnetic force can deflect them into the pockets **73** and **74**. By inclining the surface **84** the front screen of pocket **74** aids in shielding out the electro-static effects due to the positive space charge. A shielding plate **85** conductively connected to pocket **73** aids in distributing the negative charge that builds up on pocket **73** so that the electrons can be more easily deflected therein. The combination of a non-conductive plane surface preceding a shielded pocket allows the charged particle to acquire rectilinear kinetic energy due to its falling through an electro-static potential and then, when the moving charged particle is in front of the pocket, using the deflective action of the magnetic field upon said moving particle to deflect and change its direction of motion so that in effect its kinetic energy is expended against the applied electro-static field until it breaks through into the shielded interior of the pocket. Use of the magnetic field in this way tends to reverse the action of the electro-static field upon itself and so assists deionization.

The physical positioning of the magnetic poles that provide the transverse magnetic field through the deionizing chamber **30** is shown in the top view of Figure 9, where the north pole **67** is marked N and the south pole **68** is marked S.

In Figure 10 is shown a front view of an alternative form of stopping plate **54**. The construction consists of two sets of narrow parallel metallic fins **75** and **77** with their edges joined perpendicularly to the stopping plate **54**, with each set of fins **75** and **77** having their top ends inclined inward toward the center line **76**—**76** of plate **54**, resulting in a herringbone pattern.

The construction of the device shown in Figures 10 and 11 provides surface channels which tend to converge toward the centerline **76**—**76** of the major stopping plate **54**, thus counteracting the tendency of the electrons to diverge toward those regions shown in Figure 7 where leakage along parallel flux lines is possible.

Since the above described device provides a means for magnetically disrupting or limiting a direct current circuit without the use of moving contacts in the circuit controlled, it can be applied to those fields where these advantages are desired.

In Figure 12 is shown one application where the device is used as a variable resistance and switch in a direct current motor control circuit. The switch **80** connects the circuit to the power line, and **81** is the motor load. The magnetic control tube **82** is connected in series with the motor **81**. The anode **83** is shown water cooled. The deionizing chamber **84** is located between the pole faces of the U-shaped electro-magnet **85**, the magnet being energized by the coils **86**. The mercury cathode pool **87** is struck or ignited by the plunger rod **88** operating in solenoid **89**. The coils **86** of the electro-magnet have three windings the terminals of which are designated **90**—**91**, **92**—**92** and **93**—**93**. The winding **90**—**91** is connected in series with the motor **81** and tube **82**, and has shunt connections **94** and **95** extending to a control box **96**. When the control handle **97** is in open position, all of the load current through the tube **82** passes through the series magnet winding between **90**—**91**. As the control handle **97** is advanced over the contacts

1, 2, 3, etc., more of the resistance 98 in the shunt circuit 94—95 is cut out until handle 97 reaches contact 8 when the series of winding 90—91 is completely shorted out. The winding between terminal 92—92 is a bucking coil in series with the cathode sustaining circuit 99, 132, 130, 92, 92, 131, 87, 99, 91 and 80 to buck out the magnetic effects of the sustaining current flowing through the series coil 90—91 and so prevent magnetic blocking when starting the tube. The winding 93, 93 provides a strong magnetic field for disrupting the current through the load 81 and tube 82 and is energized through the circuit 93, switch 133, limiting resistor 134 coil between 93—93, 91 and 80.

The operation of the circuit in Figure 12 is as follows: On closing the main switch 80 voltage is applied to the circuit. The starting handle 97 is moved to the 0 stop, closing switch 135, thus energizing the circuit through limiting resistor 136, conductor 137, solenoid 89, connector 138, plunger 88, cathode pool 87, coils between 90, 91 to 80, causing solenoid 89 to strike an arc at 88. Since the deionizing chamber 84 is at a positive potential due to the external connection 131, a limited sustaining discharge take places from the cathode 87 to chamber 84 and the circuits 131 between 92, 92, 130, 132, 99 and 80. Due to the anode 83 being at a positive potential, the main discharge then strikes through the deionizing chamber 84 to the anode 83, the main discharge following the circuit 80, motor 81, tube 83—84—87, coil between 90—91 and 80. Since the counter-electromotive force of the motor has not yet built up, a large current would pass, except that the current also passes through the series coil between 90—91, which produces a strong magnetic field that limits the current through the circuit. The amount of the current that goes through the series magnet coil can be controlled by moving the control handle 97 over the contacts 1, 2, 3, 4 etc. After the motor is up to speed the series coil between 90—91 can be shorted out by moving handle 97 to contact 8. To open the circuit and stop the motor, the control handle 97 is moved back to the left, closing switch 133, thus energizing the main magnetic winding between 93, 93 through the circuit 99, 133, 134 coil between 93, 93, 91 and 80.

In Figure 13 is shown an application of the magnetically controlled tube as a circuit breaker switch on a direct current power line. To the + and — terminals from a source of supply, lines 140, 141 are connected. 142 is a contact switch in the line 141. For breaking the circuit 140—141, means are provided for transferring the current from the contact switch 142 to the magnetically controlled tube 143, after which the discharge is disrupted by the magnetically controlled tube 143.

The contact switch 142 is operated by the solenoid 144. The tube 143 is connected around the switch 142 so that the anode 83 is on the positive side. Two deionizing chambers 84*a* and 84*b* are shown, being separated by a section of the insulative tube envelope 144. The transverse magnetic field across the deionizing chambers 84*a* and 84*b* is supplied by the electro-magnets 85*a* and 85*b* and their energizing coils 86*a*, 86*b*, respectively. 145*a* and 145*b* are limiting resistors for the electro-magnets, 85*a* and 85*b*. The mercury cathode pool 87 is in contact with the plunger 88 which can be withdrawn by the action of solenoid 89 to strike an arc when switch 147 closes the circuit to the arc starting battery 146. Switch 147 can be controlled remotely by the action of solenoid 148. Main control switch bar 152 is remotely controlled by circuit 153 and solenoid 155 and serves to connect the contacts 149, 150*a*, 150*b* and 151 to auxiliary voltage 154.

The operation of the circuit in Figure 13 is as follows: When remote control circuit 153 is energized, solenoid 155 moves dashpot delayed plunger of contact arm 152. As contact arm 152 moves ahead it first closes contact 151, energizes solenoid 148 and closes switch 147, which strikes arc in mercury pool due to the closing of the arc starting circuit 147, 89, 138, 88, 146 and 147. Contact bar 152 next closes contact 149, energizing circuit breaker 144 and opening power line contacts 142. This causes a positive voltage to build up on anode 83 and arc strikes through from active cathode 87, the tube 143 now carrying the full line load. Finally, as the contact bar 152 continues moving it closes contacts 150*a* and 150*b*, energizing the coils 86*a* and 86*b*, thus creating a strong magnetic field across the deionizing chambers 84*a* and 84*b* and so disrupting the main load circuit.

Several modified forms of the structure embodying my invention have been illustrated and described in order to show that the invention is not limited to any specific structure and I intend no limitations other than those imposed by the appended claims.

Having thus described my invention, what I claim is:

1. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest deflected particles of the discharge, said trapping device having a plurality of conducting members forming channels parallel to the path of the discharge.

2. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a plurality of conducting members forming channels parallel to the path of the discharge, at least one of said members having a surface facing the discharge constructed with projections to restrict flow of particles of the discharge in directions parallel to said surface, said magnetic field being adapted to deflect the discharge into said surface.

3. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge and a trapping device within said field having a surface arranged to confine the discharge and to arrest deflected particles of the discharge, said trapping device having therein on at least a portion of the confining surface a plurality of fins extending therefrom and substantially parallel to the path of the discharge, said magnetic field being adapted to deflect the discharge into said confining surface.

4. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge adapted to deflect the discharge and a trapping device within said field arranged to confine the

discharge and to arrest particles of the discharge, said trapping device having at least one conductive confining surface and a plurality of conducting members substantially parallel to the direction of deflection of the discharge.

5. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a plurality of conducting members forming channels parallel to the path of the discharge, said members being constructed with openings interconnecting said channels, said magnetic field being adapted to deflect the discharge into said members.

6. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a plurality of conducting members forming channels parallel to the path of the discharge, said members being constructed with staggered openings interconnecting said channels, said magnetic field being adapted to deflect the discharge into said members.

7. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a conducting plate parallel to the path of the discharge, fins projecting from said plate substantially normal to the path of the discharge, said magnetic field being adapted to deflect the discharge into said plate.

8. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a conducting member parallel to the path of the discharge, a plurality of fins slanting downwardly from said member across the path of the discharge, said magnetic field being adapted to deflect the discharge into said member.

9. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a plurality of conducting members forming channels parallel to the path of the discharge, said members being constructed with openings interconnecting said channels, and fins projecting from at least one of the members in positions substantially normal to the path of the discharge, said magnetic field being adapted to deflect the discharge into said members.

10. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a surface comprising a plurality of shielded pockets facing the path of the discharge, said magnetic field being adapted to deflect the discharge into said shielded pockets.

11. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a surface comprising a plurality of shielded pockets facing the path of the discharge and a plate substantially parallel to the path of the discharge, said magnetic field being adapted to deflect the discharge into said shielded pockets.

12. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a surface comprising a plurality of shielded pockets facing the path of the discharge and a plurality of spaced plates substantially parallel to the path of discharge, said plates being constructed with openings interconnecting the spaces between said plates, said magnetic field being adapted to deflect the discharge into said shielded pockets.

13. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a plurality of conducting members forming channels parallel to the path of the discharge, said members being constructed with openings interconnecting said channels, fins projecting from at least one of the members in positions substantially normal to the path of the discharge, and a conductive grid in front of the fins to form a plurality of shielded pockets, said magnetic field being adapted to deflect the discharge into said members and shielded pockets.

14. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a plurality of conducting members forming channels parallel to the path of the discharge and said members being constructed with openings interconnecting said channels, fins projecting from at least one of the members in positions substantially normal to the path of the discharge, and other fins substantially parallel to the path of the discharge, said magnetic field being adapted to deflect the discharge into said members.

15. An electric discharge tube containing an ionizable medium, means for creating an electric discharge through said medium, means for creating a magnetic field across said discharge, and a trapping device within said field arranged to confine the discharge and to arrest particles of the discharge, said trapping device having a surface comprising a plurality of shielded pockets facing the path of the discharge, said pockets being formed of conductive members recessed into a non-conductive plate, said magnetic field be-

ing adapted to deflect the discharge into said shielded pockets.

16. An electric discharge tube containing an ionizable medium, an anode and a cathode therein spaced from each other, a conductive trapping device spaced from the anode and the cathode and facing the discharge path, means for maintaining the trapping device at a potential lower than the potential of the anode, means for initiating an ionic discharge between the anode and cathode past the trapping device, and means for creating a magnetic field across the trapping device and the discharge to deflect the discharge into one side of the trapping device, said side being constructed with a plurality of shielded pockets to arrest and deionize particles of the discharge.

HOWARD M. STROBEL.