Nov. 26, 1935. A. W. HULL 2,022,509

VAPOR ELECTRIC DISCHARGE DEVICE

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Fig. 1.

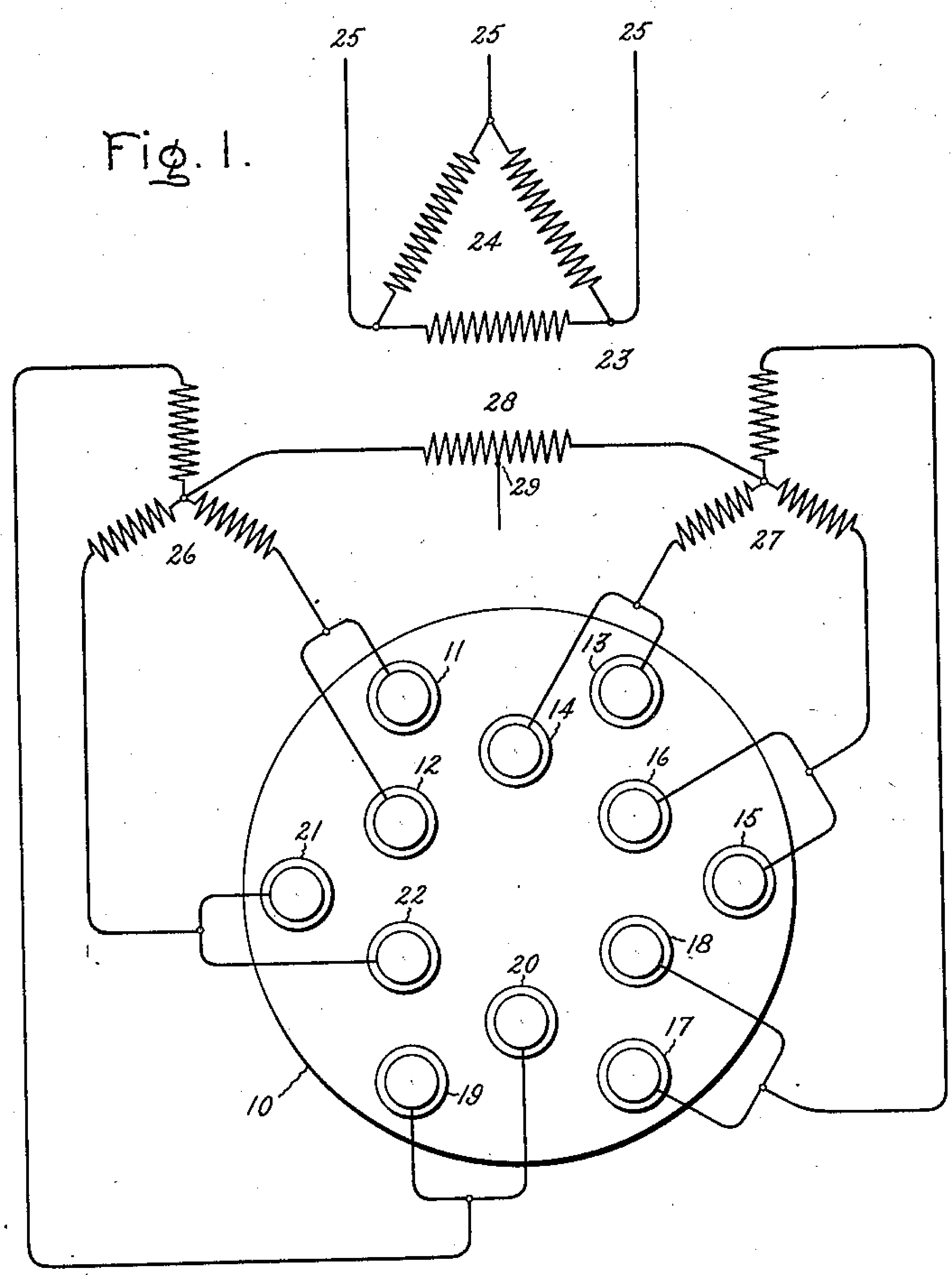

Fig. 2.

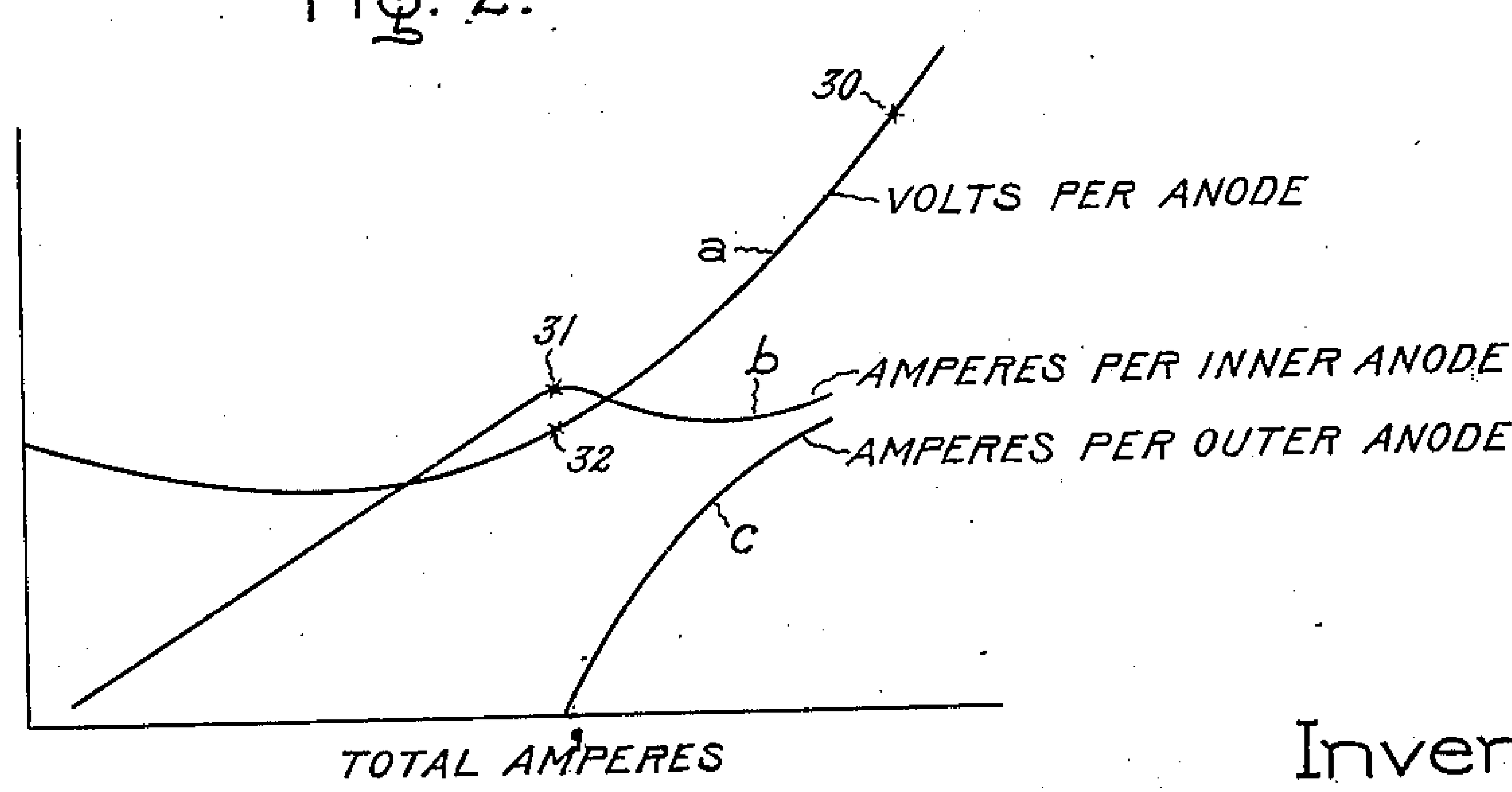

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Fig. 3.

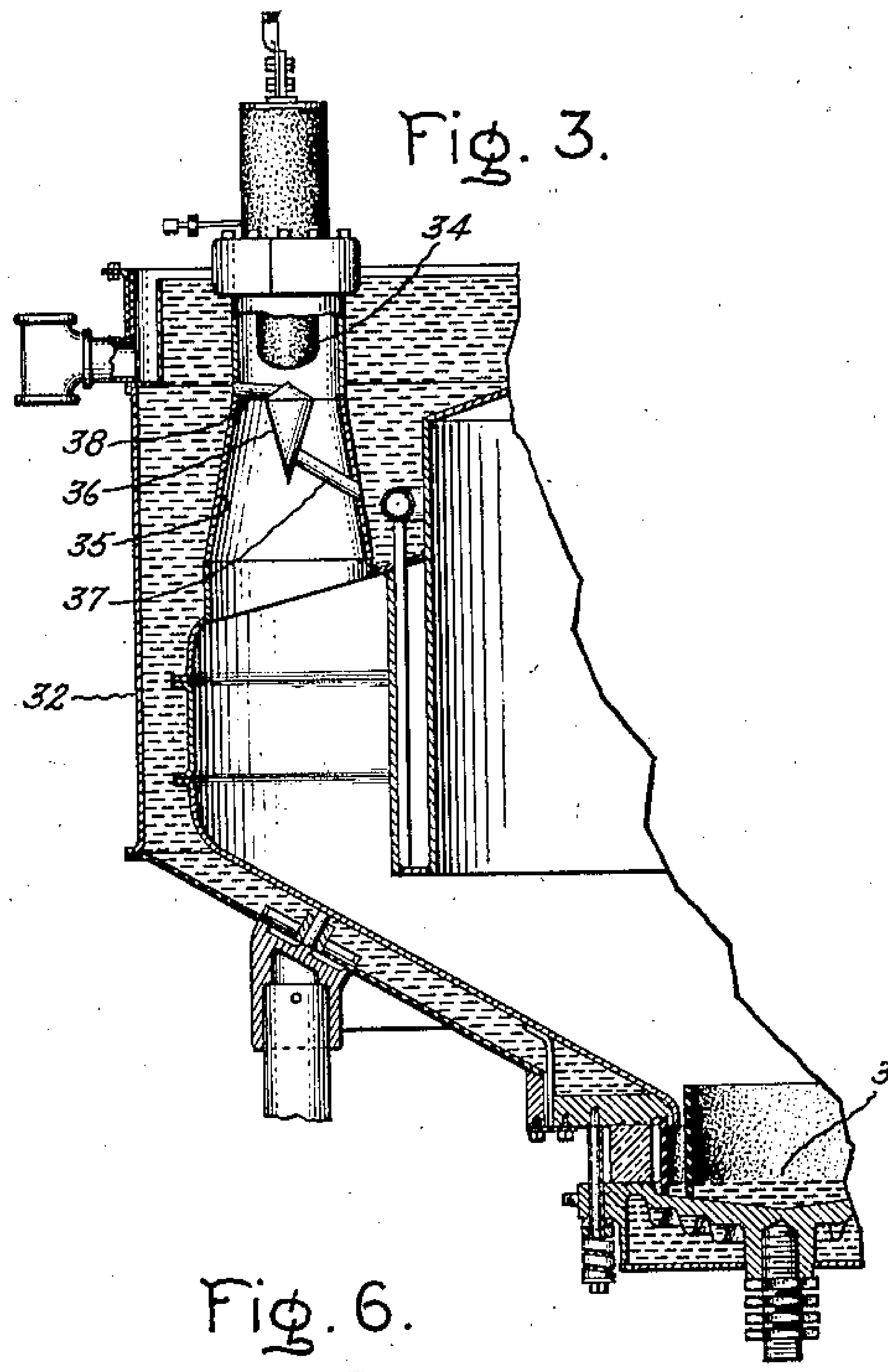


Fig. 4.

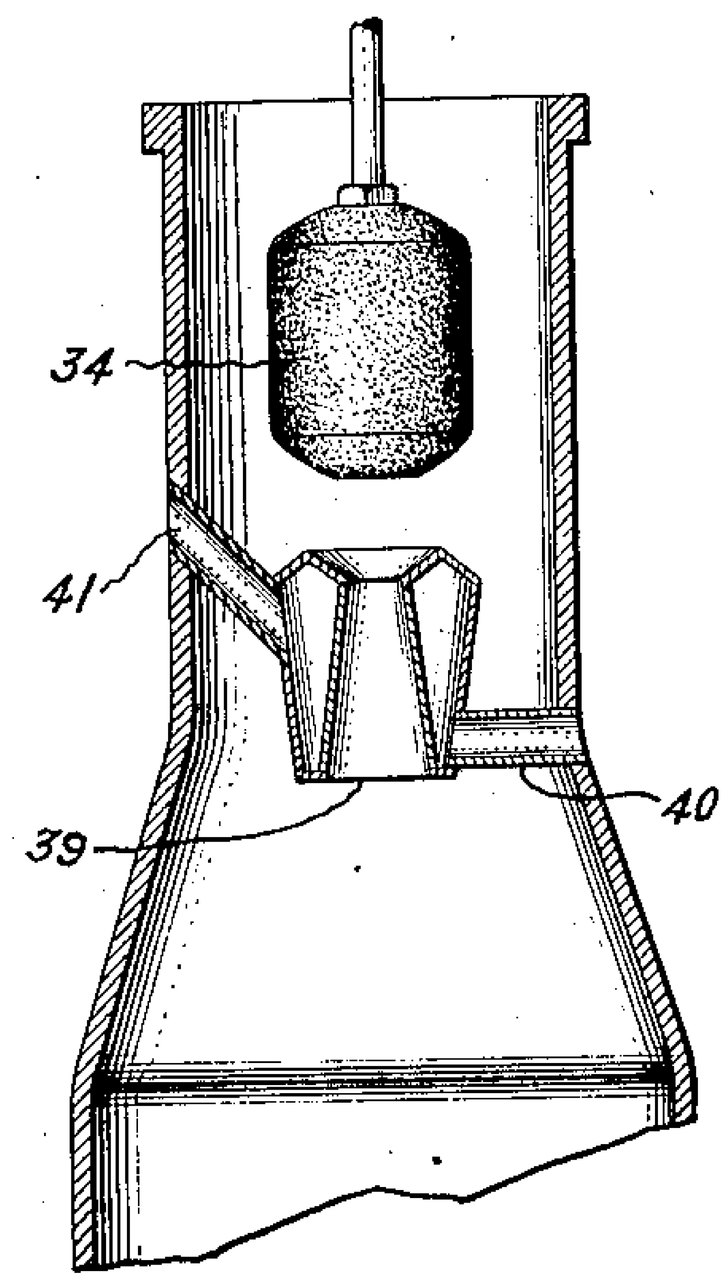


Fig. 6.

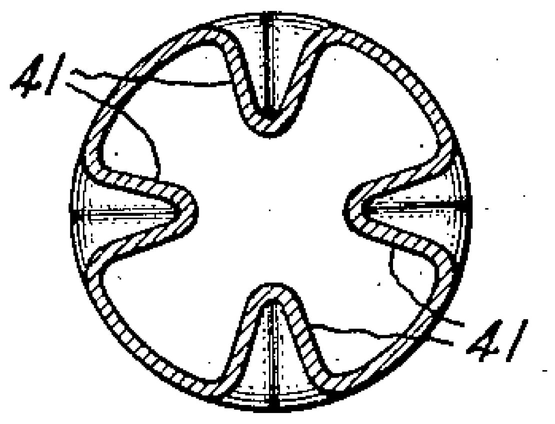


Fig. 5.

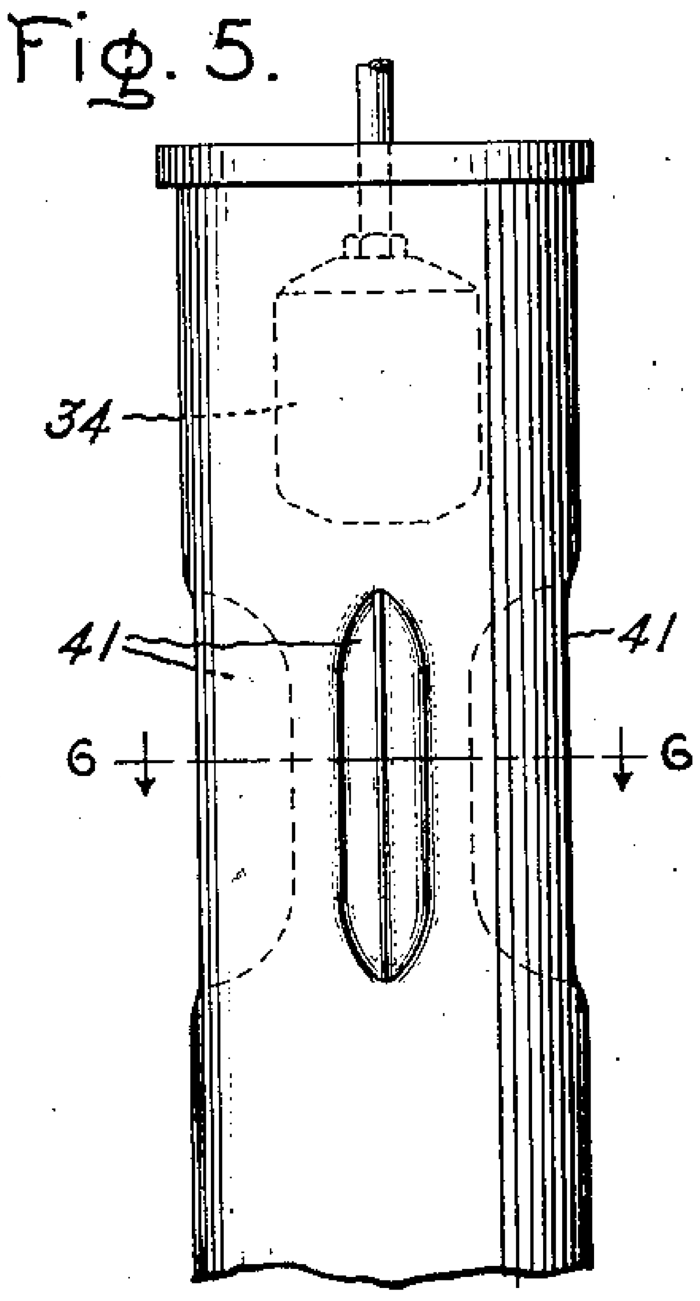
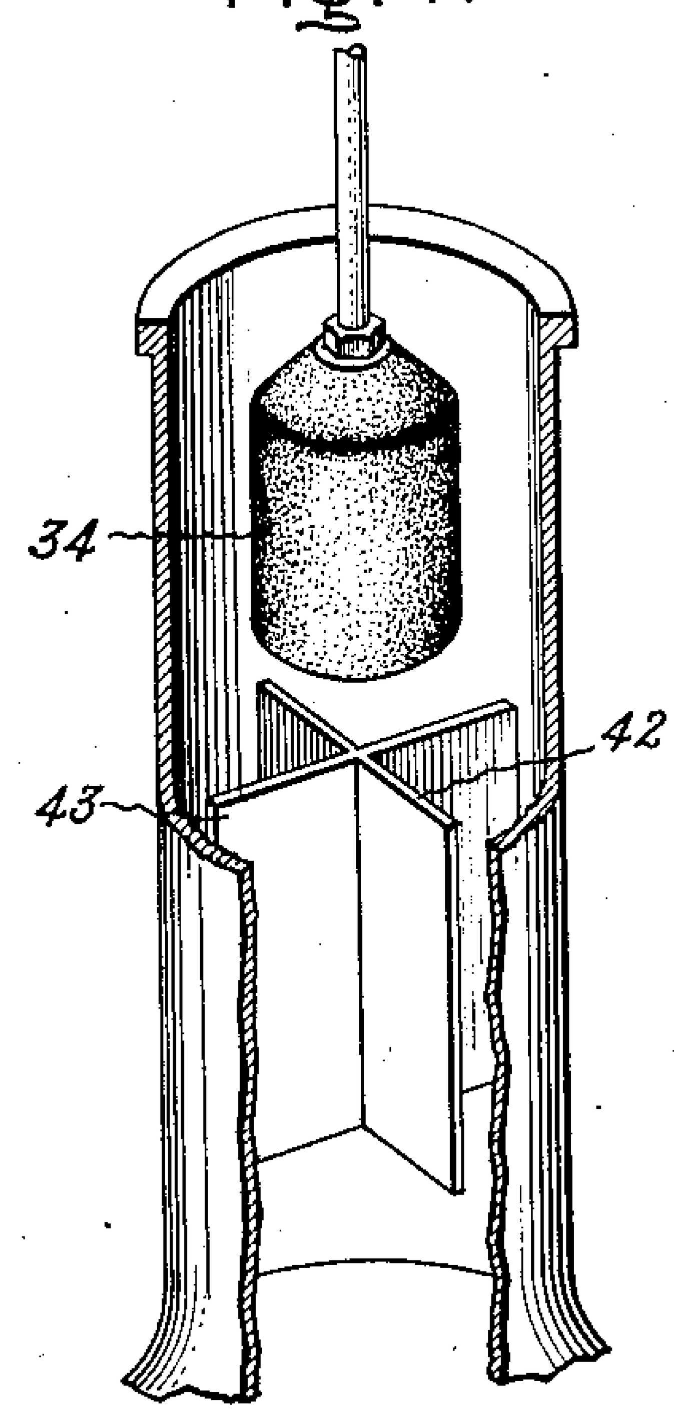


Fig. 7.



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UNITED STATES PATENT OFFICE

2,022,509

VAPOR ELECTRIC DISCHARGE DEVICE

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Application August 13, 1929, Serial No. 385,676

9 Claims. (Cl. 250—27.5)

My invention relates to electric discharge devices, such as mercury arc rectifiers or the like, and has for its principal object an improved construction and method of operation whereby the current carrying capacity of such devices is greatly increased.

Mercury arc rectifiers are well adapted for substation use because of their relative simplicity and high efficiency. Since these rectifiers are often used in substations in which space for apparatus is very limited, it has been a problem to obtain increased outputs from individual rectifier units by means of parallel connected anodes within a single unit. Attempts along this line have resulted in the use of parallel anodes having suitable inductance devices connected in series therewith to cause the anodes to share the load current equally.

In accordance with my invention the current carrying capacity of electric discharge devices such as the mercury arc rectifiers is substantially increased by an anode structure comprising a plurality of multiple anodes each of which is directly connected to the supply transformer, or by an improved construction of the anode chambers providing one or more passages of predetermined size and form for the arc passing between the anodes and the cathodes.

My invention will be better understood from the following description when considered in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

Referring to the drawings, Fig. 1 illustrates a mercury arc rectifier system using multiple or parallel connected anodes, in accordance with my invention; Fig. 2 illustrates a characteristic volt ampere curve for the individual mercury arc rectifier anodes, and the current carried by parallel anodes at various loads on the rectifier; Fig. 3 illustrates a section of an improved mercury arc rectifier anode chamber constructed in accordance with my invention; and Figs. 4, 5, 6 and 7 illustrate modifications thereof.

Fig. 1 illustrates a mercury arc rectifier tank **10** equipped with anodes **11**—**22** inclusive, in which each odd numbered anode is connected to one of the secondary phases of a transformer **23** in parallel with the succeeding even numbered anode. This transformer includes a 3-phase primary winding **24** connected to alternating current terminals **25**, and a 6-phase secondary winding divided into two Y-connected groups, **26** and **27**, which are interconnected through an interphase transformer **28**. The midpoint **29** of transformer **28** is the negative terminal of the direct current circuit.

In similar systems it has been considered necessary in the past to employ equalizing reactors in each of the anode circuits, and inductively interlink the parallel circuits so that these will share equally the load current imposed upon the phase to which they are mutually connected. I find that by properly designing the rectifier it is possible with the proper vapor pressures within the rectifier to cause the anode current to divide in each group of parallel anodes and cause satisfactory operation without these equalizing reactors.

It is known that the volt-ampere characteristic for mercury arc rectifier anodes has a negative slope from no load to what has hitherto been considered as full load. I have now found that if the anode is operated at higher current values, the volt-ampere characteristic becomes positive and rises to a considerable value. This positive resistance or positive slope of the volt-ampere characteristic is a true characteristic of low pressure mercury arcs and is coincident with and probably due to an approach to a complete ionization of all the mercury atoms in the region in front of the anode. A typical example of such a characteristic curve is illustrated by the curve *a* of Fig. 2.

I have also found that the limiting current which can safely be carried by an anode is always considerably above the value at which the arc resistance becomes positive. If then a plurality of anodes are connected in parallel, the anode having the least starting reluctance will alone carry current at small loads and will continue to do so through the negative part of the volt-ampere characteristic into the positive slope thereof up to a point at which the starting reluctance of another of the parallel anodes is overcome and that anode begins to carry current.

This condition is clearly illustrated in Fig. 2 in which curve "*a*" illustrates the volt-ampere characteristic of a low pressure mercury arc in which volts between cathode and anode are plotted as ordinates and amperes per anode as abscissae. The limiting current for an anode is some point **30** on the curve "*a*" and corresponds to about 50 volts between anode and cathode. Curves "*b*" and "*c*" illustrate the current carried respectively by two parallel connected anodes, as for example anodes **11** and **12**, Fig. 1. When the current plotted as abscissae in Fig. 2, is small, it is carried entirely by one anode **12** of the pair as illustrated by curve "*b*" since the arc resistance is negative for that current. When the current exceeds the negative resistance range, and reaches a value indicated at 31 corresponding to a point 32 on the positive resistance slope of curve "a" at which the voltage drop is higher than the starting voltage of the second anode 11, this second anode will begin to carry current as illustrated by curve "c". From this point on, the two parallel-connected anodes share the current almost equally, the difference if any in the current carried by each of the two anodes being due mainly to the difference in arc resistance caused by the difference in the lengths of the arc paths between anode and cathode.

Since the point 31 is well below the critical value of current for the first anode, the unequal division at light loads does no harm. At heavy loads, when approaching the limiting value, the two anodes share the current substantially equally and thus the total current that can be carried by the pair is about twice that which a single anode can safely carry. In like manner three or more anodes may be joined together and connected to a single transformer terminal and the total current to this terminal increased three, four or any desired number of times over that which could be delivered by a single anode.

Instead of joining the anodes externally, they may be in accordance with my invention joined inside the rectifier, and amalgamated into a single large anode, to which the arc current is fed through two or more passages, identical with or similar to the individual arms surrounding the multiple connected anodes described above. I have found that a single anode so used will carry the same current as the two smaller anodes above referred to in multiple. If however the single large anode is housed in a large arm with a single passage leading to it, it will not operate satisfactorily at the same vapor pressure as the smaller anode, but the pressure must be lowered to such an extent that it carries no more current than a single small anode. For example, an anode mounted in a 10″ diameter arm must be operated at a pressure of about 0.6 microns in order to carry the same current as an anode mounted in a 3″ diameter arm and operated at about 5 microns pressure, assuming a 3000 volt output voltage for both cases. It is not necessary that the parallel passages to the anode shall be entirely separate, but only that they shall be sufficiently narrow. I do not wish to be limited to a particular theory, but I believe that the criterion for proper structure depends upon the probability that an electron, moving from the anode toward the cathode, shall strike the walls before colliding with a molecule of mercury. If this probability is less than a certain value, reliable operation is possible, if greater arc-back may occur. The critical collision probability depends upon the voltage to be rectified, being smaller the higher the voltage.

Another important consideration is that of eliminating the ions which remain in the anode arms in the region below the anodes, at the end of a current cycle. If such ions are not rapidly absorbed they may bombard the anode and create thereon a cathode spot. To absorb these ions, the space below the anodes within the anode chamber is divided into narrow and comparatively long spaces running longitudinally with the anode chamber, by ion absorbing surfaces. These surfaces may be either insulating or conductive but if conductive must be insulated from both the anodes and cathode. They must be large enough and close enough to each other to rapidly absorb the ions. Actual dimensions of such surfaces will vary somewhat depending upon the voltage and current to be applied and carried by the anodes.

Referring to Fig. 3, I have illustrated a section of a conventional mercury arc rectifier 32, comprising the usual evacuated vessel containing the cathode 33 and the anode 34 which are insulated from the walls of the vessel and the chamber or arm 35 surrounding the anode. In chamber 35 a hollow conical member 36 whose shape resembles a plumb-bob is mounted in such manner that the apex is pointed toward the cathode. This member is supported by two hollow pipes 37 and 38, leading through the walls of 35 and attached respectively to the apex and the base of 36 to permit a circulation of cooling fluid through the member 36. The largest diameter of member 36 and its over-all length are such that the distance between it and the wall of passage 35 satisfies the above-mentioned conditions for deionization and for the collision of electrons with mercury atoms.

Fig. 4 illustrates a modification of the anode arm construction and illustrates a hollow dough-nut-shaped member 39 the cross section of which resembles that of member 36. It is supported by pipes 40 and 41 which permit a circulation of cooling fluid through the member 39. This construction permits the use of a larger diameter anode than in Fig. 4. The annular space between the wall and the member 39 and the opening through the center of 39 are so proportioned that the above-stated conditions in regard to the deionization and collision of electrons with mercury atoms is again satisfied.

Fig. 5 and Fig. 6, which is a cross-sectional view of Fig. 5, looking in the direction of the arrows, illustrate a modification in which the anode chamber is constricted below the anode by the corrugations 41 in the walls of the chamber. The number and size of these corrugations is such that the various passages created thereby are of a width and length which again satisfies the above-mentioned conditions for deionization and for the collision of electrons with mercury molecules at the desired operating temperatures. The length of the corrugations is greater than the radius of the anode chamber.

Fig. 7 illustrates a further modification of an anode chamber in which partitions 42 and 43 made of graphite or other suitable material are placed across the chamber and at right angles to each other, whereby the chamber is divided into a plurality of separate parallel chambers providing paths for the arcs and thereby simulating the condition of having a plurality of separate parallel connected anodes as in Fig. 1.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. The method of operating an electric discharge device provided with an anode structure and having positive and negative volt-ampere characteristics, which includes utilizing a given surface area of said structure as the active anode surface during all periods of operation on the negative volt ampere characteristic, and utilizing said given surface area of said structure and another surface area as the active surface area of said anode structure during all periods of operation on the positive volt-ampere characteristic.

2. In an electric discharge device, an evacuated vessel, a cathode therein and insulated therefrom, chambers having walls attached to

said vessel and communicating with said vessel, a plurality of anodes respectively insulated from and mounted within said chambers, hollow ring-shaped members mounted below said anodes within said chamber, each of said members dividing a portion of the space within the corresponding anode chamber into a relatively long and narrow central passage and an annular passage, the length of said annular passage being great relative to the distance between the walls forming said annular passage, and means for circulating a cooling fluid through said members.

3. In an electric discharge device, an evacuated vessel, a cathode mounted therein and insulated therefrom, anode chambers having walls attached to said vessel and communicating with said vessel, a plurality of anodes respectively insulated from and mounted within said anode chambers, hollow ring-shaped members mounted below said anodes within said chambers, each of said members dividing a portion of the space within the corresponding anode chamber into a relatively long and narrow central passage and an annular passage, the length of said annular passage being great relative to the distance between the walls thereof, a water jacket surrounding said vessel and said chambers, and means for circulating a cooling medium from said jacket through said ring-shaped members.

4. An electric discharge device including a cathode and an anode chamber having an anode structure mounted therein, means for causing one surface of said anode structure to be utilized as the active anode surface when said device is operative at one load and for providing an addition to the active anode surface when said load is changed to a predetermined value, said means including a hollow member dividing a portion of the space in said anode chamber into a plurality of relatively narrow passages of relatively great length longitudinally of said chamber, one of said passages cooperating with said one surface of said anode structure, another of said passages cooperating with said additional active surface of said anode structure, and means for circulating a cooling medium through said member.

5. A vapor electric device including an anode structure, and means for causing current to be transmitted through one surface area only of said anode structure through a range of current values at which the slope of the volt-ampere characteristic of said device is negative and to a predetermined maximum value of current corresponding to a point of said characteristic substantiallly beyond that point of said characteristic at which said slope begins to be positive, and for causing current to begin to be transmitted through an additional surface area of said anode structure at approximately said first-named point of said characteristic and to increase up to a predetermined maximum value of current corresponding to a point of positive slope of said characteristic substantially beyond said first-named point of said characteristic, said means including a plurality of surfaces forming substantially separate arc passages each cooperating with a different one of said surface areas of said anode structure, said passages being relatively long in the direction of the arc flow and relatively narrow in the direction transverse to the arc flow.

6. The method of operating an electric discharge device provided with an anode structure and having a characteristic the slope of which is first negative and then positive as the value of current transmitted by said device increases, which includes utilizing a given surface area of said structure as the only active anode surface during all periods of operation in which the current corresponds to the portion of said characteristic over which the slope is negative and on a relatively small part of that portion of said characteristic over which the slope is positive, and utilizing simultaneously with said given area another surface area as the total active surface area of said anode structure during all periods of operation on that portion of said characteristic over which the slope is positive and beyond said relatively small part of said characteristic.

7. A vapor electric device including an anode structure, and means for causing current to be transmitted through one surface area of said structure when said device operates with a negative volt-ampere characteristic, and for causing current to be transmitted through an additional surface area of said structure when said device operates with a positive volt-ampere characteristic, said means including separate arc passages cooperating respectively with said surface and presenting negligibly small obstruction to the arc flow, said passages being relatively long in the direction of the arc flow and relatively narrow in the direction transverse to the arc flow.

8. In an electric discharge device, an evacuated vessel having mounted therein a cathode and an anode, means forming a passage for all of the arc between said cathode and anode, and a hollow member mounted in said passage, said member dividing said passage into a plurality of relatively narrow passages, the walls of said narrow passages providing sufficient surface area to absorb rapidly the ions which remain in the region of said discharge device below said anode at the end of a cycle of current between said anode and cathode, and means for circulating a cooling fluid through said member.

9. In an electric discharge device, an evacuated vessel having mounted therein a cathode and an anode, means forming a passage for all of the arc between said cathode and anode, deionizing means mounted in said passage and dividing said passage into a plurality of narrow passages providing sufficient surface area exposed to said arc to absorb rapidly the ions which remain in the region of said discharge device below said anode at the end of a cycle of current between said anode and cathode, said deionizing means comprising passages formed therein for the flow of cooling medium, and means to circulate a cooling medium through said last-named passages.

ALBERT W. HULL.