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March 17, 1925. 1,530,468

W. ST. G. ELLIOTT

VAPOR ELECTRIC GENERATOR

Filed July 22, 1922 9 Sheets-Sheet 1

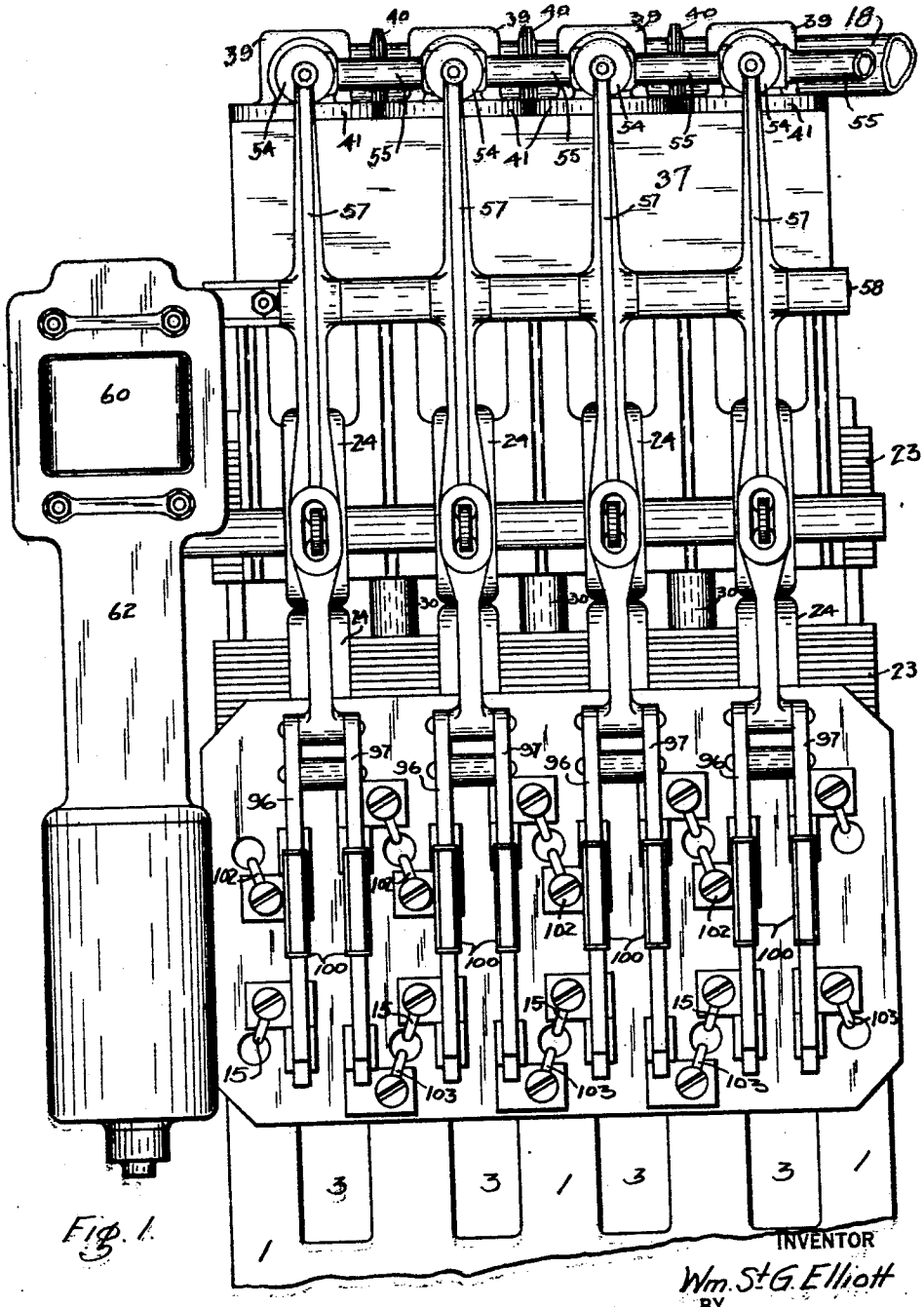


Fig. 1.

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174, ELECTRICITY,
Generation,
Magneto Electric,
Uniform Field.

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VAPOR ELECTRIC GENERATOR

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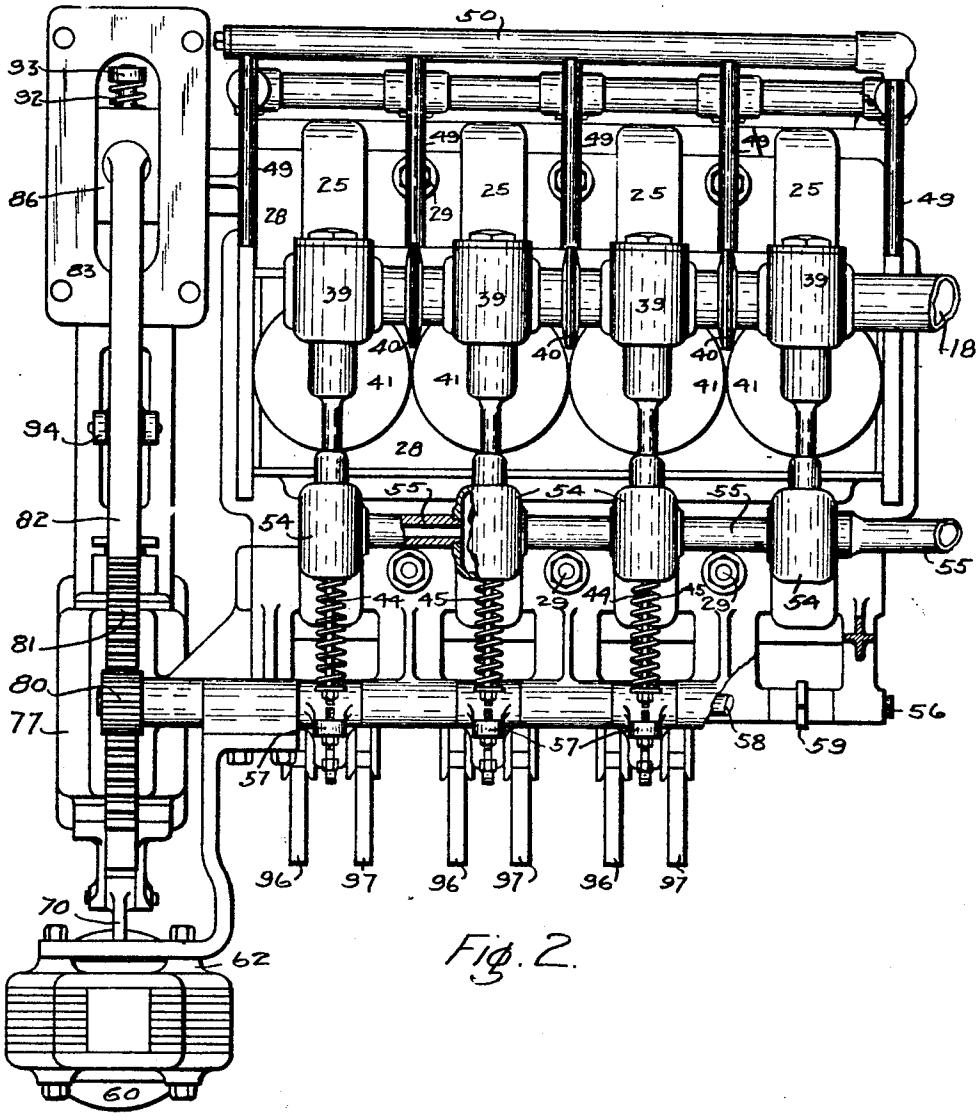


Fig. 2.

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Magneto-Electric,
Uniform Field.

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VAPOR ELECTRIC GENERATOR

Filed July 22, 1922

9 Sheets-Sheet 3

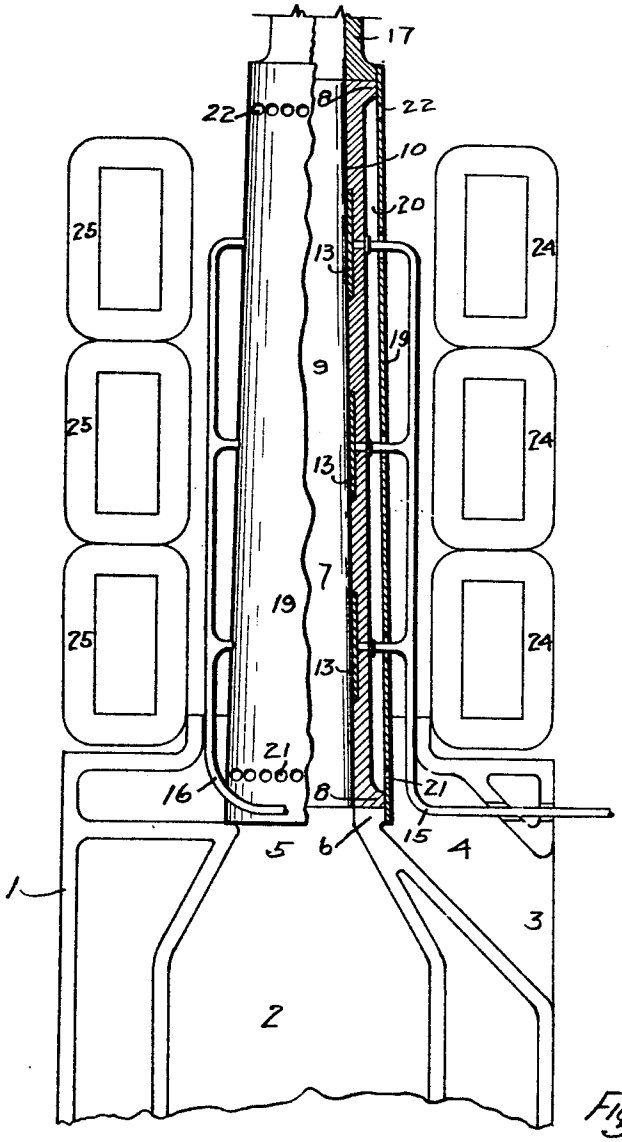


Fig. 3.

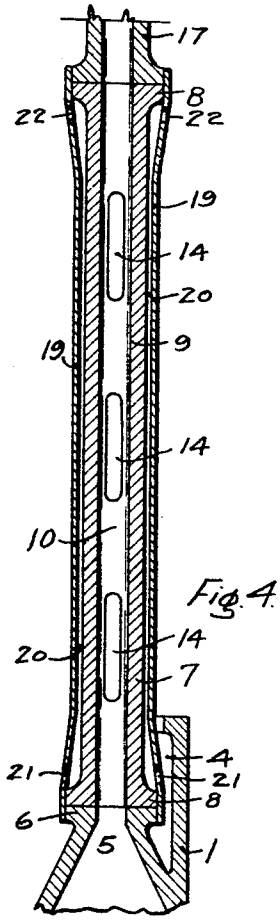


Fig. 4.

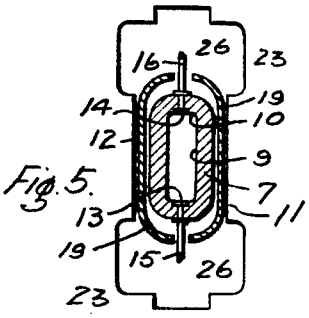


Fig. 5.

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171. ELECTRICITY,
Generation,
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March 17, 1925.

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VAPOR ELECTRIC GENERATOR

Filed July 22, 1922 9 Sheets-Sheet 4

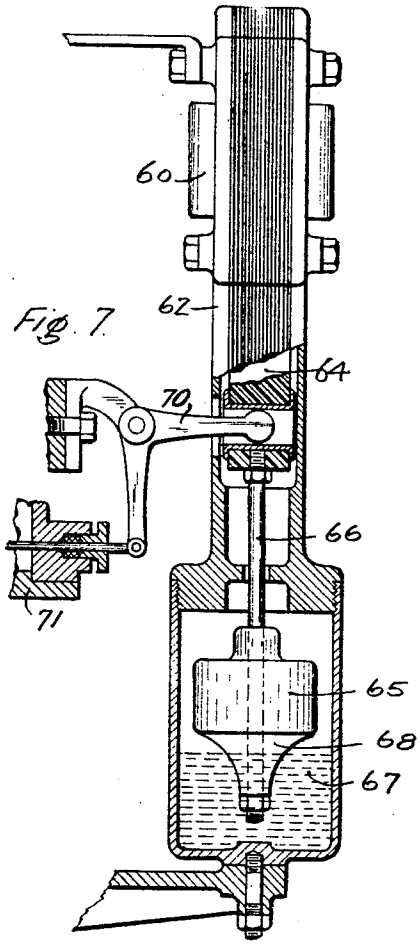


Fig. 7.

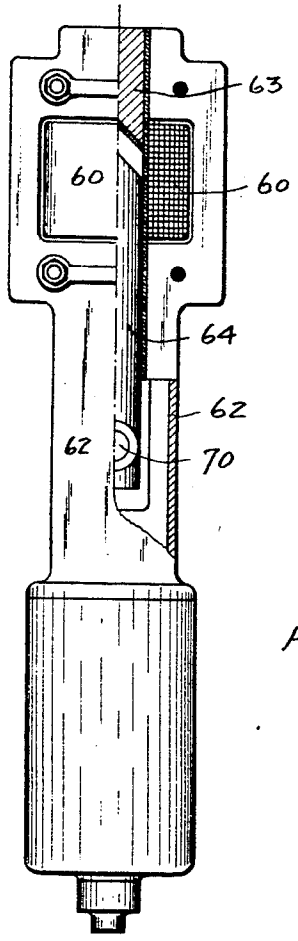


Fig. 6.

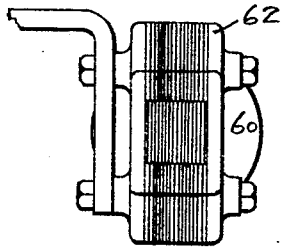


Fig. 8.

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Electricity,
Generation,
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VAPOR ELECTRIC GENERATOR

Filed July 22, 1922

9 Sheets-Sheet 5

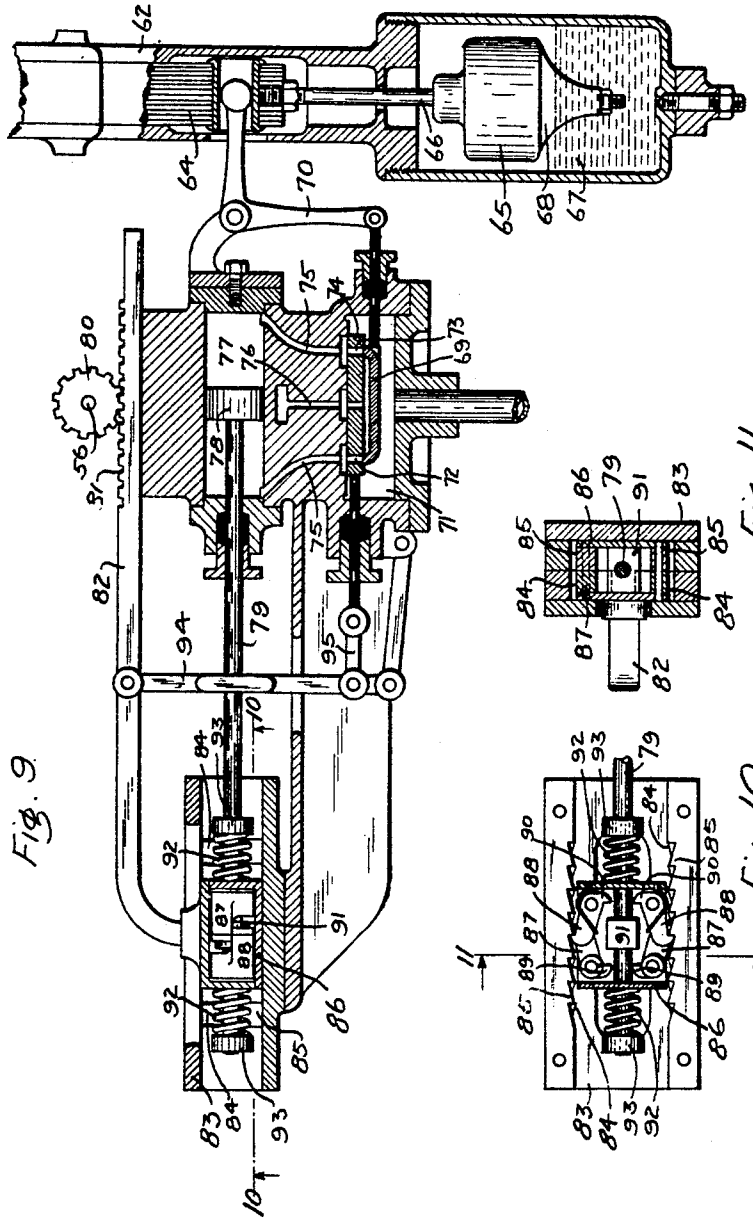


Fig. 9

Fig. 11.

Fig. 10.

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ELECTRICITY,
Generation,
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VAPOR ELECTRIC GENERATOR

Filed July 22, 1922 9 Sheets-Sheet 6

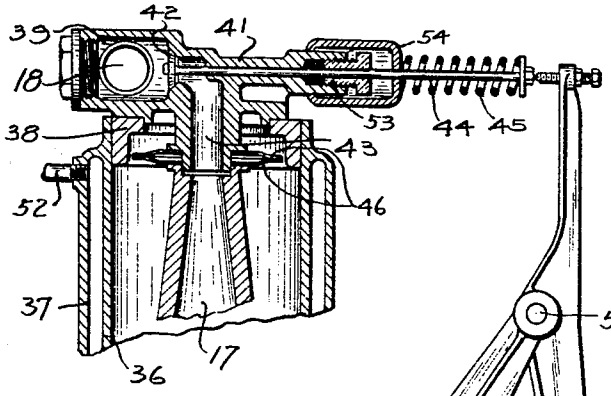
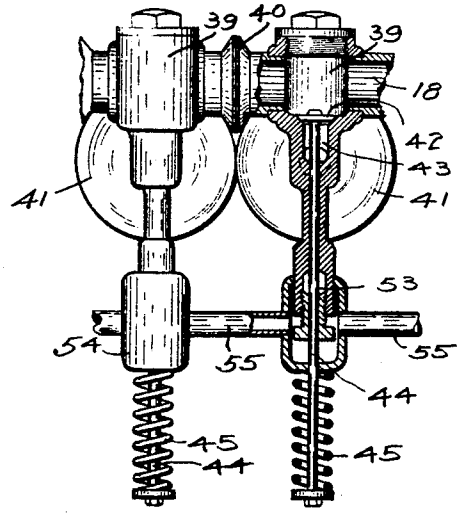
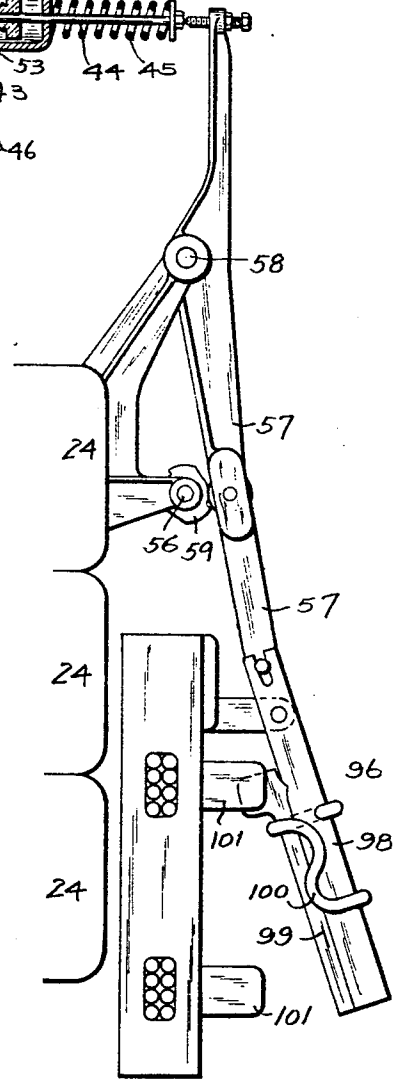


Fig. 12.

Fig. 13.





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1,530,468

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VAPOR ELECTRIC GENERATOR

Filed July 22, 1922 9 Sheets-Sheet 7

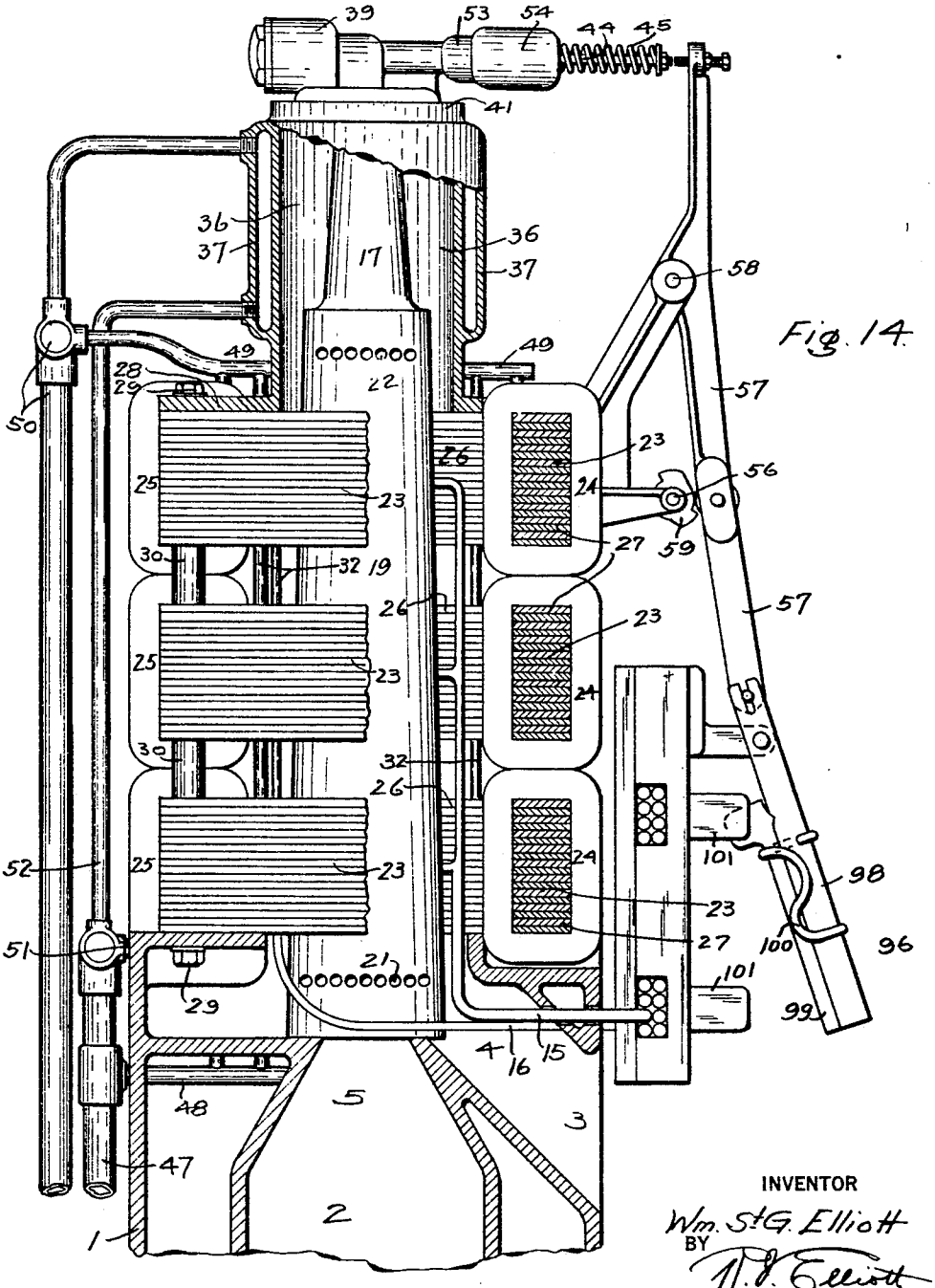


Fig. 14.

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171, ELECTRICITY,
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Uniform Field.

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March 17. 1925.

1,530,468

W. ST. G. ELLIOTT

VAPOR ELECTRIC GENERATOR

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Fig. 15.

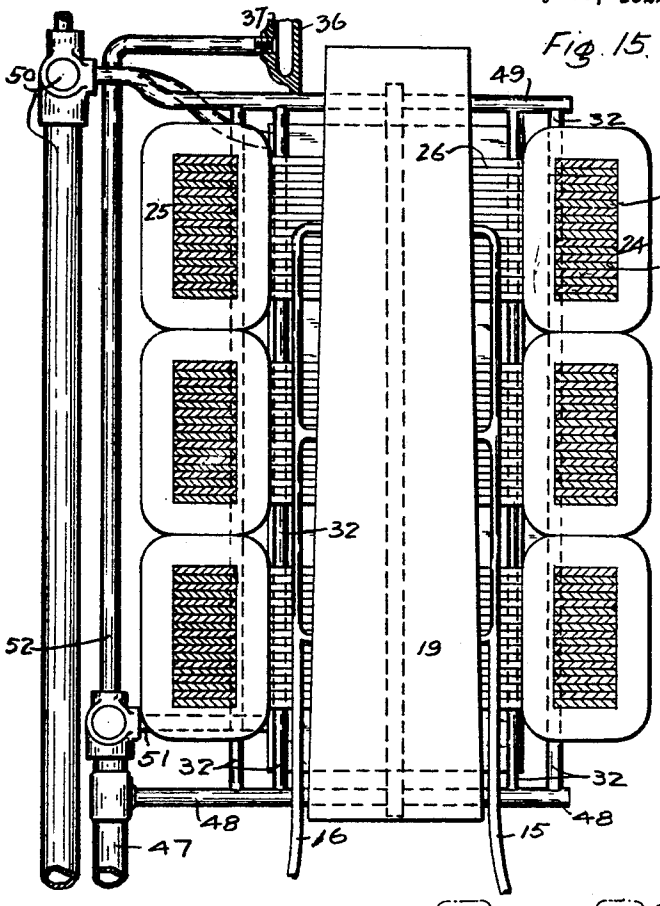
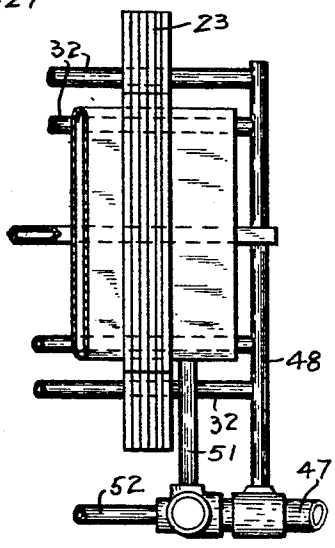


Fig. 16.



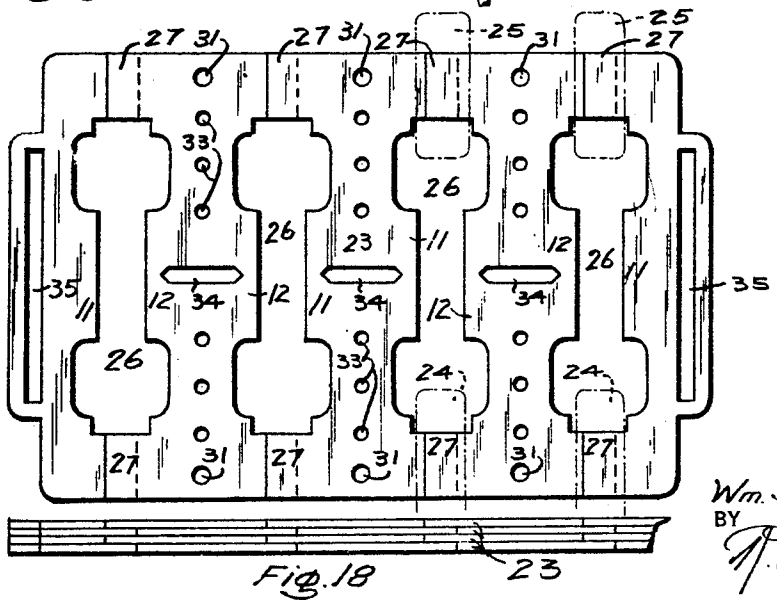


Fig. 17.

Fig. 18.

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171. ELECTRICITY,
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March 17, 1925. 1,530,468

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VAPOR ELECTRIC GENERATOR

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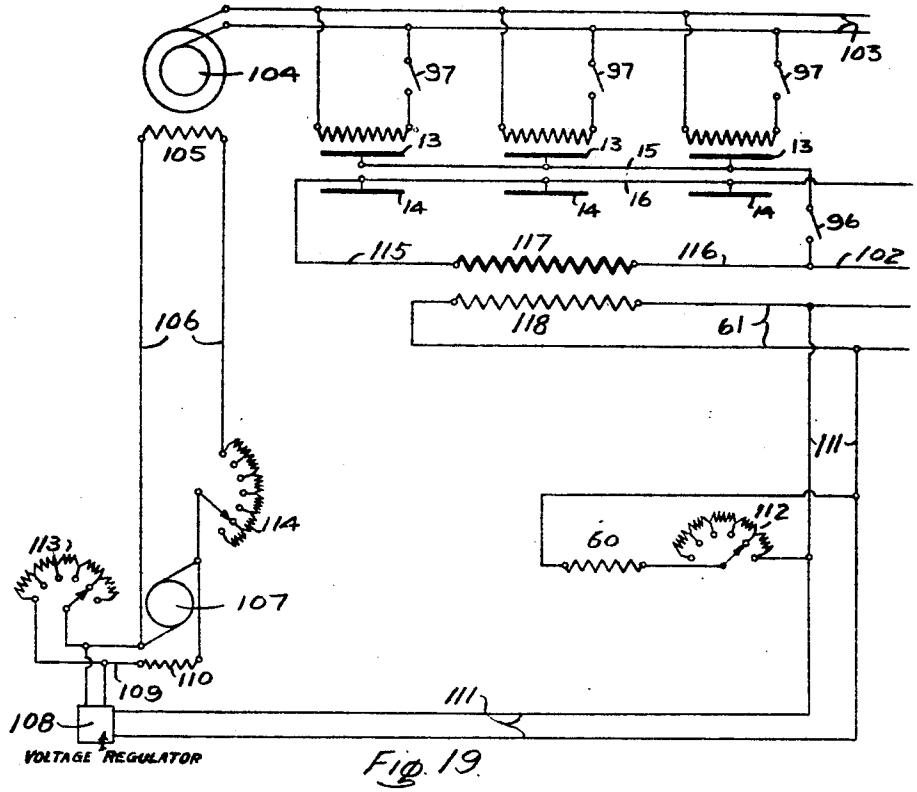
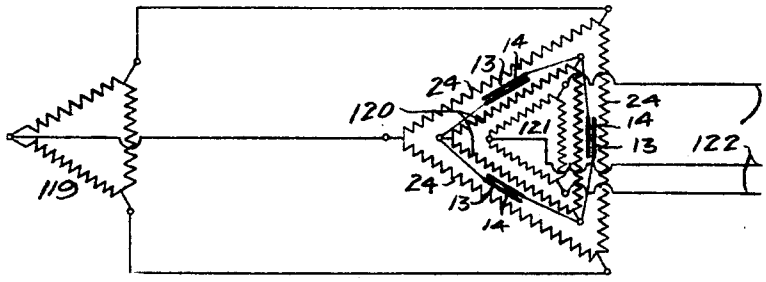


Fig. 19.

Fig. 20.



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Patented Mar. 17, 1925. 1,530,468

UNITED STATES PATENT OFFICE.

WILLIAM ST. G. ELLIOTT, OF NEW YORK, N. Y.

VAPOR ELECTRIC GENERATOR.

Application filed July 22, 1922. Serial No. 576,727.

To all whom it may concern:

Be it known that I, WILLIAM ST. GEORGE ELLIOTT, a citizen of the United States, and a resident of the city of New York, in the county of New York, State of New York, have invented certain new and useful Improvements in Vapor Electric Generators, of which the following is a specification.

This invention relates to machines for generating an electric current in which the motion of a conducting vapor past and through a magnetic field induces an electric difference of potential in the vapor.

This invention relates further to certain improvements in means for automatically starting or shutting off one or more of the sections of the apparatus, forming a part of the battery of generators, in accordance with the demands of the circuit supplied thereby: in means for regulating the strength of the current produced by the generators, as desired; in means for cooling the generator; and in means for interconnecting the several controlling means whereby they act together to attain a perfect control of the machine in accordance with the circumstances of the moment.

The objects of my invention will be more fully comprehended by those familiar with the art as the description thereof develops. My invention is illustrated in the accompanying drawings, in which:—

Fig. 1 is a front elevation of a battery of four units of my improved generators; Fig. 2 is a plan thereof; Fig. 3 is a view of the generator tube, shown partly in elevation and partly in section, and shown in relation to the surrounding parts; Fig. 4 is a section of the same tube taken at right-angles to that shown in Fig. 3; Fig. 5 is a horizontal cross-section thereof showing it in relation to the field magnets; Fig. 6 is a front elevation of the circuit-controlled magnetic mechanism whereby the battery of machines is controlled, a part thereof being shown in section; Fig. 7 is a vertical section thereof, a part thereof being shown in side elevation; Fig. 8 is a plan view thereof; Fig. 9 is a vertical section of the trip mechanism connected to said control mechanism and controlled thereby; Fig. 10 is a section thereof on the line 10—10 in Fig. 9; Fig. 11 is a section thereof on the line 11—11 in Fig. 10; Fig. 12 is a side elevation of the means for controlling the vapor valve, together with a section of the upper portion of the generator; Fig. 13 is a plan view thereof, a portion thereof being shown in section; Fig. 14 is an end elevation and partial section of one of the generators and its controlling and cooling devices; Fig. 15 is a section of the magnetic field magnets in relation to the generator tube, showing the means of cooling the magnets; Fig. 16 is a partial front elevation of the cooling system; Figs. 17 and 18 are a plan and front elevation, respectively, of the field magnet cores, as partially built up; Fig. 19 is a diagrammatic view of the wiring connections of one generator as connected up to give an alternating current; and Fig. 20 is a similar view showing the connections for a multiphase current. Similar numerals of reference refer to similar parts throughout the several views.

The hereinafter described generator is a portion of a closed circuit or ring traversed by the mercury or other liquid and vapor and comprising a boiler or vaporizer, connected by vapor pipes to this generator and thence to the condenser and back to the boiler, together with the necessary vacuum and pressure pumps all being understood as necessary to the operation of this generator, but being omitted from the drawings in order to prevent complication therein. In general said process consists in vaporizing mercury, or some other liquid whose vapor is a conductor of electricity, and conducting said hot vapor from the boiler, in which it has been vaporized, to a valve-controlled nozzle; then allowing it to expand in said nozzle to reach the desired velocity and passing it through an unobstructed passage which is strongly magnetized in a direction at right-angles to the flow of the vapor, and collecting it in a condenser; then pumping the condensed vapor, now a liquid, back into the boiler and repeating the cycle. The vapor, as it passes from the nozzle to the condenser, travels at a very high rate of speed on account of the difference of pressure between the boiler and the condenser. The result of the passage of such vapor through said magnetic field is a difference of electric potential in a direction at right-angles to both the flow of the vapor and of the magnetic stream, and this generated electricity is collected on suitable plates within the magnetized passage, such plates being positioned at the points of greatest potential difference, and is conveyed therefrom to the circuits where it is to be utilized.

This application is to be understood to cover the generation of either a direct, an alternating or a multiphase current, the particular type of current generated being dependent on the character of the current in the magnets and on the arrangement of the magnetizing and collecting circuits.

Although the generators in the battery illustrated in the drawings are all shown as of the same size, it is to be understood that said battery may be indefinitely extended in the number of units, and that the units comprising the battery may well be, and preferably are, of graduated sizes; as, for instance, the smallest may be counted as of a capacity of one unit; the next of two units; the next of four units; and the largest of eight units,—thus securing a total capacity of fifteen times that of the smallest unit by grades of said smallest unit, and yet using only four generators; or any other desired combination of sizes may be used.

Although in this specification, particular mechanisms, materials, or connections may be mentioned, it is to be understood that I do not wish to be confined to such construction, materials or connections, but describe them solely to give those acquainted with the art of generation of electricity a more thorough understanding of the invention, to whom many variations in such mechanisms and materials will readily occur from their knowledge of the art under the usual conditions of generation and application of electricity.

Referring now to the drawings:—The base 1, on which the several generators rest, contains a condenser space 2 in which a high vacuum is maintained by any suitable means (not shown), and into which the streams of vapor flow direct from the generator tubes. Within this space 2 the vapor is condensed into a liquid which is collected and pumped back therefrom into the boiler, to be again vaporized as above described. The base 1, is also provided with a series of air openings 3 and passages 4, one for each generator tube, entirely separated from the vacuum chamber 2, by means of which a stream of cooling air is conducted to the air jackets surrounding the generator tubes and to the space between the magnet coils and the said air jackets. The vacuum space 2 has upward-extending openings 5, each of which connects with a generator tube secured thereon, and each of which is provided with a flange 6 surrounding it.

The generator tubes 7 are each secured to the upper side of the base 1, and have their lower ends communicating through the said openings 5 with the vacuum chamber 2 in the base 1. The tubes 7 are all similar, except in size as above noted, and therefore the description of one will be understood to apply to all. Since the boiling point of mercury is about 675 degrees (Fahrenheit) it is necessary that the tube 7 be made of some special material, such as fused felspar or other highly fusing material, that has a low heat and electric conductivity and is not readily acted upon by the vapors as they pass therethrough. Flanges 8 are formed on the outside of the tube, at both ends, those at the lower end being of the same size as the flanges 6 on the base 1. The tube 7 is preferably not circular in section but is flat and has two opposite long sides 9 substantially parallel with each other, and these two sides are made close together in order to reduce as far as possible, the distance between the magnetic poles, which lie outside of the said flat sides 9 of the tube, and therefore the distance which the magnetic lines have to traverse outside of the magnet cores. The two short sides 10 of the tube 7 are preferably not parallel but are closer together at the top of the tube than at the bottom, thus gradually increasing the cross-sectional area of the tube towards the bottom, without increasing the distance which the magnetic lines must travel. The purpose of thus increasing the sectional area of the tube is to approximate an area inversely proportionate to the reducing pressure on the vapors as they pass therethrough and thus maintain a constant velocity of the expanding vapor in all parts of the tube.

Each tube 7 is preferably of considerable length and has one or more pair of magnetic poles 11, 12, adjacent to it between its upper and lower ends. In the drawings I have shown three such magnets for each tube 7. A strong magnetic field is therefore created in the tube, the magnetic lines thereof crossing the tube at its smallest dimension, at right-angles to the stream of vapor. At proper positions in the opposite short sides 10 of the tube, I mount pairs of collector plates 13 and 14, such plates being made of conducting material and being positioned at the points of greatest potential difference in each magnetic field. The plates 13 and 14 are permanently secured in the tube 7, and are provided with conductors 15 and 16, respectively, which pass through the tube to the outside thereof. The plates 13 and 14 of the various sets are shown as being connected together in parallel, as in Figs. 3, 14, 15 and 19, but it is understood that each pair of plates forms a definite separate generator and they may be connected up in series, or in any other way desired. The plates 13 and 14 are arranged in pairs, one opposite the other, and serve as the positive and negative brushes or collectors, for the current generated in the passing vapor. One such pair of collectors 13 and 14 is provided opposite each electro-magnet.

The upper end of the tube 7 has a nozzle piece 17 secured to it, said nozzle being

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preferably made of the same material as the tube. The nozzle piece 17 connects the tube 7 with the valved vapor supply pipe 18, and is shaped so as to permit an expansion of the vapors passing therethrough such that the vapor has the desired velocity on entering the tube. The vapor passage from the valved pipe 18, the nozzle 17, and the tube 7, to the vacuum chamber 2 is absolutely unobstructed, the vapor passing from the supply to the vacuum chamber under the impulse of the difference of pressure between said parts, modified by the expansion thereof as the pressure thereon decreases and by the size of the generator tube and retarded somewhat by the reaction due to the generation of an electric current therein.

The lower flange 8 of the tube 7 fits on the flange 6 surrounding the opening 5 of the vacuum chamber 2. A jacket 19, made of non-magnetic material, surrounds the tube 7 in such manner as to provide an air space 20 between it and the tube 7, and this jacket 19 fits over the above-mentioned flanges 6 and 8 and is provided with air-inlet holes 21 near the bottom and with air-outlet holes 22 near the top, thus permitting a free circulation of air from the bottom to the top for the purpose of keeping the tube 7 at as nearly uniform temperature as possible. The inlet holes 21 are positioned in the air passage 4 in the base 1, as clearly shown in Fig. 3. The jacket 19 fits over the flange 8, on the bottom of the tube, and the flange 6 surrounding the opening 5 to the vacuum chamber 2, and thus fastens the tube 7 securely in position on the base 1, and prevents the leakage of air from the outside into the condenser space 2.

The electro-magnet cores for the battery of generators are built up of sheets or laminations 23 of soft iron, as indicated in Figs. 17 and 18, and are magnetized by means of field coils 24 and 25 wound around their outer front and rear portions, respectively, the magnetism from two adjacent such coils 24 or 25 on the same side being of opposite character so as to force the magnetic lines from the outside of the sheets 23 towards the center. Also, the magnetism from two corresponding coils 24 and 25 on opposite sides are of similar polarity thus forming corresponding poles in the center. As seen in Fig. 17, the magnetic plates 23 are formed with central slots 26 whose sides are shaped closer together at the central portion than nearer their ends, thus providing two poles 11 and 12 in each slot 26. The above-mentioned coils 24 and 25 are wound on spools in the usual manner and are placed so that the part of the cores between the ends of the slots 26 to the outside, pass through the spools. Since the magnetism of two corresponding coils 24 and 25 is of the same polarity, the two poles 11 and 12 formed between two slots are also of the same polarity; thus, for instance, if the two right-hand coils 24 and 25 have their right-hand ends of north polarity, the right-hand pole 11 will be north, and will be magnetized by both of said coils 24 and 25; and their left-hand ends will be of opposite polarity, so that the whole strip of metal between the first and second slots 26, including the two poles 12 formed thereon, will be of south polarity, and the next two magnets 24 and 25 will have their right-hand ends of south polarity and their left-hand ends of north polarity, so that the third strip of iron between the second and third slots 26 will be of north polarity; and so on.

In the drawings I have shown three such groups of magnets, formed one above the other, and giving three separate magnetic fields for each generator tube, through each of which the several streams of vapor pass. The laminations 23 are built up into a solid body and are all secured together between the base 1 and the top plate 28, by means of a series of bolts 29 which pass entirely through them all and which clamp them all together. In the case, as shown, where there are more than one such magnet body, I separate the cores by means of hollow separators 30, through which the said bolts 29 pass. These bolts 29 pass through the large end holes 31 formed in the plates 23 of the magnet cores as shown in Fig. 17. Each lamination of the magnets is formed by a series of plates which are interwoven to break their joints, as shown in Fig. 18. The magnets are kept cool by means of water pipes 32 which pass through the holes 33 and the central slots 34 and the end slots 35, shown in Fig. 17, said pipes 32 being connected to the hereinafter described water circulation system.

The top plate 28 which clamps the magnet cores to the base 1, as above described, has a series of vertical cylinders 36 extending upward therefrom, such cylinders being positioned to surround the upper portion of the vapor tubes 7. Each cylinder 36 is provided with a water jacket 37 whereby it is kept at a uniform temperature. The upper end of the cylinder 36 is provided with an inward flange 38. The hot vapor is conducted from the boiler by the pipe 18 to the valve chambers 39 for the several vapor tubes 7. These valve chambers 39 are secured together in series and are provided with expansion joints 40 between them, to compensate for changes in the temperature thereof. Each valve chamber 39 forms a part of a head casting 41 which is secured to the inward-extending flange 38 on the top of the above-mentioned cylinder 36. The outlet for the valve cham-

ber 39 is horizontal and is closed by means of a poppet valve 42 seated therein. The outlet connects with a downward extending passage 43 which connects with the above described nozzle 17 and which is positioned in the central axis of the cylinder 36. The poppet valve 42 is operated by a push rod 44 suitably packed to resist the escape of vapor therefrom, and this push rod is actuated by a spring 45 to keep said poppet valve 42 closed except when it is opened by means of the hereinafter described automatic valve-opening mechanism. The end of the downward-extending passage 43, above mentioned, connects with the nozzle 17 which leads directly to the top of the flat vapor tube 7.

The joint between the head casting 41 and the nozzle 17 is also expandible to compensate for changes in temperature of the said parts and is illustrated particularly in Fig. 12. This joint consists in a sliding connection between the two bodies 41 and 17 and in a pair of flexible annular dished plates 46 welded, respectively, to the flanges on the two bodies and extending outward therefrom, and having their outer edges welded together, thus completely preventing the escape of vapor while permitting a slight movement between the two bodies. The joints 40 between the valve chambers 39 are of the same character as that above described.

It will therefore been seen that the hot vapor from the boiler passes through all the valve chambers 39, and if any poppet valve 42 therein is open, it passes therethrough and then downward by the passage 43 through the nozzle 17 into the flat tube 7 and thus to the vacuum chamber 2 in the base 1, where it is condensed; and, while passing through said tube 7, it traverses through one or more magnetic fields and consequently develops a difference of electrical potential between the edges 10 of the tube 7; and, if the collectors 13 and 14 are properly located, they become charged with electricity at said different potentials.

It is evident from the drawings that a stream of cold air enters the openings 3 in the base 1, and passes upward through the large slots 26 in the field magnet cores, outside of the jackets 19 surrounding the tubes 7, and also passes through the inlet holes 21 at the bottom of the air jacket 19 and through the space 20 around the tube 7, and out by the upper outlet holes 22 through the said jacket 19 into the cylinder 36, and passes out through the top of the cylinder around the head casting 41. Thus the hot vapor portions are kept at a substantially uniform temperature, and being made of a poorly conducting material, the vapor therein is not materially cooled by the air. A supply of cold water is conducted to the machine by means of a pipe 47, from which branches pass. One such branch 48 is a cross-pipe to which vertical cooling pipes 32, passing through the holes 33 and slots 34 in the field magnet plates 23, as above described, are secured. The said pipes 32 join a header pipe 49 at their upper end, and this pipe 49 connects with the return pipe 50. Another branch 51 connects with the large flat pipes which are mounted in the end slots 35 of the magnet plates 23, and still another branch 52 passes to the water jacket 37 surrounding the upper cylinder 36. The upper ends of these pipes and jackets are all connected to the return pipe 50. Thus it will be seen that the cold water flowing into the bottom of the cooling pipes and jackets becomes heated and flows out at their upper ends by the return pipe and may be cooled and used again in any of the well known ways.

The poppet valves 42, which control each of the generators, are mounted on a stem or push rod 44 which passes through a suitable stuffing box 53; and this box 53 is mounted within an outer casing 54. All the casings 54 for a battery of generators are connected together by means of pipes 55, which leads to an air pump (not shown) which constantly draws away all mercury vapor which may leak through the stuffing box 53, thus preventing its escape and loss. A similar system of saving the escaped mercury vapor may be used at any part of the apparatus where leakage is likely to occur. It must be rememberd, however, that the mercury vapor is under pressure only at the early part of its travel through the generator, the pressure on the vapor gradually decreasing from the high pressure in the nozzle 17 to the low pressure in the condenser 2.

Each of the above-mentioned valve stems 44 is operated from a cam shaft 56 through a lever 57 which is pivoted at 58 to a bracket secured to the frame, and which engages the cam shaft 56 and the valve stem 44. The cam shaft 56 extends in front of all the generators and determines, by its position which, and how many, of them shall be in operation. One cam 59 is formed on the shaft 56 for each lever 57 and is shaped to hold the valve 42 entirely open or to permit the valve to be tightly closed by the spring 45, no intermediate position being contemplated.

Referring to Figs. 1, 2, 6 to 12, and 19, wherein the means for operating the cam shaft 56 are illustrated, it will be noted, especially in Figs. 6 to 8 and 19, that an electric solenoid 60 is electrically connected to the outside circuit 61. The magnetism of the solenoid 60 varies with the needs of the

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outside circuit 61 so that for each condition of said circuit there is a corresponding magnetic condition in the solenoid 60. The solenoid is mounted in a vertical position in a frame 62 secured to one end of the battery of generators and has a core 63 extending part way through it. A magnetic armature 64 is mounted below the core 63 and is adapted to be drawn up into the solenoid 60 into various positions, depending on the strength of the current in the circuit. In order to compensate for the loss in tractive force which the solenoid 60 exerts on the armature 64 as the armature passes away from its highest position, I have provided a means of increasing the effective weight of the armature as it is drawn up into the solenoid, by means of a float 65, (Fig. 7) which is attached to the lower end of the armature 64 by means of the rod 66, and which dips into a body of liquid 67, such as mercury, and tends to counteract the weight of the armature and its parts. The lower portion 68, of the float 65, which dips into the liquid 67 is of rapidly varying cross-section, increasing in area upward. The effect of the shape of the part 68 is that the farther down the float is pressed by the difference between the constant total weight of the armature and its parts and the variable tractive force of the solenoid 60 thereon, the greater is the counteracting buoyant effect of the float 65, thus making a substantially uniform motion of the armature 64 for any given variation in the strength of the current in the solenoid 60, independent of whether the armature is near or far from its uppermost position. In other words the effective weight of the armature is increased in proportion as the tractive effect of the armature is increased, and the armature 64 therefore has a definite position in the solenoid for each condition of the outside circuit. The armature is connected through intermediate mechanisms with the several poppet valves 42 but it is not desirable that it should be direct connected thereto or to do the actual work of moving them, for the double reason that the armature may occupy any position between no load and full load while the generator valves should be operated only at definite values of the load, and also since the valves are opened against the action of the springs 45 it requires some force to do so and this would interfere with the accuracy of the motion of the armature in the solenoid. It is not desired to use this mechanism which cuts in or out one or more of the generators in regulating for minor changes in the outside circuit, such minor changes being cared for by changes in the strength of the magnetic fields through which the vapor is passing, as hereinafter described. However, it is desired to cut in or out, by means of this intermediate mechanism, one or more of said generators to take care of such major changes in the outside circuit as occur. This action must be rapid, definite in extent, and intermittent in character, in order to properly accomplish the objects thereof.

It will be seen (Figs. 7, 8–11) that the vertical motion of the armature 64 is communicated to a pilot valve 69 by means of a bell-crank lever 70 mounted on the frame. This pilot valve 69 is mounted in a valve chest 71 and controls the end passages 72 and 73 through the main valve 74, which in turn controls the inlet and exhaust ports 75 and 76 of a cylinder 77. Oil, or other suitable fluid, under pressure, is admitted into the valve chest 71 and when the pilot valve 69 moves to a certain position, corresponding with a definite position of the armature, one of the passages 72 or 73, through the main valve 74, will be uncovered to admit oil under pressure to one or the other port 75 of the cylinder and the other passage will connect the other port 75 with the exhaust port 76, and thus operate the piston 78 in the cylinder 77, which, in turn, operates through hereinafter described mechanism the main valve 74 to again close the said passages therethrough; so that for every motion of the pilot valve 69, there is a corresponding larger and more powerful motion of the piston 78 and for every position of the pilot valve there is a corresponding position of the piston in the cylinder. It is unnecessary to describe this valve mechanism in detail, as it is clearly indicated in Fig. 9 and is a well-known mechanism, the only feature necessary to call attention to at this time being the fact that for every position of the armature 64 in the solenoid 60 there is a corresponding position of the piston 78. The piston 78 is provided with a piston rod 79 which extends outward from the cylinder to the mechanism for operating the cam shaft 56.

The cam shaft 56 is provided with a gear 80 at its end, said gear meshing with the teeth of the rack 81 formed on a bar 82 so that the motion of the bar will turn the cam shaft 56. This bar 82 extends to and is operated by a trip mechanism.

A fixed hollow frame 83 (Figs. 9, 10 and 11) is provided with a double set of sawlike ratchet teeth 84 and 85, on each of its two opposite inner walls, the teeth 84 an the upper half of each of said walls being inclined in opposite directions, while the teeth 85 in the lower half thereof are inclined in the reverse directions. The pitch, or distance between these ratchet teeth is such as to move the cam shaft to open or close one generator tube valve. All the teeth have one inclined surface and one surface at right-angles to the wall. A trip carriage

86 is mounted within the hollow frame 83 and is secured to the said bar 82 which operates the cam shaft 56, and this carriage 86 has two pairs of spring actuated ratchet dogs 87 and 88 mounted in it. The two upper dogs 87 engage the upper row of ratchet teeth 84 to prevent motion of the carriage in one direction while the two lower dogs 88 engage the other ratchet teeth 85 to prevent its motion in the opposite direction. All four of the ratchet dogs have lugs extending therefrom to positions near the piston rod, the lugs 89 for one pair 87 being near one end of the carriage 86 and the other lugs 90 for the other pair of dogs 88 being near the other end thereof. The carriage 86 is mounted on the piston rod 79 and is free to move thereon. The piston rod 79 passes entirely through the carriage, but has a collar 91 within the space in the center of the carriage and between the pairs of lugs 89 and 90, said collar 91 being adapted to engage one or the other pairs of lugs 89 or 90 of the above-described dogs in such manner that when the collar does thus engage the lugs it moves the respective dogs so as to release their connection with the ratchet teeth. The collar 91 is of such dimensions that the piston rod 79 has a definite limited motion between the points where it engages the said lugs 89 or 90 on the dogs to release either the one pair or the other. The carriage 86 is loosely mounted on the said piston rod 79 between two spiral springs 92 which are mounted on the piston rod between the ends of the carriage and a pair of collars 93 on the piston rod. The action of this mechanism is as follows:— Suppose (Fig. 9) that the electric circuit draws up the armature 64 into the solenoid 60; this action moves the pilot valve 69 towards the right, which, in turn, opens the left-hand passage 72 through the main valve 74 and connects the valve chamber with the left end of the cylinder and also connects the right-hand passage 73 with the exhaust passage 76, thus forcing the piston 78 toward the right. This action compresses the left-hand spring 92 against the left end wall of the carriage 86 but is unable to move the carriage because all the dogs are engaging the ratchet teeth. When the piston moves far enough to bring the central collar 91 against the lugs 89 of the right-hand pair of dogs 87, it will disengage them from the ratchet teeth 84. The carriage 86 is then free to move towards the right and does so under the impulse from the said left-hand spring 92 which had been compressed, as above. As the carriage thus suddenly jumps towards the right, it moves the bar 82 connected therewith and turns the gear 80 of the cam shaft 56; also, it moves, by a floating lever 94 and a link 95, the main valve 74 of the control towards the right and closes both the passages 72 and 73 through the main valve, and thus prevents any further motion of the piston 78 in the cylinder 77. As soon as the carriage 86 begins to move towards the right, as above, the lugs 89 on the dogs 87 become disengaged from the central collar 91 on the piston rod 79 and the dogs 87 then fly back into engaging position and grip the next ratchet teeth 84, thus holding the carriage in this position. If, however, the motion of the carriage 86 has not been sufficient to cause the main valve 74 to move far enough so that the pilot valve 69 will close its passages 72 and 73, then the piston 78 continues to move and again brings the central collar 91 against the lugs 89 to release the dogs 87 from engaging the ratchet teeth 84 thus permitting the carriage 86, together with the main valve 74 to move a greater distance, and turning the cam shaft 56 into its next position. Thus it will be seen that the cam shaft 56 is turned suddenly into one of a series of positions, each position corresponding to one position of the carriage 86 in the frame 83 and that it is firmly held in such position by the dogs 87 and 88 engaging the several ratchet teeth 84 and 85; so that, although the armature 64, the pilot valve 69 and the piston 78 may occupy intermediate positions and may move slowly thereto, the cam shaft 56, the carriage 86 and the main valve 74 will occupy only one of a series of definite positions and will move rapidly thereto.

As above described, the cam shaft 56 operates the several poppet valves 42 controlling the inlet for the vapor in the several tubes 7, and each said valve 42 is either held fully open by the cam shaft or is closed, because said cam shaft 56 does not occupy intermediate positions in which any one of the valves 42 may be partially open. The cams 59 may be arranged on the cam shaft 56 to cut in any number of vapor tubes together in order to vary the number of generators in use with the demands of the circuit which controls the solenoid.

When any of the vapor tubes is shut off from the vapor supply it becomes highly rarified because it is in direct communication with the vacuum chamber 2, hence if the collector plates therein are connected to those of another generator tube which is in service, it is possible under certain conditions for the current to jump across the unused tube. In order to overcome this condition I mount a series of knife switches 96 and 97 in connection with the several levers 57 which operate the valves 42, as above described. Each knife switch 96 or 97 consists of a lever 98 pivoted to the frame and engaging and operated by the above-mentioned lever 57 and having a switch blade 99 loosely connected therewith by means of

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a spring 100, such switch blade 99 engaging the spring contact lugs 101 of the switch when the switch is closed; but, when the lever 98 is drawn away from the closed position, the switch blade 99 drags behind the lever until the strain in the spring 100 is sufficient to draw it away from the contact lugs 101, and then the said knife blade 99 moves at a high speed to break the contact therewith and thus break the circuit. As shown in the drawings two such switches 96 and 97 are shown for each generator tube 7 and one of them, 96, is placed in the conductor 15 between the collector plates 13 and the transformer line 102 (Fig. 19); thus, when the vapor is turned off from any generator, the collector plates thereof are simultaneously disconnected from the transformer line. As stated, there are two such switches for each generator tube, one switch 96 controls the said connection as above described, while the other switch 97 is interposed in the circuit controlling the current in the electro-magnets 24 and 25 of the same generator. These switches 97, of course, may be connected as stated or other switches might be added, as, for instance, (Fig. 19) one switch for each pair of electro-magnets or one switch for each pair of collector plates but I have not thought it necessary to insert in the drawings other views illustrating the possible variations in the number of switches and connections.

In large machines the field coils 24 and 25 are supplied with an alternating current from a circuit 103 (Fig. 19) energized by separate alternating current generator 104, which has its field 105 magnetized by a direct current from a separate circuit 106 energized by the direct current generator 107. The current supplied by the direct current generator 107 is controlled by inserting a Tirrill, or other automatic voltage regulator 108 in the field circuit 109 thereof, such regulator 108 being controlled by the main outside circuit 61, thus varying the magnetic strength of the direct current fields 110, according to the requirements of the line 61, and correspondingly varying the strength of the alternating current supplied by the alternator 104 to the electro-magnets 24 and 25 of this generator. Since the magnetic fields 24 and 25 are thus controlled by the circuit 61 being supplied by the generator, and the speed of the vapor through said fields is constant, it follows that the difference of potential developed by the vapor will be controlled by the demands of the circuit. Thus the major variations in demand by the main line are taken care of by automatically cutting in or out one or more of the generators, while the minor variations are provided for by changes in the magnetism of the generators in use at any time. There are other methods of thus varying the strength of the magnetic fields but as they do not form a part of this invention I have not described them herein.

Referring again to Fig. 19, I have shown therein the connections of one only of said generators 7, wherein three pairs of collector plates 13 and 14 are mounted. The main line 61 is connected by a shunt line 111 both with the solenoid 60 and with the Tirrill regulator 108, which connects with the field magnet circuit 109 of the direct current generator 107. Suitable variable resistances 112 and 113 respectively are also inserted in the said solenoid and field magnet circuits. The direct current supplied by this generator 107 passes by the circuit 106 to the field magnet 105 of the alternating current generator 104, and the variable resistance 114 is inserted in this circuit 106. The alternating current generator 104 supplies the circuit 103 which leads to all the electro-magnets 24 and 25 of all the vapor generators, the above described switches 97 being inserted in these field magnet circuits. I have shown in this drawing each of these field magnet circuits provided with a separate such switch, but it is readily understood that a single switch 97 may be provided for the three magnets of each generator. The collector plates 13 and 14 are shown as connected together in parallel, in pairs, one side 15 thereof being connected through the above described switch 96 to the circuit 102 which correspondingly connects the similar parts of the other generators together: the other pair of collectors is connected by the conductor 16 to the other side of the same circuit 102. The collectors 13 and 14 are also connected by the wires 115 and 116 to the two ends of the primary winding 117 of a transformer, the secondary winding 118 thereof being connected to the main line 61. By passing the current generated by the several generators through the transformer 117, I am able to secure the greatest vapor efficiency and bring the voltage to the strength required by the circuit.

In Fig. 20 I have shown a variation in the electrical connections of my generator, in which a three-phase current is generated in each tube. That is to say, each generator tube is a unit in itself but all may be connected to the same exciter and transformer, if desired. In this case there are three sets of magnets 24 in the generator, as shown in the drawings, and each magnet is connected to a phase in the alternator 119, and each has its collector plates 13 and 14 connected to the ends of the primary coil 120 in the transformer, the secondary coils 121 thereof supplying the outside circuit 122 with the corresponding three-phase current. There are many other variations in the electric connections which might be

made to obtain certain effects or to satisfy certain conditions but it is not considered necessary to show them as those familiar with the art will readily devise them to suit the requirements of each case; that arrangement shown in the drawings being simply a single illustration thereof.

It should be noted, however, that the nature of the current delivered by my generator follows closely the nature of the current supplied to it by the exciters. The current delivered by these generators is dependent on the strength of the magnetic field and the loss of energy experienced by the vapor in passing through the magnetic fields.

Having described my invention what I claim is:—

1. The process of generating electricity comprising forcing a stream of elastic conducting vapor through a passage of expanding section whereby a substantially uniform velocity of the vapor is maintained from end to end of said passage; causing a series of magnetic fields in said passage, whereby substantially identical differences of potential are generated in said vapor stream at said magnetic fields; and collecting the resulting electricity at such points of potential difference.

2. In an apparatus for generating electricity from a stream of conducting vapor, a generator tube positioned to receive the stream of vapor, said tube being of increasing cross-sectional area from the inlet to the outlet thereof whereby the vapors passing therethrough will maintain a substantially constant velocity as they expand under the reduction of pressure between the ends of the tube.

3. In a machine for generating electricity, means for supplying an electric current of a certain character to an electro-magnet thereby transforming the energy thereof into magnetism of a corresponding character; means for passing a stream of conducting vapor through and across the magnetic field thus made, thereby causing a difference of potential between the edges of the stream, said difference of potential corresponding with the character of the current supplied to the magnet; and means for collecting and conducting the generated electricity from said stream edges.

4. In an apparatus for generating electricity from a stream of conducting vapor, a generator tube positioned to receive the stream of vapor, said tube being of increasing size from the inlet to the outlet thereof, the section thereof being oblong, the long sides thereof being parallel throughout the length of the tube and the short sides thereof being farther apart at the outlet than at the inlet, whereby the vapors pass therethrough in a thin stream and will maintain a substantially constant velocity as they expand under the reduction of pressure thereon between the ends of the tube.

5. In an apparatus for generating electricity from a stream of conducting vapor, means whereby the vapor is supplied to the apparatus at substantially its initial pressure; a tube connected to said vapor supplying means and adapted to receive and conduct the vapor through the apparatus; means for receiving the vapor from the tube, said receiving means being maintained at a reduced pressure, the difference in pressure between the two ends of the tube causing a stream of vapor to pass therethrough and to expand as the pressure thereon is reduced; means for maintaining a substantially constant velocity of said stream throughout its passage through said tube; means for forming a magnetic field across the stream of vapor as it expands in said tube, thereby generating a difference of electric potential between the edges of said stream of vapor; and means for collecting the electricity from said stream edges.

6. In a machine of the class described, a base; an expansion tube mounted thereon through which hot vapors pass; a head having a passage therethrough and supported from the base independently of said tube, said inlet passage communicating with the upper end of said tube; and a sealed expansion joint between said head and said tube whereby relative motion between the parts is permitted and the vapor passage is sealed.

7. In an apparatus as set forth in claim 6, wherein the expansion joint comprises two dished annular plates each secured to one of said parts at their inner edges and each secured to the other at their outer edges.

8. In an apparatus of the class described, a vapor passage wherein a vapor under pressure is conducted; a closure communicating with the vapor passage, but permitting leakage of the vapor therethrough; a jacket surrounding said closure; and means for causing a reduced pressure between said closure and said jacket to convey away any vapor which has leaked therethrough.

9. In an apparatus of the class described, a base having a vacuum chamber formed therein; a hot vapor tube mounted on the base and communicating with said vacuum chamber; an air passage in the base and separated from said vacuum chamber; an air jacket surrounding the tube and forming an air space around the tube; and passages through said jacket permitting the circulation of air from said air passage in the base, around and along the tube to cool it.

10. In an apparatus of the class described comprising a battery of a plurality of generators having separate generator tubes; magnetic cores for said battery of generators, having slots through which said gen-

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erator tubes pass, the central parts of the slots being closer together than their ends to form magnetic poles, one on each side of each tube; a plurality of pairs of electromagnetic coils wound on said cores from the ends of the slots to the outside, one such pair of coils being provided for each generator tube, said pair of coils for each slot being of the same polarity, and said pairs of coils for adjacent slots being of opposite polarity, thereby forcing the magnetism into two magnetic circuits both of which pass through the generator tube.

11. In an apparatus for generating electricity from a stream of conducting vapor comprising a battery of generators each connected to a supply of vapor by a valve-controlled passage; a circuit supplied with electricity by said battery of generators; and means controlled by said circuit and adapted to operate the valves controlling the generators of said battery in accordance with the needs of said circuit.

12. In apparatus as set forth in claim 11 wherein said valve-operating means acts to either completely open or leave entirely closed the said valves, whereby one or more of the generators forming the battery may be placed in or cut out of operation in accordance with the needs of said circuit.

13. In apparatus as set forth in claim 11 wherein said valve operating means includes a unit wherein electrical variations in the circuit produce definite mechanical motion, and independently actuated mechanical means for actuating said valves, said mechanical means being controlled by the mechanical movements in said unit.

14. In apparatus as set forth in claim 11 wherein said valve-operating means includes a solenoid controlled by the circuit, an independently actuated mechanical means controlled by said solenoid, and step-by-step means controlled and actuated by said mechanical means and operating said valves.

15. In apparatus as set forth in claim 11 wherein said valve operating means includes a single mechanism adapted to act on any, or any number, of the valves whereby one or more of the generators of the battery may operate in accordance with the needs of said circuit.

16. In apparatus as set forth in claim 11 wherein said valve operating means includes a single connecting mechanism adapted to act on any, or any number, of the valves in non-continuous manner, whereby one or more of the generators of the battery will be in full operation and the others will be completely shut off, in accordance with the needs of said circuit.

17. In apparatus for generating electricity from a stream of conducting vapor, comprising a battery of generators each connected to a supply of vapor by a valve-controlled passage; a circuit supplied with electricity by said battery of generators; a vertically pulling solenoid connected to said circuit and controlled thereby; a vertically movable armature for said solenoid; means for counterbalancing a part of the weight of said armature; and means controlled by said armature and adapted to operate the valves controlling the generators of said battery in accordance with the needs of said circuit.

18. In apparatus as set forth in claim 17 wherein the effect of said counterbalancing means on said armature varies inversely as the effect of the solenoid on the armature.

19. In apparatus as set forth in claim 17 wherein said counterbalancing means comprises a liquid contained in a vessel and a float partially immersed in the liquid and attached to the armature to counterbalance a portion of the weight thereof.

20. In apparatus as set forth in claim 17 wherein said counterbalancing means comprises a liquid contained in a vessel, and a float having an upwardly increasing horizontal cross-section partially immersed in the liquid and attached to the armature to counterbalance a portion of the weight thereof in inverse proportion to the effect of the solenoid on the armature.

21. In apparatus as set forth in claim 17 wherein said valve-operating means is independently actuated but is controlled by said armature.

22. In apparatus as set forth in claim 17 wherein said valve-operating means comprises a step-by-step mechanism connected to the generator valves; a piston actuating and controlling said step-by-step mechanism; a cylinder wherein said piston is mounted and provided with a pair of inlet and exhaust passages; a main valve connected to said step-by-step mechanism and having passages therethrough and controlling said inlet and exhaust passages; a pilot valve controlling the passages through the main valve and connected to the armature; and a valve chest containing a fluid under pressure to enter the cylinder under the control of the solenoid and of the step-by-step mechanism to operate the piston therein.

23. In an apparatus for generating electricity from a stream of conducting vapor, comprising a source of supply of a conducting vapor; a condensing chamber; a battery of generator tubes each in free communication at one end with the condensing chamber; valved passages connecting the other ends of the tubes to the source of vapor supply; electro-magnets for each tube and forming a magnetic field thereacross; switches controlling said electro-magnets; means within each tube for collecting the electricity generated; and means joining each switch to the valve of the valved passage controlling the corresponding generator tube whereby

when the valve is open the switch is closed and when the valve is closed the switch is open.

24. In an apparatus for generating electricity from a stream of hot vapor, a vapor tube; means for cooling the vapor tube to a substantially uniform temperature; a magnetized core surrounding the vapor tube and forming a magnetic field across the tube; means for protecting the core from the heat of the tube; and means for cooling the core.

25. An apparatus as set forth in claim 24, wherein said vapor tube is formed of a body of poor heat conductivity and is surrounded by a jacket spaced therefrom, with passages through its ends, whereby the tube is heat insulated from the magnetized core.

26. An apparatus as set forth in claim 24 wherein said means for protecting the core comprises a jacket spaced from the tube, with passages through its ends, and said core is spaced from the jacket.

27. In apparatus for generating electricity from vapor, a circuit for the vapor; a tube traversed by the vapor; a magnet external to said tube and producing a magnetic field therein; and means for largely dissipating the heat of the vapor in the tube before it penetrates to the magnet.

28. In apparatus as set forth in claim 27, together with means for circulating a cooling liquid through said magnet to carry off the excess heat.

29. In apparatus for generating electricity from a stream of conducting vapor, comprising a source of supply of the vapor; a condensing chamber; a battery of generator tubes, each in free and continuous communication at one end with the condensing chamber whereby the inactive tubes are maintained at a low pressure; valved passages connecting the other ends of the tubes to the source of vapor supply; means in each such generator tube to collect the electricity generated therein; an electric circuit supplied with electricity from any of said collecting means; a switch between said electric circuit and said collecting means for each generator tube; and means joining each switch to the valve of the valved passage controlling the corresponding generator tube, whereby when the valve is open the switch is closed and when the valve is closed the switch is open and the current supplied by the other generator tubes to the circuit is prevented from leaking across the collecting means of the inactive generator tubes.

30. An apparatus as set forth in claim 29, together with a single controlling mechanism operating all the valves of said valved passages and the switches, whereby which of said generator tubes are inactive and cut off from said circuit is determined.

Signed at New York, in the county and State of New York, this 21 day of July 1922.

W. ST. G. ELLIOTT.