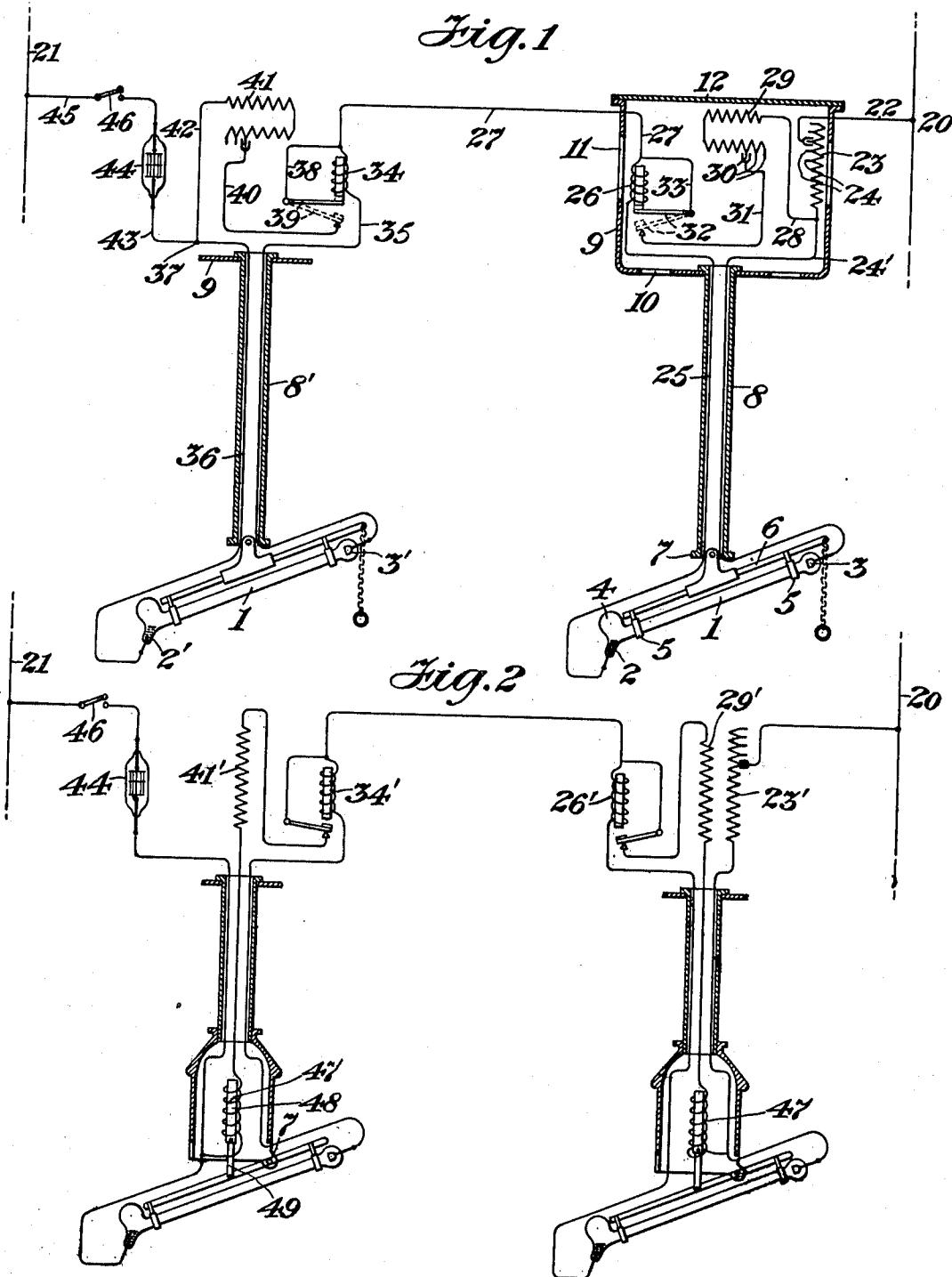


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VAPOR ELECTRIC APPARATUS.
APPLICATION FILED NOV. 22, 1906.

1,054,257.

Patented Feb. 25, 1913.

2 SHEETS-SHEET 1.



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2 SHEETS—SHEET 2.

Fig. 3

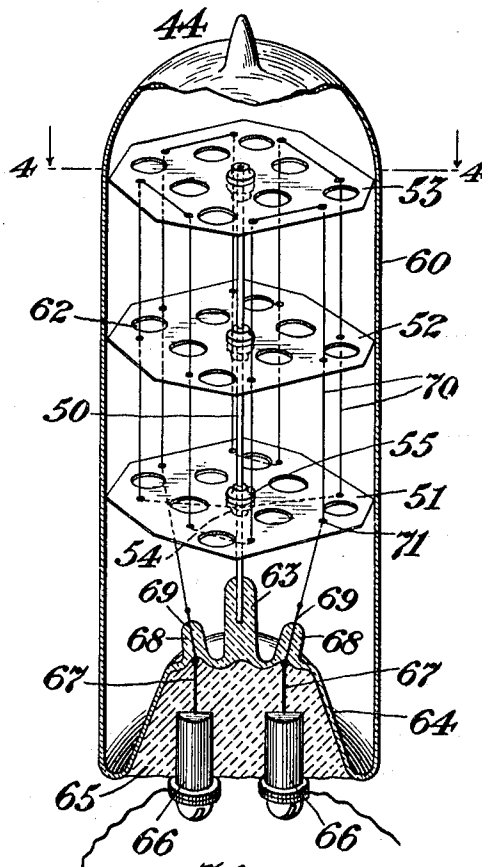
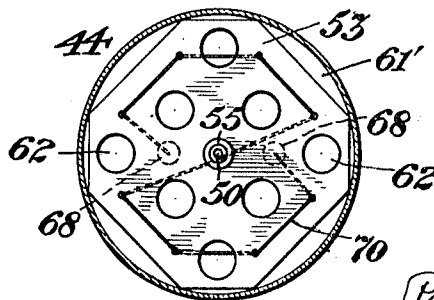


Fig. 4



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VAPOR ELECTRIC APPARATUS.

1,054,257.

Specification of Letters Patent.

Patented Feb. 25, 1913.

Application filed November 22, 1906. Serial No. 344,545.

To all whom it may concern:

Be it known that I, PERCY H. THOMAS, a citizen of the United States, and resident of Montclair, county of Essex, State of New Jersey, have invented certain new and useful Improvements in Vapor Electric Apparatus, of which the following is a specification.

This invention relates to mercury vapor devices of the Cooper Hewitt type; to auxiliary apparatus and circuits, whereby they may be adapted for operation on commercial supply systems; and more specifically to an organization of such apparatus and circuits whereby a plurality of lamps or analogous devices may be operated in series with each other on a constant potential supply system; as, for instance, a series arrangement of two or more mercury vapor lamps in a single bridge across a commercial lighting circuit. It contemplates a certain flexibility of apparatus whereby commercially standardized outfits may be provided having predetermined proportions and adjustments adapted for direct application to any commercial circuit having characteristics within certain typical ranges commonly met with in practice and for which the apparatus is standardized.

The vapor devices employed may be, and preferably are, mercury vapor lamps of the type which are started by bodily movement of an electrode, as, for instance, rotating or tilting the same to control the make or break of a conducting bridge between the negative electrode and a positive electrode. The movement of the container to effect this purpose may be by hand or by automatic electromagnetic devices controlled by current from the line.

Each lamp is preferably arranged for starting and operation independently, whether there is or is not in series therewith another lamp of the same type, and whether or not such other lamp happens to be in operation. To this end I provide a shunt circuit having operatively arranged therein resistance of such value that the current taken by the shunt is substantially equal to or slightly less than the current taken by the lamp when operating, and I provide a cut-out controlled by the starting of the lamp, operating to interrupt the

shunt circuit thereof, so that current cannot flow through both the lamp and its shunt circuit, except for a brief interval too short to cause undesirable effects.

Sustaining or steadying inductance for the lamps is preferably embodied in two or more coils, so disposed as to be in close proximity to the lamps to be steadied thereby. The coils are most effective in this position, their action being direct so that there is no opportunity for dissipation of the energy through electrostatic capacity action or insulation leakage.

The supplemental potential exerted by such a coil on the lamp is developed only in the conductors between the coil and the negative electrode and in parts electrically connected therebetween. For this reason I make the sustaining coils electrically separate from the resistance ballast and otherwise arrange them in such a manner as to reduce to a minimum the length of wiring and the apparatus which is to be subjected to the higher potential, thereby decreasing the portion of the apparatus requiring high insulation. I prefer to utilize as sustaining inductance, the coil of the electromagnetic cut-out for the shunt. Where two lamps are arranged in series, I may locate the coils of the cut-outs of each in common connection between the two lamps, so that these two coils are at all times directly in series with each other and operate to produce an accelerated potential in the same direction so that when both lamps are in operation, they constitute in effect a single steadying inductance common to both lamps.

The steadying inductance provided in this way operates in a well known manner to smooth out abrupt fluctuations in the circuit through the lamp, but this is only one of the regulating appliances in my standardized commercial outfits. The regulating devices also provide for control of the current through the wide range of resistance involved in the bridging operation; also through the range of variation of current due to the normal variations of a given supply circuit; and also through the range of standard voltages of different individual supply systems nominally belonging to the same general class. They also provide for the variations of voltage found in different

lamp tubes of the same size and model which might be supposed to have the same voltage, but which in practice are found to differ.

5 In order that the apparatus may be standardized for wide variations involved in the one or the other or all of these variables, I prefer to employ a certain amount of series resistance. This may be partly ohmic resistance of automatically shifting value and
10 partly simple ohmic resistance of definite value, which may be more or less inductive, if desired.

The series ohmic resistance of definite
15 value may be arranged to sustain across its terminals a certain part, say 10%, of the total voltage across the line, and the remainder of the excess voltage above what is required across the terminals of the lamp
20 when in operation, may be taken up by a ballast resistance having a positive temperature coefficient preferably characterized by a critical region of rapid temperature-resistance variation, in which it normally
25 operates, when current flows therethrough at the rate required for normal operation of the apparatus to be protected.

Ballasts of iron wire have been thus used to control the comparatively small current
30 necessary for the operation of a Nernst light glower, but such ballasts are not adapted for mercury vapor devices of the Cooper Hewitt type, particularly those which are adapted to be started by short circuiting of the vapor
35 column of the lamp through a low resistance bridge between main electrodes or between a main and an auxiliary electrode.

The conditions are essentially different in that the Nernst glower operates with an
40 initially high resistance, decreasing rapidly as it heats up until at the temperatures where it begins to be most efficient as a light giving means, it is very near the critical region, where a comparatively slight momentary
45 excess of current and resulting increase of temperature will damage or destroy the glower. Because of these characteristics, the Nernst ballast must have an extremely small time period of heating in
50 order that the glower may not be damaged or destroyed by excessive overrunning, while the ballast is being heated up to a normal, steady state.

The necessary small time period of heating involves several factors: The total mass
55 of the wire and resulting heat capacity is small in order that the rise of temperature in the wire may not lag behind the increase of rate of heat development due to increase
60 of current; and heat capacity of the surroundings is also small, so that the device as a whole quickly attains the critical temperatures. The ballast wire, which is necessarily of considerable length, is therefore
65 disposed in a small space, usually by first

bending into an open spiral and then arranging the spiral in closely spaced lengths in a suitable container. Furthermore, the inert gas used to prevent oxidation of the iron at high temperatures, is a gas of the smallest possible specific heat, namely, hydrogen. Such Nernst ballasts have been perfected by experiment and modification, until they are very well adapted for their purpose, but the necessity that they embody a definite value
70 of resistance and that they attain a steady average of temperature in the critical region, under the influence of the current which will flow therethrough against such resistance, precludes any great flexibility of variation to meet materially different requirements and conditions. As illustrating this, take the case of a translating device having a substantially constant voltage characteristic for
75 varying currents such as the lamps or apparatus of the present application and suppose it be desired to adapt such a ballast to operate in the critical region to protect or regulate a translating device requiring a normal current flow, say, seven times that of the Nernst glower. Then with a constant
80 voltage on the translating device and constant supply voltage it is clear that the ballast device must absorb the same voltage as before; namely the difference between the voltage of the supply and the voltage of the translating device. With the seven fold current this means a reduction of resistance in the ballast to 1/7th. If the required reduction of resistance were attained by merely
85 shortening the ballast wire, then, theoretically, the total heat generation would be multiplied by seven and the total heat radiating area divided by seven. The required reduction in resistance must, therefore, be attained in other ways. The obvious way of getting the decreased resistance and increased current without change of the critical temperature resistance governing effect, is to arrange a desired number of similar
90 Nernst ballasts in parallel. This expedient might be employed in connection with the Cooper Hewitt vapor devices if they had an operation analogous to that of the Nernst glower, but they had not. For instance, even lamps started without short circuiting, as by high potential discharge between electrodes, offer when first started an initially low resistance rising slowly to normal operating resistance, as the lamp heats up. Such expedient is therefore inapplicable to the conditions contemplated herein, for, if enough of the Nernst ballasts are employed so that the current flowing in the normal operation of the lamp will heat them to the required
95 critical temperature, they will not stand the starting overload. On the other hand, if enough of them are used so that they will stand the starting overload, they will not attain the desired critical temperatures un-
100
105
110
115
120
125
130

der the smaller currents flowing during the normal operation. One method of meeting this difficulty is to arrange in series with the ballast, a conductor having a normal high resistance and a negative temperature-resistance coefficient, such as the carbon filament described in my prior Patent 809,643, granted January 9th, 1906. In such an arrangement the comparatively high resistance of the filament when cold, serves to protect the ballast to a certain extent by interposing its own falling resistance, thus proportionally retarding the rise of current in the ballast during the time required for heating the filament to the lower resistance condition.

In attempting any other solution of the problem, there is always the difficulty that a ballast adapted to be heated so as to operate in the critical region on a given normal current flow, will in general be burned out by a given percentage of excess current flow. In my present invention, however, I have taken advantage of the fact that the time required for burning out by a given percentage of overload is not the same in all cases, but varies to a certain extent with the total heat capacity of the ballast, which is determined by the mass of the wire and by the volume, specific heat, etc., of the immediate environment, including the geometrical arrangement and space relations of the wire, the size of the container, and the density of the contained gas. I have discovered that this difference in time period of burning out being due to the heat capacity, is greatest in actual lapse of time where the overload is applied to the ballast when cold, and that matters may be so arranged that the extreme overload will come only when the ballast is cold; also that in practice the time period required for destructive overheating may be lengthened to such a value in seconds as will easily permit bridging and breaking of the bridge between the electrodes to start the lamp before the heat capacity of the ballast has been satisfied and destructive temperatures reached.

The required heat capacity tends to make the ballast sluggish as a regulator of normal current flow, but sluggishness, which would be fatal in a Nernst ballast, is of no disadvantage in a Cooper Hewitt ballast, because a Cooper Hewitt lamp may "overrun" to a considerable extent and for a comparatively long time without damage, whereas in the case of the Nernst glower, the overrunning must be very small and must be limited to fractions of a second in duration.

I have discovered that the actual time values of safe overload for a Cooper Hewitt ballast may be made such as to afford the time practically necessary for the bridge making and breaking operation and for heating up to the normal, steady state, and this without making the ballast too sluggish

for its proper regulating function during the normal operation of the lamp and without making it of such proportions as to throw it out of the critical region of temperature resistance change.

In designing the Cooper Hewitt ballast, the favorable factors are at a maximum when all of the ballast is put in a single length of wire and when the arrangement is such that the ballast will be cold at the time of the contemplated overload, but some distribution of the ballast in parallel wires and some initial heating, will only decrease the factor of safety and, if kept within limits, will not completely destroy the desired time period of safe overload.

In designing the Cooper Hewitt ballast, I decrease the total resistance so that the resistance of the ballast, preferably a single length of wire, equals the combined effective resistance of the required number of parallel Nernst ballasts. This is done by selecting an entirely new diameter and a new length, such that the heat radiating rate will be increased proportionally to the increase in the rate of the heat development. Each of the Nernst ballasts being known to have heat radiation and heat development rates suitable for proper operation with a definite fraction of the current desired for the new ballast, say one-seventh, the new ballast must be one-seventh the resistance to carry seven times the current. The heat development rate will be about seven times as great and, other things being equal, the surface area ought to be about seven times as great. Theoretically one-seventh the resistance, requires that the cross section divided by the length be seven times as great, and seven times the radiating area requires that the circumference times the length also be seven times as great. Hence, the new diameter and lengths must be such that in the new ballast

$$\frac{\pi D^2}{4L}$$

and πDL should both be seven times as great as in the Nernst ballast. The dimensions for the new ballast may be found by taking successively increasing values of diameter, and the corresponding values of length which will give the desired resistance, until values are reached which will satisfy both conditions.

The dimensions necessary for the changed value of current can be but roughly approximated in this way, for it will be found that other conditions change and that dimensions and also the construction of the ballast will require further modification. By my invention, however, it will usually be unnecessary to do more than alter the length to vary the resistance, the corresponding change in radiation rate being effected by change of the

construction and relative arrangement of parts, or of the character or density of the gas within the container.

In construction of Cooper Hewitt ballasts
 5 dissipating considerable quantities of heat
 and consequently having considerable physical
 size, uniform heating of the wire is desirable
 and at the same time the disposition of the
 wire must be such that it will be capable
 10 of radiating or otherwise transferring the
 heat, out of the wire at the required rate,
 the heat to be developed and transferred per
 unit time, being relatively very great both
 for the entire device and for each unit
 15 length of the wire. For convenience in
 manufacture and practical use, the size of
 the container cannot be increased indefinitely,
 and matters should be arranged so that the
 rate of transfer of heat outside of the
 20 container is very rapid. To insure this, I
 make the distance through which such transfer
 must be made, comparatively small. For the
 above reasons, the wires are not coiled so
 as to bring adjacent turns into
 25 proximity and are not disposed in a container
 of small volume. On the contrary, I prefer
 to dispose the wire in straight lengths
 suitably supported at equal distances from
 the walls of the inclosure and
 30 preferably closely adjacent thereto, so that
 the transfer of heat outside of the container
 may be as direct as possible. In order that
 the heating may be uniform, so that all
 parts of the length of the wire will be heated
 35 to the critical regions as far as possible at
 the same time, care should be taken that all
 parts of each length of wire be parallel with
 the surface of the container as well as that
 the distance be the same for each length. It
 40 will be understood that in practice there is a
 certain fraction of the length of the wire
 adjacent the supports which it is so difficult
 to arrange for heating to the critical temperature
 at the same time with the rest of the wire,
 45 that it is hardly worth while in practice to
 attempt to do so. Such fraction of the length
 of the wire as cannot well be made uniform
 in operation with the more effective portions
 acting in the critical regions, should be so
 50 disposed that they will always be underheated
 rather than overheated, because by this expedient
 their effect is practically unobjectionable since
 they merely operate to impair the sharpness of
 55 the current governing function, whereas if they
 tended to reach a higher temperature than the
 other parts of the wire, the critical region
 would only be utilized on a small fraction of
 the ballast and only a very minor governing
 60 effect would be obtained, for such overheated
 parts of the ballast would burn out before the
 other parts were sufficiently heated.

Uniform heating of the wire also requires
 65 a low pressure of the surrounding inert gas

so that diffusion will be much freer, for
 with a higher pressure in the container for
 the large ballast, certain portions of the gas
 will become hotter than other portions, and
 on account of the limited diffusion, this will
 70 give rise to convection currents caused by
 movement of bodies of the gas having different
 densities from adjacent bodies. The bodies of
 higher temperature, tend to collect in the
 upper portions of the receptacle and render
 75 these portions hotter than others, so that the
 radiation of heat developed in the wire is less
 rapid. This causes uneven heating of the
 wire, and this, from the nature of the operation
 of iron, particularly in the critical region,
 80 tends to be self-exaggerating, a slight elevation
 of temperature in any one spot tending to
 produce greater resistance and greater heating
 effect at such point. In order that the ballast
 may serve its purpose, it is very desirable
 85 that as much as possible of the length of the
 iron reach the same critical temperatures at the
 same time. I, therefore, prefer to arrange
 matters so that the heat will be largely
 dissipated by radiation and diffusion, so that
 90 it will be rapidly and uniformly diffused
 throughout the whole adjacent region, instead
 of being carried by convection movements of
 the gas. The Nernst lamp ballast inclosure or
 95 envelop is only $1\frac{1}{4}$ inches long, and diffusion
 of hydrogen is so good as to keep the whole
 thing at practically uniform temperature. To
 get nearly as good diffusion in the Hewitt
 ballast envelop or inclosure, which for a 3.5
 100 ampere current may be five or six inches
 long, it is necessary to have a low pressure.
 In the Hewitt ballast with a pressure of
 hydrogen near atmospheric, the diffusion in
 each $1\frac{1}{4}$ inch would be about the same as in
 105 the given Nernst ballast, but as the space to
 be covered is much greater, the diffusion
 would be very imperfect, and different
 temperatures in different parts of the container
 would be unavoidable.

Where two lamps are used in series, one
 ballast may be used to control the current
 for both lamps, whether one or both of said
 lamps are in operation. In such case, I may
 further protect the ballast by arranging
 115 symmetrically therewith in the other lamp
 fixture a certain amount of series resistance,
 which will limit the initial flow of current.
 I also prefer to so adjust the shunt resistance
 that current taken by the shunt shall be
 120 slightly less than the current which will
 flow through the lamp when the latter is put
 into operation. This furnishes an additional
 margin of safety for the ballast by keeping
 it comparatively cool during the
 125 period when current is flowing through the
 shunt. This may occur when one lamp only
 is in operation, or it may occur at the time
 of starting, when neither lamp is in operation,
 but the current has been turned on 130

preparatory to the tilting and starting. By this expedient, the ballast, though heated to some extent, still has a margin of heat capacity to stand the starting overload for the necessary short time. The slight cutting down of the current capacity of the shunt necessary to effect this result, does not affect the operation of other lamps which may be already operating in series therewith.

The effect of the reducing of the current in the shunt to one of two serially operated lamps can be illustrated numerically. Take a ballast so adjusted that its maximum safe voltage occurs at 3.6 amperes and having perhaps $\frac{1}{3}$ its maximum voltage at 3.2 amperes. Such a ballast traversed by three amperes will be relatively cold while at 3.6 amperes the ballast conductor will be at a luminous red heat. Then when one lamp is operating and the shunt to the other lamp is set to give 3.6 amperes for the operating lamp, it will be clear that during the abnormal period while the non-operating lamp has a short circuit between its electrodes for starting, a current larger than 3.6 amperes will be momentarily forced through the ballast heating it above what is taken as a safe operating temperature. Take on the other hand a slightly higher resistance shunt giving 3 amperes instead of $3\frac{1}{3}$ amperes (the lamp itself has a constant voltage regardless of current) through the initially operating lamp, the ballast conductor will be running comparatively cold, but while as before during the momentary short circuit accompanying the starting of the second lamp, an excessive current will traverse the ballast conductor, a certain period of time is required for it and the surrounding casing to become heated to a high temperature which time interval I have found can be made sufficient to protect the ballast from over heating during starting. In general the fact that when operated singly the lamps run upon 3 amperes, while when operated together they may run upon a somewhat higher current as shown, can be usually neglected in practical service. The extreme sensitiveness of the adjustments here outlined results from the very wide range of voltage change on the ballast with small changes of current, as is well known in the art, and on the constant voltage characteristic of the lamps or apparatus involved.

I may make the operation of the apparatus automatic, by including in the shunt circuit an electromagnet adapted and connected to tilt the container when current is applied to the circuit. When such tilting movement shall have started current flow through the lamp, the automatic cut-out referred to, will operate to deenergize the magnet and restore the lamp to its original position. The lamp is properly weighted or

otherwise arranged so as to return automatically from the up tilted position to its normal position.

A more favorable adjustment of the starting current and corresponding reduction in the size of the magnet necessary for the tilting operation, may be secured by utilizing one or more additional ballasts in the shunt circuit supplying said magnet. This may be of such design as to allow a heavy initial flow of current for starting the lifting operation, and then cut down the current to such lower value as may be needed for completing the tilting movement. I preferably arrange this outfit in such a manner that the various controlling parts, such as ballast resistance, cut-outs, etc., are contained within a suitable inclosure and fastened to the ceiling while the lamp itself is suspended below at any desired height.

The various auxiliary devices in the operation of the lamp, including the series resistance, the shunt resistance, the ballast, and the steadying inductance, such as the cut-out coil, all necessarily operate to generate considerable amounts of heat and for a commercial installation it is desirable that this heat should be dissipated in such manner as not to injuriously affect the apparatus, or adjacent portions of the walls or other supports to which they are fixed. To this end, the design of the various elements must be such as not to cause too intense heat generation in any one of them, and the distribution of said elements should be such as to avoid too great combined heating effect in any one locality.

Where two lamps are used in series, having certain of these auxiliary devices in common, I prefer to so apportion them between the two sets that the total heat generation in each casing or fixture is approximately the same. For instance, where there is a common ballast and a common series resistance, each generating considerable quantities of heat, I prefer to locate the ballast resistance in the casing of one fixture and the series resistance in the casing of the other fixture. In practice, the total heat evolution in each fixture must not exceed a safe maximum.

Mercury vapor lamps are from their nature sensitive to variations in voltage, so much so that in practice it is necessary to make special adjustment of controlling resistance for commercial circuits, whereas by my organization of the circuits, and especially by the use of a ballast, I am enabled to utilize these lamps on commercial circuits of the same general character without adjustment.

In actual practice commercial outfits are standardized so that for all commercial circuits ranging from 125 to 109 volts, the outfit is identically the same, and it is ex-

pected that on any circuit whose normal voltage is around 118 to 120, the lamp will stand within about 10 to 15% drop in voltage without going out. On circuits ranging from 117 to 101 volts, whose normal voltage is around 109 to 111, the same outfit as above is sent out, with the exception of the series resistance, which is arranged to take eight volts less. It is expected that this outfit will stand the same variations of potential as the first. For circuits ranging from 109 down to 93 volts, a third outfit is used, identical with the second, except that a tube taking eight volts less is furnished, there being an additional cutting down of the shunt resistance to correspond to the lower tube voltage. The groups are 118 to 120, 109 to 111, and around 100.

By changing the length of the light giving tube in suitable relation, the same outfit may be used on circuits of lower or higher potential, without change other than adjustment of the shunt resistance to maintain its value slightly less than that of the lamp.

By using four lamps in series they may be adapted to commercial circuits of the nominal 220 volt class in like manner as above, the flexibility or operative voltage ranges being substantially the same percentages as above.

Having thus fully explained the various features of my invention in such manner as will enable any one skilled in the art to embody the broad principles thereof in the various specific forms and arrangements of apparatus, which may be necessary or desirable for various specific purposes, I will not describe certain illustrative embodiments indicated in the accompanying drawings, it being understood that the invention is as broad as hereinbefore indicated and that my claims are not limited to any feature or element not specifically included therein.

Referring to said drawings: Figures 1 and 2 show vapor lamps of the Cooper Hewitt type and fixture therefor, the general arrangement of the circuit connections and of the auxiliary devices being indicated diagrammatically. Figs. 3 and 4 show a desirable form of ballast for such lamps, Fig. 3 showing the ballast support in perspective and the container in vertical section, while Fig. 4 shows the ballast support in plan and the container in horizontal section, on the line 4—4, Fig. 3.

The arrangement indicated in Figs. 1 and 2 are broadly similar. Both show lamps arranged in series in a bridge across a suitable supply circuit with normally closed shunts for each lamp, adapted to be opened by automatic cut-outs when the lamps are in operation. The lamp tubes are of substantially the same type, and are adapted to

be tilted so as to cause the mercury constituting the negative electrode to form a conducting bridge as an initial path for the current, the lamp being then restored to its original position so as to cause the mercury to flow back into the negative electrode receptacle and thereby establish electric current flow through the vapor column, which flow continues during the normal operation of the lamp.

In Fig. 1 the tilting is performed by hand, whereas in Fig. 2 this operation is performed by automatically operating electromagnets in the shunt circuit across each lamp.

Referring more particularly to Fig. 1, it will be seen that the vapor device to be operated is a lamp of the Cooper Hewitt type, comprising a tube 1, having a negative electrode 2, preferably of mercury, and a positive electrode 3, preferably of pure iron. The tube is formed with a chamber containing the mercury of the negative electrode and with a condensing chamber 4, adjacent thereto. The large cooling surface of the chamber 4 in connection with the high temperature established at the solid positive electrode 3 has the effect of determining the condensation almost entirely in said chamber 4, which, being closely adjacent the negative electrode, permits the return of condensed mercury to the latter without serious mechanical disturbance of the surface thereof. In a lamp thus formed, the normal operative position may be approximately horizontal if desired, provided the tilting operation be such as to restore the mercury to the negative electrode 2 after the starting operation. There being little or no condensation in the tube 1, the normal position thereof while running, need not be such as would be necessary to drain mercury toward the electrode 2. This lamp is connected by suspension members 5, 5 to a tilting frame 6 pivoted at 7. It will be obvious from the description of the nature of my invention that many features of circuit arrangement, etc., are equally applicable where the lamps are of a type adapted to be started by tilting about their longitudinal axis to start current flow by making and breaking a bridge between the main negative electrode and an auxiliary positive electrode.

In Fig. 1, the lamp is pivoted as shown, at a desired distance from the ceiling at the end of the tube 8, at the upper end of which is a suitable casing or chamber 9, containing the auxiliary devices and circuits. This chamber may be of any desired construction and is preferably provided with ventilating openings 10 and 11, which may or may not be completed by closure 12, which may be secured directly against the ceiling if desired, and in such case may be formed of asbestos or other fireproof or nonconduct-

ing material. It will be understood that this chamber may be of any desired or conventional form, and while I have indicated a cylindrical form in Fig. 1, a spherical, hemispherical, spheroidal, or other form may be used. Though I have shown only one complete chamber 9, each fixture may have such chamber, or, if desired, the auxiliary apparatus may be located partly or wholly outside of the fixture.

By my invention, lamps and fixtures of the class described, may be arranged in series in a bridge across the line, with the connections substantially as shown. Beginning with the positive side of the line 20, the circuits, lamps, and auxiliary apparatus across the bridge to the negative side of the line 21, may be traced as follows: From 20, the supply conductor 22 leads to the interior of chamber 12, where it connects with a series resistance 23, through a desired one of the loop connections 24. As previously described, this resistance may be of such value as to sustain across its terminals a desired fraction of the voltage of the line, say 10%. Beyond the resistance 23, the circuit divides. One path comprises a conductor 24', which leads through the tube 8 to the positive electrode 3. From the latter, the circuit may be completed through negative electrode 2, conductor 25, and cut-out coil 26, to the conductor 27, leading to the other fixture. The other path is a shunt connection from 23 across the lamp. This shunt path consists of a conductor 28, series resistance 29, adjustable connection 30, conductor 31, to the switch 32, and thence through conductor 33 to the conductor 27, previously mentioned.

The resistances 23 and 29 are preferably provided with loop contacts 24, 24', and 30, 30', as shown, the value of resistance on each contact being preferably predetermined for recognized standard variations met with in practice, and the resistance 29 is preferably slightly greater than the resistance of the lamp when in operation, all as and for the purposes hereinbefore set forth.

The cut-out switch 32 of the shunt is operated by the coil 26 in the lamp circuit, and opens only when current flows through the lamp.

The series connection 27 leads across to the other lamp fixture, and is there divided so as to form parallel paths, one constituting the main circuit through the lamp, and the other a shunt circuit across the same. In this fixture, the arrangement is electrically symmetrical with that in the first fixture, the various auxiliary devices being in the reverse order. Where the circuit from conductor 27 divides, the path constituting the main circuit through the lamp is through the cut-out coil 34, and conductor 35, which extends down through the tubular

support 8', thence to the positive electrode 3', negative electrode 2', and conductor 36, to the point of junction with the shunt circuit at 37.

The shunt path branches off above coil 34, and includes conductor 38, cut-out switch 39, conductor 40, resistance 41, conductor 42. The resistance 41 is in all respects similar to the resistance 29 previously described.

From the point 37, conductor 43 leads through the ballast 44, and conductor 45 to the negative side 21 of the supply circuit.

It will be noted that the ballast 44 is symmetrical with the series resistance 23, and that there is only one such ballast and only one such resistance for the two lamps. It will be noted also that the cut-out coils 26 and 34 are electrically adjacent to each other and to the negative electrodes of both lamps. They are wound and connected so as to furnish accelerated potential in the same direction, and when both of them are in operation, they mutually cooperate in their steadying effect on both negative electrodes 2, 2'. Each coil is a direct electrical connection with its negative electrode, there being no shunt or branch connections or auxiliary apparatus to impair the directness and efficiency of the application of the accelerated potential from each coil to its negative electrode. For example, were the resistances 23 and 29 connected to the conductor between the coil 26 and the negative electrode 2, any capacity or leakage effect thereof would tend to diminish the strength of the action of the coil 26 in maintaining the operation of the negative electrode 2. Such resistances are relatively difficult to insulate while ordinary wire for connecting parts may be insulated to any desired degree. The fact that the coil, 34, operates through the positive electrode 3' to reach the negative electrode 2' does not materially limit its action, since the positive electrode and the vapor column are inherently practically perfectly insulated.

The resistance 23 is in the common lead from the line in one fixture, and the ballast is in the common lead to the other side of the line in the other fixture. The maximum heat generation which occurs at these two points of the circuit, is therefore divided between the two fixtures. The lesser heat development from the other auxiliary apparatus is the same for both fixtures, the heat developed in resistance 29 being practically the same as that developed in resistance 41, and that in coil 26 being practically the same as that in coil 34.

The principles governing the construction, proportion, and operation of the ballast 44 have been hereinbefore fully set forth, and the specific construction, wherein these principles are embodied will be more fully described hereinafter in connection with

Figs. 3 and 4. It is sufficient here to repeat that the ballast is so proportioned as to pass the necessary amount of current for operation of the lamp; to be thereby heated to the critical region; and to have such heat capacity and heat radiation rate, as will cause it to operate in the desired critical region of temperature resistance variation when passing such amount of current. The ballast will not be heated to the full normal extent when current passes through the shunt paths only, because as before explained, the shunt resistances 29 and 41 are each adjusted to pass slightly less current than will be passed by the respective lamps in normal operation.

When one lamp is in operation, the running temperature of the ballast will be preferably less than when both lamps are running, so that the temporary overload, due to the starting of the second lamp, will not cause the same to burn out. With this organization of circuits, either lamp may be started and run independently of the other, and both may be run together in series, if desired.

In preparing the installation, the standardized commercial units are built up with the ballast 44, resistances 23, 29, and 41, and the length and operating voltage of the tube predetermined for certain standard conditions, after the manner hereinbefore set forth. By adjusting the loop connections of the resistances, certain definite predetermined values of resistance are plugged in or out to standardize the apparatus for other conditions commonly met with in practice. Different standard lengths of tube may also be employed, as explained above.

In operation of the device, the circuit being closed through the switch 46, current flows across the bridge through the two shunt paths around the lamps, the amount of flow being regulated by the series resistance 23 and ballast 44. If, now, either of the lamps be tilted so as to cause the mercury to form a conducting bridge across to the positive electrode and thence back to its initial position, the electric current flow will be established through the vapor, the shunt path being cut-out at the first passage of current through the coil 26. The lamp thus started, may be run singly, or the other lamp may be tilted and started in the same way, the shunt path operating to permit suitably regulated flow of current until the second lamp has been started and the cut-out 39 thus operated.

In Fig. 2 like parts are indicated by like numerals. The symmetrical arrangement of the series resistance and the ballast and the shunt resistance and cut-out, are substantially the same. The tilting operation, however, is performed automatically by the coils 47 located in the shunt across the lamps. In

this arrangement, when the current is turned on at the switch 46, current flows through the shunts and energizes the coils 47, thus lifting the cores 48, which, through links 49, tilt the lamps about the pivots 7. The mercury bridge between terminals being formed, the coils 26', 34', operate the shunt cut-outs, thereby deenergizing coils 47, and permitting the lamp to return to its normal position, so that the mercury bridge is broken and the flow of current established through the vapor column of the lamp. As previously stated, the resistances 29' and 41' may be ballast resistances, so that when the current is first turned on, there will be a relatively great flow through the coils 47, and corresponding maximum development of power at the time when the mercury is in the far end of the tube, and the leverage is therefore most disadvantageous. After the lamp has been tilted a certain distance, the leverage improves and the mercury begins to flow down the tube, the work of the coil becomes easier, and by that time the ballast will have heated up, thus cutting down the current to a desired lesser value to correspond with the decreased work to be done.

It will be noted that in Fig. 2, the shunt paths are connected outside of coils 26', 34', so that the steadying of said coils upon the negative electrode will be direct and not diffused through the rest of the apparatus.

The ballast 44 has been fully disclosed as to all its broader characteristics of construction and purpose. A desirable, specific form, is shown in Figs. 3 and 4. A wire of suitable material, such as iron, and of a length and diameter necessary to pass the desired amount of current at a given voltage, is arranged in a container of suitable size upon supports adapted to maintain the lengths thereof in fixed relation to each other and to the walls of the container.

As shown, the support consists of a wire or thrust member 50, of substantial size, carrying disks 51, 52, 53, of nonconducting material, preferably of mica. These disks are spaced apart on the said support and held in fixed relation by collars 54 and 55, engaging the opposite side of each. These collars may be secured in any desired way, as by pinching the smaller ends thereof into secure engagement with said supports 50.

The disks are of such size and shape as to extend laterally nearly or quite into contact with the sides of the container 60, so as to be centered and guided thereby. They are formed in such manner as to have ample ventilating passages. For these reasons, they may conveniently be made in the shape of squares with the corners clipped off, thereby affording ample bearing surface, and yet leaving considerable spaces, as at 61, for circulation and diffusion of the gas adjacent to the walls of the container. Diffusion

throughout the volume of the container, is arranged for by providing perforations 62 of ample area and of suitable distribution for this purpose, and yet without materially affecting the stiffness and substantial character of the support to be afforded by the disks. The size of all these parts, and the diameter and length of the container 60, as well as the disposition of the wire within the same, are determined in accordance with the rules hereinbefore set forth, which require that the facility of radiation be proportional to the heat generated, the actual sizes of the parts being, of course, no greater than required by such considerations.

The standard 50 is fused into the nipple 63, which secures it firmly from endwise displacement, while the mica disks engaging the surface of the glass, insures against lateral displacement, which might result from vibration or shocks incident to practical use of the device.

The nipple 63 may be formed upon an inwardly extending projection 64, the exterior cavity of which may be filled, as at 65, with nonconducting cement of any suitable composition. Embedded in this, are terminals 66, 66, connected by substantial conductors 67, 67, with leading in wires 69, 69, sealed into nipples 68, 68. The specific construction and arrangement of these parts may be of construction or materials well known in the analogous arts involving such constructions.

The ballast wire 70, is lead through registering perforations 71 in the various disks, preferably passing from the leading in wire to the upper disk, thence across to an adjacent perforation and down to a lower disk, thence again to the upper disk, and back to the lower disk, then diametrically across the lower disk to a perforation on the far side, then up and down, as before, and out to the other leading in wire 69. The arrangement is such that the wires are positively held substantially parallel with each other and parallel with the surface of the glass, closely adjacent to the surface of the glass, and at equal distances from the surface of the glass. It is not necessary that the spacing be exactly as described, provided each length of wire is parallel with the wall of the container, comparatively close thereto, and all of them the same distance therefrom. The lengths are preferably parallel with each other, unless separated by considerable distances, for otherwise their mutual heating effect would serve to cause portions of the length close to each other to run hotter than those more distant. If the parallelism with and the distance from the walls of the container are maintained, the lengths may be located in pairs or groups, provided they be symmetrical or regular, so as to avoid any unequal heating.

In a divisional application Serial Number 743,920, filed January 24th, 1913, claims are made upon certain features of the invention described herein.

I claim as my invention:

1. A plurality of vapor electric devices adapted to operate in series, each said device being provided with a shunt circuit containing a resistance slightly greater than the normal resistance of said device when running, in combination with means for opening the shunt circuit upon the starting of the vapor electric device in parallel therewith.

2. A plurality of vapor electric devices adapted to operate in series, each said device being provided with a shunt circuit containing a resistance slightly greater than the normal resistance of said device when running, in combination with a cutout for the shunt circuit having an operating coil in the parallel circuit of the vapor electric device.

3. A plurality of vapor electric devices adapted to operate in series, each said device being provided with a shunt circuit containing a resistance approximately equivalent to the resistance of said device when running, in combination with a cutout for the shunt circuit having an operating coil in the parallel circuit of the vapor electric device, the coils of two adjacent lamps being arranged electrically adjacent each other in their circuits and adapted to cooperate in their steadying effects when both lamps are in operation.

4. Two vapor electric devices arranged to operate in series, in combination with two inductance coils arranged each electrically adjacent to one of these vapor devices and in coöperative relation with each other.

5. Two vapor electric devices arranged to operate in series, in combination with two inductance coils arranged each electrically adjacent to one of these vapor devices and in coöperative relation with each other, together with auxiliary apparatus for each lamp, separated from said coils by the respective negative electrodes of said vapor electric devices.

6. A varying supply circuit and a lamp characterized by a large starting current in combination with a ballast liable to be injured by the said current and having a time period slow relative to the continuance of the starting current.

7. A varying supply circuit and a plurality of lamps characterized by a large starting current in combination with a ballast liable to be injured by the said current and having a time period slow relative to the continuance of the starting current.

8. A varying supply circuit and a lamp characterized by a large starting current, in combination with a ballast of a time period

slow relative to the continuance of the starting current, and resistance of negligible or small temperature resistance coefficient in series with said device.

9. A varying supply circuit and a lamp characterized by a large starting current, in combination with a ballast of a time period slow relative to the continuance of the starting current, and adapted to operate normally at temperatures of rapid temperature resistance change.

10. A varying supply circuit and a plurality of lamps characterized by a large starting current, in combination with a ballast of a time period slow relative to the continuance of the starting current, and resistance of negligible or small temperature resistance coefficient in series with said device.

11. A varying supply circuit and a plurality of lamps characterized by a large starting current, in combination with a ballast of a time period slow relative to the continuance of the starting current, and adapted to operate normally at temperatures of rapid temperature resistance change.

12. Two serially arranged lamp outfits, each comprising vapor tubes, shunt resistances and cutouts therefor, in combination with a ballast and a resistance in series with both outfits, the ballast being located in one outfit and the resistance in the other.

13. Two serially arranged lamp outfits, each comprising vapor tubes, shunt resistances and cutouts therefor, in combination with a ballast and a resistance in series with both outfits, the ballast being arranged in the line connection in one outfit and the resistance adjacent the line connection in the other outfit.

14. Two serially connected vapor lamps having similar auxiliary devices symmetrically or reversely arranged with cutouts adjacent each other, in combination with a ballast and a resistance common to both and symmetrically located, one in the path of the current to one of the lamps, and its auxiliary devices, and the other in the path of current from the other of said lamps and its auxiliary devices.

15. The combination with a plurality of vapor electric devices in series, which are adapted to be started by rupturing a mercury film or bridge between electrodes, of an ohmic resistance having a small or negligible temperature resistance coefficient, adapted to operate in series with said apparatus, and a ballast also adapted to operate in series with said devices, said ballast having a relatively large positive temperature coefficient and operating at the critical temperatures of high temperature resistance change, when one or both of said vapor electric devices are in operation.

16. The combination with a plurality of

vapor electric devices, which are adapted to be started by rupturing a mercury film or bridge between the electrodes, of a resistance having a negligible temperature resistance coefficient adapted to operate in series with said devices, and a ballast also in series said ballast having a comparatively large positive temperature resistance coefficient.

17. A plurality of electrical devices adapted in operation to oppose to the passage of the current resistances of widely fluctuating value for short periods, and a supply circuit therefor, in combination with a resistance having a negligible temperature resistance coefficient, adapted to operate in series with said electrical devices, and a ballast having a comparatively large positive temperature coefficient also adapted to operate in series with said devices, said ballast being proportioned and arranged to have such heat development and radiation rates as will cause it to operate at the critical temperatures of maximum temperature resistance change when said electrical devices are in operation.

18. A plurality of electrical devices adapted in operation to oppose to the passage of the current resistances of widely fluctuating value for short periods, and a supply circuit therefor, in combination with a resistance having a negligible temperature resistance coefficient, adapted to operate in series with said electrical devices, and a ballast having a comparatively large positive temperature coefficient also adapted to operate in series with said devices, said ballast being proportioned and arranged to have such heat development and radiation rates as will cause it to operate at a temperature of high temperature resistance change when one of said electrical devices is in operation.

19. A plurality of electrical devices adapted in operation to oppose to the passage of the current, resistances of widely fluctuating value for short periods and a supply circuit therefor, in combination with a resistance having small positive temperature coefficient adapted to operate in series with said devices, and a ballast having a relatively great positive temperature coefficient and also adapted to operate in series with said devices, said ballast being proportioned to maintain conditions of current flow suitable to the normal operation of said apparatus.

20. A plurality of vapor electric devices adapted to operate in series and to oppose to the passage of the current, resistances of widely fluctuating value for short periods, and a supply circuit, in combination with a serially arranged resistance having a small positive temperature resistance coefficient and proportioned to afford an initial ohmic resistance sufficient to compensate for a mo-

mentary short circuit through said apparatus, and a serially arranged ballast adapted upon passage of the current, to change its resistance to a value corresponding with the normal changes or resistance of said vapor electric apparatus when beginning to operate.

21. The combination with a vapor electric apparatus which is adapted to be started by rupturing a conducting film or bridge between electrodes, of a resistance having a small or negligible temperature resistance coefficient, in series with said apparatus and a ballast also in series with said apparatus, said ballast having a relatively great positive temperature coefficient.

22. The combination with a vapor electric apparatus, which is adapted to be started by rupturing a mercury film or bridge between electrodes, of a conductor having a small positive resistance temperature coefficient adapted to operate in series with said apparatus, and a ballast also adapted to operate in series with said apparatus, said ballast having a relatively large positive temperature coefficient, and being proportioned and arranged to have such heat development and radiation rates as will cause it to operate at the critical temperatures of maximum temperature resistance change when said lamp is in operation.

23. The combination with a vapor electric apparatus, which is adapted to be started by rupturing a mercury film or bridge between electrodes, of a resistance adapted to operate in series with said apparatus, and a ballast also adapted to operate in series with said apparatus, said resistance and said ballast both having a positive temperature coefficient.

24. An electrical apparatus adapted in operation to oppose to the passage of current resistances of widely fluctuating value for short periods, and a supply circuit therefor, in combination with an intermediate conductor having a negligible temperature resistance coefficient adapted to operate in series with said apparatus, and a ballast having a comparatively large positive temperature coefficient also adapted to operate in series with said apparatus, said ballast being proportioned and arranged to have such heat development and radiation rates as will cause it to operate at the critical temperatures of maximum temperature resistance change when said lamp is in operation.

25. An electrical apparatus adapted in operation to oppose to the passage of current, resistances of widely fluctuating value for short periods, and a supply circuit therefor, in combination with an intermediate conductor having a small positive temperature coefficient adapted to operate in series with said apparatus, and a ballast having a

greater positive temperature coefficient and also adapted to operate in series with said apparatus, said ballast being proportioned to maintain conditions of current flow suitable to normal operation of said apparatus.

26. A vapor electric apparatus adapted in operation to oppose to the passage of current, resistances of widely fluctuating value for short periods, and a supply circuit in combination with a serially arranged resistance having a small positive temperature coefficient and proportioned to afford an initial ohmic resistance sufficient to compensate for a momentary short circuit of said apparatus; and a serially arranged ballast adapted upon passage of the current, to change its resistance to a value corresponding with the normal change of resistance in said vapor electric apparatus when beginning to operate.

27. Two electric lamps adapted to operate in series and fixtures therefor, in combination with a plurality of auxiliary devices common to the operation of both lamps, apportioned between the fixtures so as to insure substantially equal heat dissipation in each.

28. Two electric lamps adapted to operate in series and fixtures therefor, in combination with a plurality of auxiliary devices common to the operation of both lamps, apportioned between the fixtures so as to occupy substantially equal spaces and to generate substantially equal amounts of heat in each.

29. In an electric lighting system and in combination, a supply circuit and a shunt circuit across the same, said shunt circuit having serially arranged therein a resistance and a ballast, and in series between said resistance and ballast, two vapor lamps each having shunt resistances and automatic cut-outs for the shunts, said series resistance being adapted to sustain a predetermined definite percentage of the voltage across the line, and said ballast being adapted to sustain the remainder of the excess voltage above the voltage required across the terminals of the lamp when in operation.

30. In an electric lighting system and in combination, a supply circuit and a shunt circuit across the same, said shunt circuit having serially arranged therein a resistance and a ballast, and in series between said resistance and ballast, two vapor lamps each having shunt resistances and automatic cut-outs for the shunts, said resistance being located in the fixture of one lamp and said series resistance being located in the fixture of the other lamp.

31. A varying supply circuit and a lamp adapted to start by automatic tilting of the container and characterized by a large starting current, in combination with a ballast liable to be injured by the said current and

having a time period slow relative to the duration of said starting current.

32. In connection with a mercury vapor electric apparatus having the property of taking an excessive current during starting and a ballast, the method of operation, which consists in causing the time, temperature constant of the ballast to exceed the starting period of the lamp.

33. The combination of two mercury vapor lamps, supporting parts including suspending bars containing the leads to the lamps, pivotally supported holders, said lamps being in series connected, in combination with an adjustable resistance in shunt to each lamp, and a coil in series with each

lamp within the shunt being connected by one terminal to the series connection between the lamps, cut-outs in said shunts in operative relation with said coils and electrically adjacent thereto, and an adjustable series resistance between one lamp and one line and a ballast between the other lamp and the other line with suitable controlling switches.

Signed at New York in the county of New York and State of New York this 21st day of November, A. D. 1906.

PERCY H. THOMAS.

Witnesses:

WM. H. CAPEL,
THOS. H. BROWN.