P. H. THOMAS.

SYSTEM OF CAR OPERATION BY VAPOR CONVERTERS.

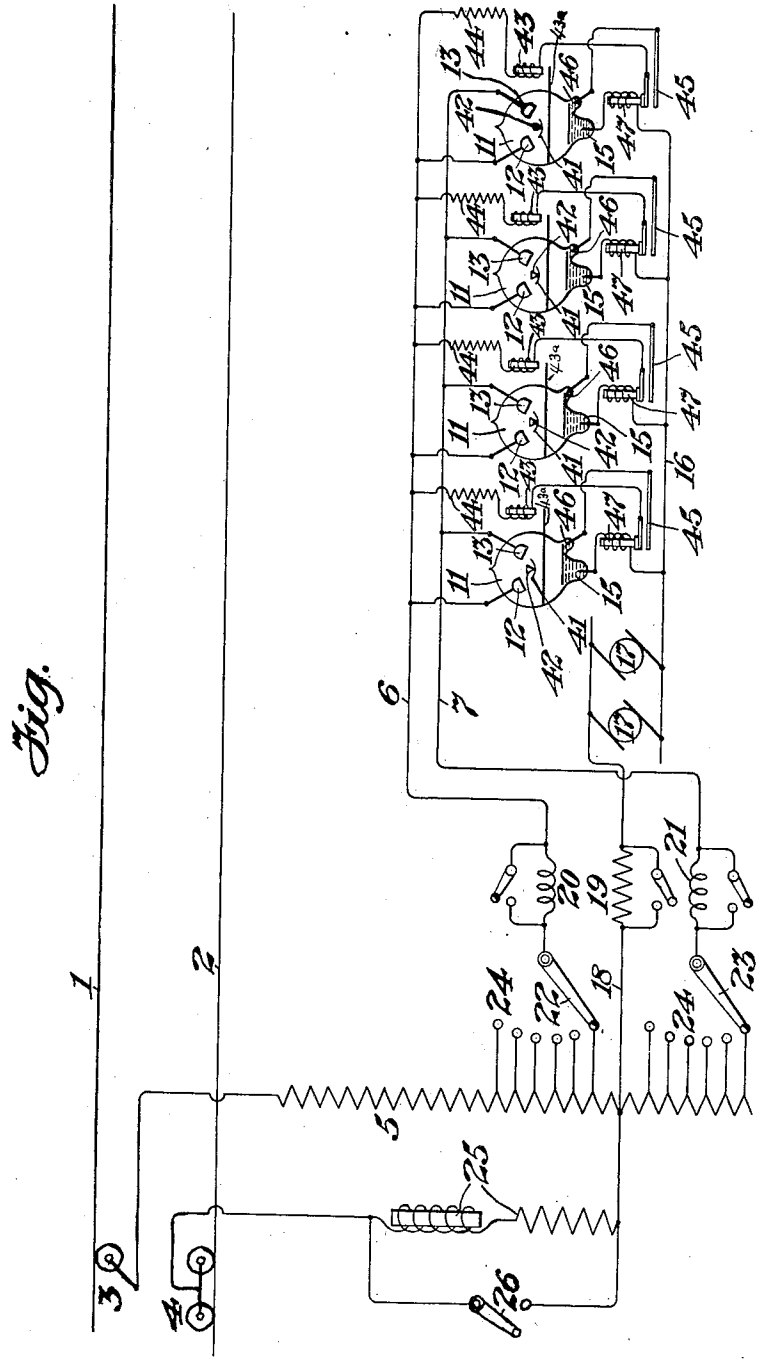
APPLICATION FILED AUG. 2, 1905.

1,157,823.

Patented Oct. 26, 1915.

5 SHEETS—SHEET 1.

Fig.



Witnesses:

Chas. J. Clagett

Thos. H. Brown

Inventor

Percy H. Thomas

By his Attorney

George H. Stockbridge

P. H. THOMAS.

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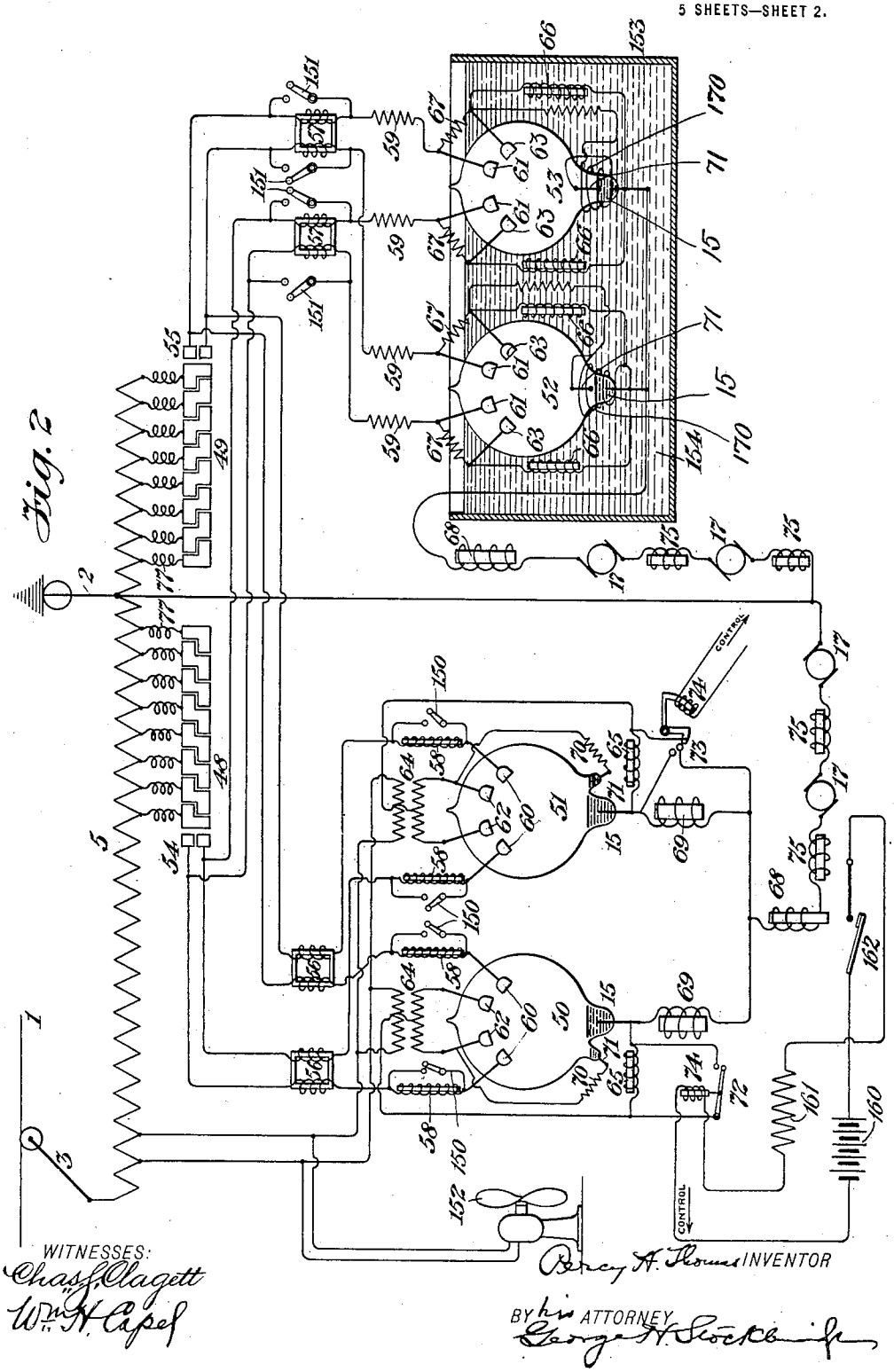
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5 SHEETS—SHEET 2.

Fig. 2



WITNESSES:

Chas. F. Clagett

Wm. H. Capel

Percy H. Thomas INVENTOR

BY his ATTORNEY

George H. Stockbridge

P. H. THOMAS.

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5 SHEETS—SHEET 3.

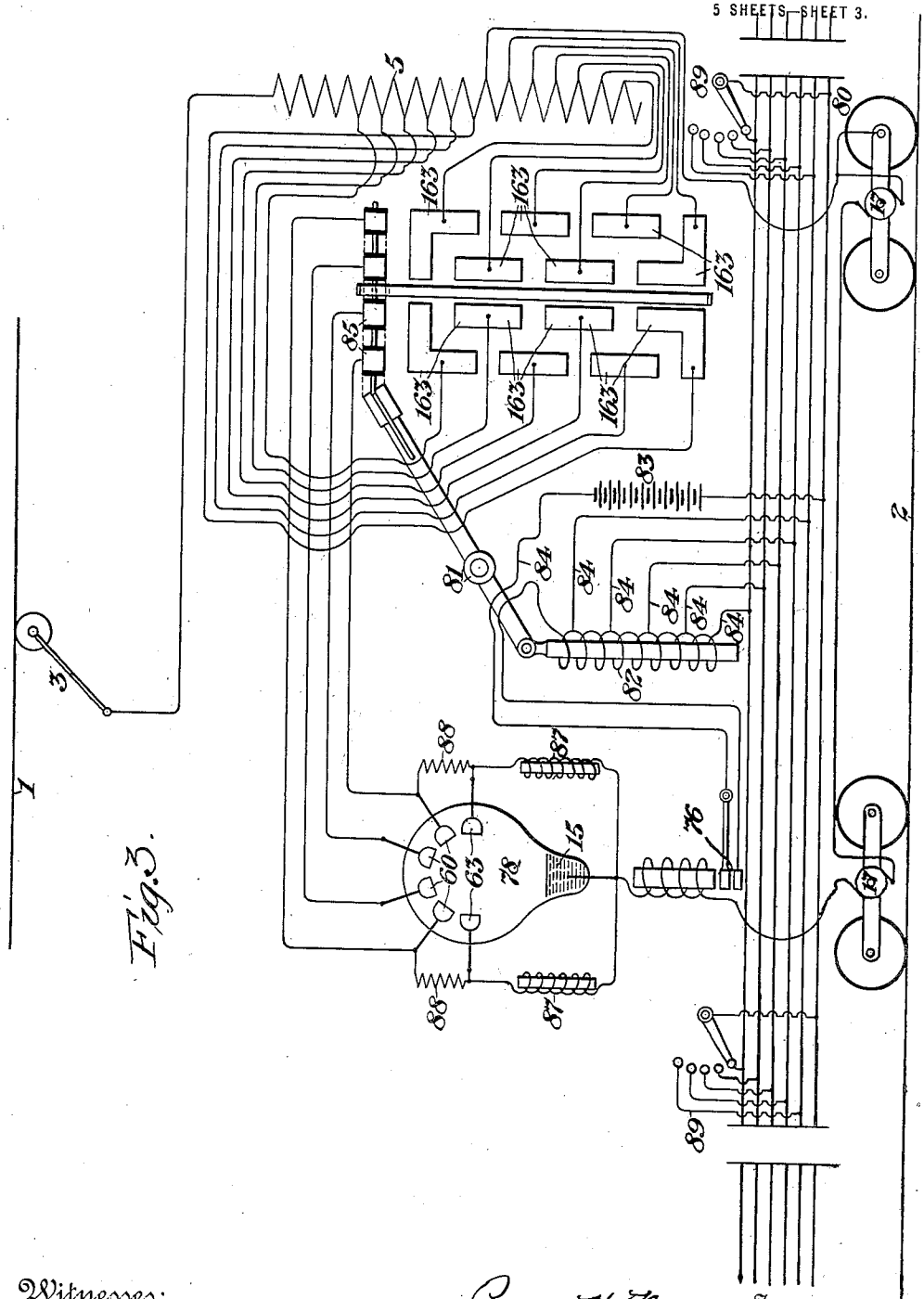


Fig. 3.

Witnesses:
Chas. F. Clagett
Thos. H. Brown

Percy H. Thomas Inventor
By his Attorney
George H. Stockbridge

P. H. THOMAS.

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5 SHEETS—SHEET 4.

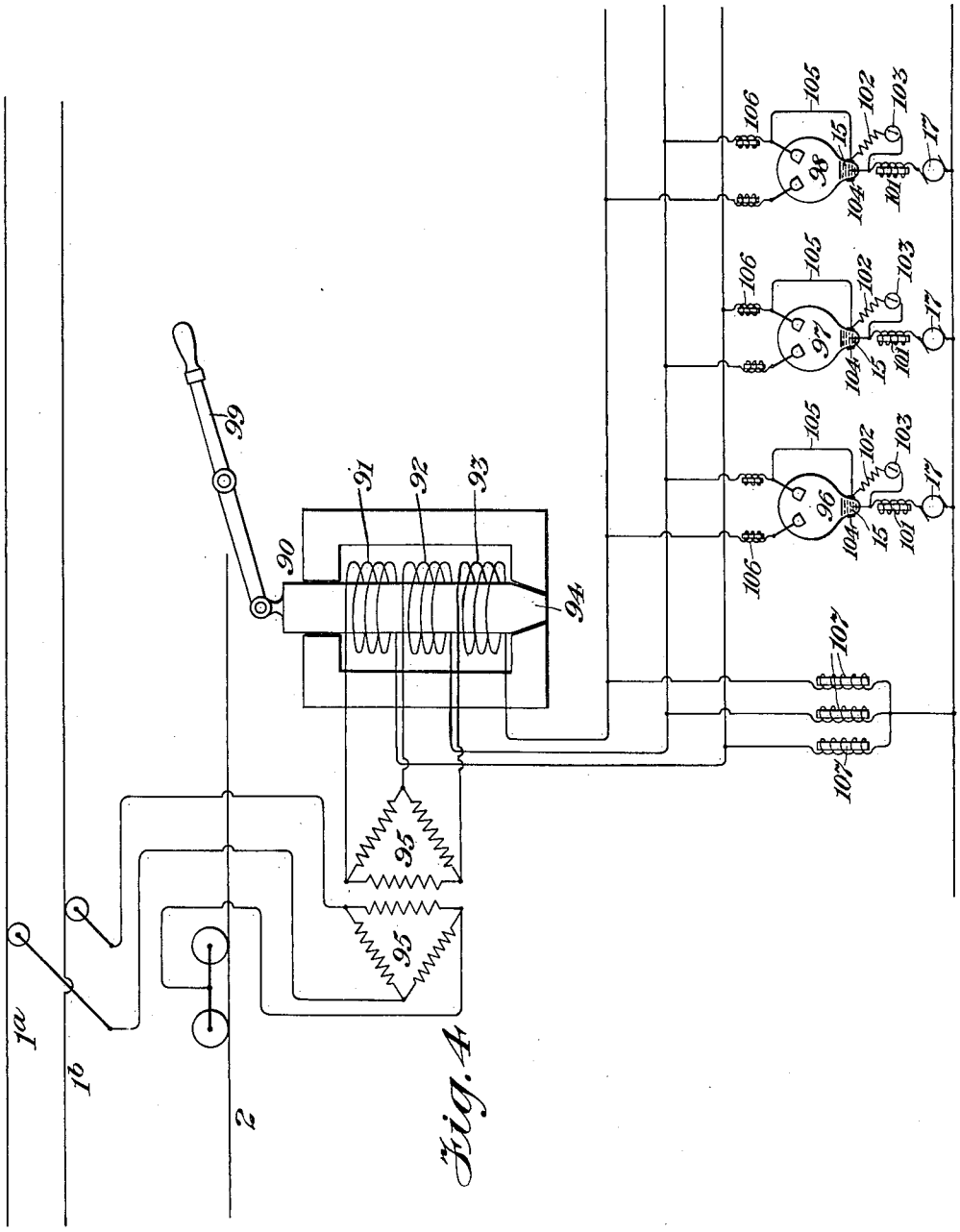


Fig. 4.

WITNESSES:

Chas. F. Clagett

Wm. H. Capel

Percy H. Thomas INVENTOR

BY his ATTORNEY

George H. Stockbridge

P. H. THOMAS.

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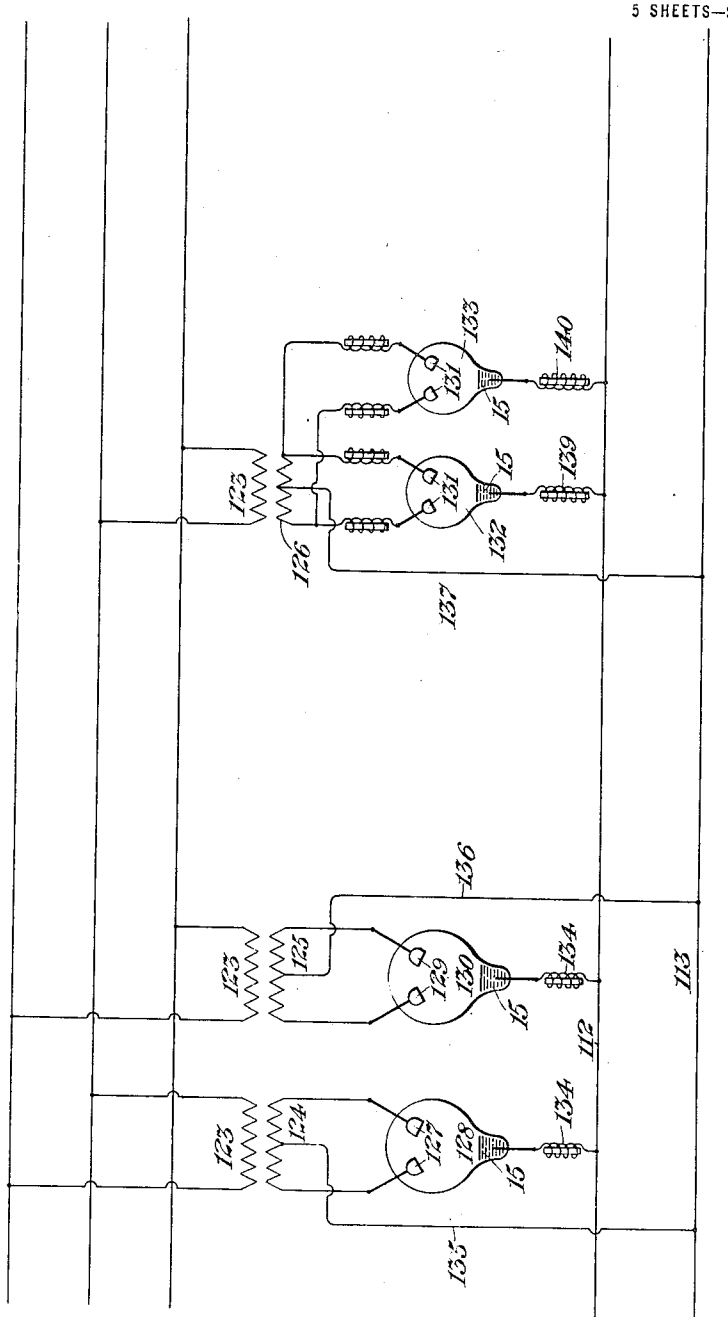
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5 SHEETS—SHEET 5.

Fig. 5.



WITNESSES:

Chas. J. Clagett

Wm. F. Capes

Percy H. Thomas INVENTOR

BY his ATTORNEY

George N. Stockbridge

UNITED STATES PATENT OFFICE.

PERCY H. THOMAS, OF MONTCLAIR, NEW JERSEY, ASSIGNOR, BY MESNE ASSIGNMENTS, TO COOPER HEWITT ELECTRIC COMPANY, OF HOBOKEN, NEW JERSEY, A CORPORATION OF NEW JERSEY.

SYSTEM OF CAR OPERATION BY VAPOR-CONVERTERS.

1,157,823. Specification of Letters Patent. Patented Oct. 26, 1915.

Application filed August 2, 1905. Serial No. 272,352.

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 Systems of Car Operation by Vapor-Converters, of which the following is a specification.

The present invention relates to the application of vapor converters to systems involving the operation of moving cars from an alternating current supply main.

The invention contemplates employing a single converter or two or more converters in parallel with direct current motors in multiple or in series.

The vapor converters and the regulating and starting apparatus therefor, together with the transformer used for getting the middle point may be in some instances mounted on a single car; or such devices may be mounted on each of a number of cars forming part of a train; or some or all of these devices may be located at sub-stations along the track upon which the train travels.

The electric power may be transmitted through a trolley wire or third rail or by any of the well-known methods.

Electrically operated cars are usually driven by direct current systems, as is well understood. It is possible, however, to operate such cars by means of single phase alternating currents, it being preferable in both instances to use series wound motors. I am aware that it has been proposed as well to utilize motor generator sets or rotary converters for the transformation of alternating current to direct current for the purpose of operating cars. This system, however, has, in general a number of disadvantages, such as synchronous apparatus, starting troubles, large size and weight of apparatus, increased initial cost, and cost of operation, which disadvantages are to a greater or less extent done away with by my invention. The employment of a direct current system throughout has certain disadvantages in the lack of economy in distribution of electrical energy and the large size of conductors and apparatus necessary for transmitting considerable quantities of power. It also has certain other disadvantages which it is not necessary here to specify. On the other hand, the alternating current system requires the use of an alternating current motor which is generally somewhat larger and less efficient than a direct current motor and ordinarily requires the use of more or less expensive regulators.

It is the object of the present invention to secure the advantages of alternating current distribution to approximately the points of utilization, such distribution being by means of polyphase or single phase transmission as desired and at the same time to secure the economy, the small size, and the generally favorable characteristics of the direct current series motor. I purpose obtaining these results by utilizing for the conversion of the alternating currents derived from the source vapor converters, and making use of the direct current thus produced for the propulsion of a car or cars. In some instances vapor converters may be substituted for the present rotary converters used in certain systems and in this case the advantages of efficiency, sensitiveness and general adaptability of vapor apparatus can be obtained without any important sacrifice. It will usually be desirable in such cases to locate the converters and the immediate connections thereof at sub stations and in general the number of sub-stations will be increased as compared with the number used with rotary converters. On the other hand, it may often be desirable to carry the alternating currents directly to the trolley or other means of distribution as the case may be and to provide a single car or a group of cars upon which transformation to direct current is made in sufficient quantities for operating the car or train of cars. Or in still another embodiment of the invention a train may be divided into groups or sub-divisions, each group or sub division being provided with its own converter or set of converters and transforming only such current as is needed for the groups or sub-divisions. Obviously, the system herein described permits of various modifications as, for example, that each motor or group of motors should be supplied with its own converter or converters. Similarly, regulating apparatus may be provided for each motor or group of motors or for all the motors together.

An advantage of the method of distribu-

tion and operation herein set forth is that of making it possible to accelerate the motors in the most economical manner and with the smallest expense of apparatus.

In many instances it will be found more satisfactory to use polyphase converters, and it may be advantageous to use both polyphase and single-phase converters upon the same train or section of the line. If single-phase converters are used, the advantages of the polyphase transmission and single-phase apparatus may be obtained by connecting single-phase converters to the several phases of the supply in such manner that, on any desired portion of the line, substantially equal current shall be drawn from the various phases. If desired, a short section of the line may be fed entirely from one phase and another section or branch be fed from another phase and so on, giving substantially the above distribution of current.

In certain of the figures of the drawing various types of converters have been shown and various arrangements of circuits illustrated as being combined in a single system. While this is a possible arrangement, it will be understood that similar types may be used throughout the system, if desired. Also direct current motors are shown in series or parallel in the various figures. It is understood that any combination known to the art may be utilized, series, parallel or not, and that the well-known methods of direct current regulation may be used.

A number of methods of starting are illustrated in the drawings and in some of them no method of starting has been shown. It is not attempted to show all possible methods of starting, but any of those known in the art are applicable and may be applied. Of course, the third rail may be substituted for the trolley and other equivalents may be used in place of those shown in the drawing.

Figure 1 illustrates the application of my apparatus to a moving car, Fig. 2, shows an embodiment for full regulation and heavy output, Fig. 3 is a multiple current system of regulation, Figs. 4 and 5 show methods of distribution.

In the first figure of the drawing a trolley wire is shown at 1 and a rail or return conductor at 2. The usual connections for a trolley arm, 3, are roughly indicated and also the connections to a truck, 4, traveling on the rail 2. Interposed in the circuit leading from the trolley-arm is an auto-transformer, 5, suitable points of which are joined, respectively, by conductors, 6 and 7, with the positive sides of a group of vapor converters, 11, suitably located in the system. The conductor 6 is joined to the positive electrodes 12, 12, 12, 12, in said converters while conductor 7 is similarly joined to the positive electrodes, 13, 13, 13, 13, therein.

The negative electrodes, 15, 15, 15, 15, of the vapor converters are joined in parallel to a return wire, 16, leading through a power circuit containing motors, 17, 17, and through a conductor, 18, to an intermediate point on the auto-transformer, 5. A resistance, 19, may be inserted in the conductor 18, although means are provided for short-circuiting the same. Similarly inductances, 20, 21, are provided in the conductors 6 and 7, respectively, and these may also be cut-out or short circuited at will, as indicated.

The regulation of the voltage supply through the conductors 6 and 7 is accomplished by means of pivoted arms, 22, 23, adapted to operate over different contacts, 24, 24, 24.

In the return lead to the truck 4 I may place an impedance 25, although this is not necessary. To indicate the fact that this impedance may or may not be used I supply a cut-out switch, 26, as shown, by means of which the said impedance may be short-circuited. The impedance 25 is shown in this instance as comprising both an inductance and an ohmic resistance.

Referring to the converters 11, each is provided with supports at opposite sides, one of said supports being shown at 41 and the converter being provided with knife edges resting on said supports. One of the knife edges is illustrated at 42. In connection with each converter I have provided a tilting magnet 43 energized by current from the conductor 6 controlled by the resistance 44 and passing through the normally-closed cut-out 45 and the supplemental starting electrode 46 and thence through the mercury which normally connects the said electrode to the electrode 15 through the inductance and cut-out coil 47 back to the source. When voltage is applied to the system, the coil 43 becomes energized, tilting the container through its action on the armature, 43^a, attached to the container until the mercury separates between the electrodes 15 and 46 thus giving a starting arc. The converter either picks up from the main positive electrodes 12 and 13 to the main negative electrode 15, in which case the coil 47 acts as a magnet to open the cut-out 45, or the arc drops out causing the converter to tilt toward its original position until the mercury again closes the circuit between 15 and 46 and the operation is repeated till successful. In any case the cut-out 45 remains open while current passes through 47, cutting out the tilting circuit.

It is expected that where desirable the method of starting shown in connection with the converters 11 may be used. In this case, the starting operation of the system as a whole is as follows: On the application of voltage, each converter receives its supply individually and goes through the starting

operation exactly as described above for the individual converters 11, each operating substantially independently of the others so that when all are started the system is in normal operating condition. Under other conditions one or more of the converters may be provided with the starting method shown in connection with converters 50 and 51 of Fig. 2 and described hereinafter. In this case upon the application of voltage each converter will be started as described for converters 50 and 51 in Fig. 2 so that when this result has been accomplished in each case the system has been started into normal operation. Similarly, the starting method shown in Fig. 4 may be applied to individual converters and the system started as already described. Similarly, with any other suitable method of starting individual apparatus.

Impedances 20 and 21 act in the same manner and for the same purposes as described in Fig. 4 for the impedances 106, 106 but serve for the several bulbs together instead of serving individual bulbs as in the case of inductances 106, 106. The resistance 19 and impedance 25 serve also to control the flow of current as described for the impedance 68 of Fig. 2 and in as far as they may be inductive to steady the flow of current and sustain the operation of the converters.

Fig. 2 illustrates an organization of circuits for operating and controlling a system of direct current motors of considerable capacity having vapor converters interposed in the system at a suitable point or points. In connection with this figure I have illustrated cooling means applied to the converters, such means consisting in one case of an electric fan operated from the alternating current side of the circuit and in another case of a tank containing glycerin and water, or other cooling liquid, in which the converters are immersed. It will be understood that similar cooling means may be utilized in connection with converters comprised in any of the systems of circuits disclosed herein. The source of power in this instance is a circuit including a trolley wire, 1, and a ground or metallic return, 2. In the drawings the ground return is illustrated.

The source assumed for the system disclosed in Fig. 2 is a single-phase source of energy. The trolley arm is shown at 3 leading to one terminal of an auto-transformer, 5, different points of which are connected to the contact-bars, 48, 48, and 49. 49. Converters, 50, 51, 52 and 53 are connected through their several positive electrodes, 60, 60, and 61, 61, to the auto-transformer 5, as will presently be described, and through their negative electrodes, 15, 15, 15, 15, to the motors, 17, 17, whose field coils are shown at 75, 75. The means of connection between the respective positive electrodes and the auto-transformer are the contact-bars, 48 and 49, and suitable sliding blocks, 54, 54, and 55, 55, arranged in pairs and adapted to operate in opposite directions upon the two groups of contact-bars. It will be seen that the members of each pair of blocks are connected by suitable circuit-wires to the positive electrodes of the converters and since said blocks are capable of being brought into contact successively with the contact-bars 48 and 49, varying voltages may be applied to the positive electrodes, as will be readily understood. The blocks 54 and 55 are shown in Fig. 2 as being just off the extreme high voltage position. It is to be assumed that originally the two sets of blocks are near each other and inside the inner end of the rows of contact-bars 48 and 49, respectively. The blocks are connected to the several positive electrodes through impedances 56, 56 and 57, 57, and through inductances 58, 58, 58, 58, or resistances 59, 59, 59, 59, as clearly shown upon the drawing. These impedances serve for purposes of regulation and also to prevent short-circuiting between the positive electrodes. That is, starting with the contact blocks 54 and 55 on the first position nearest the ground connection 2, which is the starting condition for the motors, we have the corresponding right hand main electrodes 60 and 61 in the bulbs 50, 51, 52, and 53 all connected in parallel to the first tap on the right hand in the auto-transformer 5. Similarly, with the left hand main-electrodes 60 and 61 which are then connected to the corresponding lowest tap on the left of the ground connection 2; the negative electrodes 15 of the converters are connected through the motors to an intermediate point of the auto-transformer 5. In this case evidently a low voltage is impressed upon the system.

Assuming now the contacts to be moved one position outward, the two blocks 55 will be in contact with different taps, namely, the first and second taps on the right, and the two blocks 54 will be connected to the first and second taps on the left hand side. The voltage upon the motors is thus increased while no short-circuit has been produced between the consecutive taps on the auto-transformer 5, as each block is so arranged and operated as not to touch two contact-bars at the same time. When moved to the next position all right hand main electrodes 60 and 61 are in parallel as before, as are all left hand electrodes 60 and 61. The next step raises the voltage one tap higher as before and so on throughout the full range of operation. Evidently, the direct current voltage impressed upon the motors has been increased step by step, thus

causing their acceleration. The suddenness of the transfer of current from step to step is lessened by the impedances 77 connected in the taps of the auto-transformer as well as by the other impedances and resistances in the circuit. Furthermore, the inductances 56 and 57 which include two coils, each in the circuit to a converter, and a common core, tend to equalize the flow of current between the converters when wound in the proper direction, since a rising current in one coil magnetizes the core in such a way as to cause an electro-motive-force in the other coil in such a direction as to pass current therethrough in the same direction as in the first coil. This action evidently facilitates the parallel operation of the converters as well as cushioning the steps of voltage between the taps of the transformer 5. At times it may be desirable to dispense with the coils 56, 57 or other coils such as 58, 59, which may be done, as indicated by the short-circuiting switches 151 and 150, or any other suitable manner. The impedances 68 and 69 serve the same functions as the impedances 47 in Fig. 1. In the converters 50 and 51 the starting electrodes 71 are connected through resistances 70 to supplementary positives 62. These serve for starting purposes as is well known in the art, namely by allowing current to flow from the alternating source upon the connection of the electrodes 15 and 71 by motion of the container or otherwise and by the breaking down of the negative electrode resistance on the separation of these electrodes while current is still flowing. In converters 52 and 53, the same separation of a starting electrode and a negative electrode 15 is accomplished by a magnet coil 170 connected either between a positive electrode as 63 and a starting electrode, as 71, or between a starting electrode, 71, and the negative electrode 15. In the former case the electrodes 71 and 15 are normally in contact, as in converter 53, having been connected upon the cessation of operation of the starting circuit on the last action and are drawn out of contact, while carrying current, by the magnet coil 170. In the latter case, the starting and negative electrodes 71 and 15 are normally out of contact, as in converter 52, and are drawn into contact by the magnet coil 170 upon the application of voltage and are released from contact by the short-circuiting of the magnet coil which results from this connection.

Referring again to impedances 56 and 57 it is evident that these devices facilitate the parallel operation of the converters by causing a tendency for equal currents to flow in the parallel converters as, for example, the converters 52 and 53. They serve as well to limit short-circuiting in the converters.

Impedances 58 and 59 serve controlling, sustaining and short-circuiting functions. Any of these devices may be dispensed with where found desirable.

It will be seen that supplemental positive electrodes, 62, 62, in the converters 50 and 51, are connected to transformer secondaries, 64, the corresponding primaries of which are supplied from the auto-transformer 5. An intermediate point of each secondary is connected through a choke coil, 65, with the lead to the negative electrode 15 of the corresponding converter. The object of this construction is to assist in keeping the converter in operation during periods of low voltage, as described in connection with the similar apparatus in Fig. 1.

The arrangement in connection with converters 52 and 53 is somewhat different. Here choke-coils, 66, 66, 66, 66, are employed in connection with resistances 67, 67, both these sets of devices being connected with the main electrodes 61, 61 and also with the supplemental electrodes, 63, 63, in said converters.

For stopping the operation of the converters 50 and 51 control magnets 74 are provided, which may be energized by closing a suitable electric circuit by hand or automatically as, for example, by means of the current flowing through the system. The magnets 74 act on switches 72 and 73, which serve to short circuit the sustaining coils 65, and 65 and 69 of their respective converters. Evidently with the sustaining coils short-circuited, no energy will be stored in them and they will not serve the function of keeping the negative electrode alive during low points of supply voltage and the converters will, in general, cease to operate. This operation is shown clearly in Fig. 2 where 160 is a storage battery or other source of electro-motive-force; 161 a controlling resistance, and 162 a magnetic cut-out, energized by the coil 68, the whole serving as an automatic means for stopping the operation of the converter 50 when the current in coil 68 is sufficiently great to energize the cut-out 162 which can be set at any desired value. Evidently, upon the closing of the cut-out 162, the battery 160 passes current through the cut-out 162, the resistance 161, and the magnet coil 74, which operates to close the short-circuiting switch 72.

The various leads from the auto-transformer 5 to the contact-bars 48 and 49 are provided with impedances 77 to prevent jerky acceleration. These impedances tend to limit the momentary flow of current as the contact-blocks 54 and 55 pass to new positions, as already described above.

The cooling means already referred to in the form of a fan operated from the alternating current side of the circuit are shown in Fig. 2 at 152; while the other

cooling means described above are illustrated at the right of the figure as a tank, 153, containing a liquid, 154, which may be any suitable cooling liquid such as glycerin and water, for example. Such artificial cooling serves very useful purposes. For example, it is found in operation of converters, such as are contemplated in this invention, that cooling very much reduces the tendency to the short-circuiting between the positive electrodes and, further, the forced lowering of the temperature allows a larger value of current to be passed through the converter without overheating, which is very desirable in some cases, since it allows of smaller size apparatus for the same capacity.

Fig. 3 illustrates a system of circuits and connections for an individual car in a train controlled by a multiple unit system in which a single vapor converter, 78, is utilized for operating motors 17, 17, the energy being derived from a trolley-wire, 1, through a trolley-arm, 3, and also from a ground connection or metallic return, 2, with an intermediate auto-transformer, 5. The control of the supply to the individual car is secured by means of a regulator, 81, operated by a magnet, 82, which is fed by a storage battery, 83, through leads, 84, 84, 84. Evidently, when the switches, 89, are at the top on the extreme limit of their motion from the position shown the storage battery 83 passes current through the upper section only of the coil 82 and drawing the lever 81 only slightly downward. As the lever of the switch 89 is passed to other positions, other sections in the coil 82 are included within the circuit of the battery 83, each new section added drawing the plunger to a lower position in the coil 82 and operating the lever 81. It is evident that any of the switches 89 in this car or any other car causes the same operation of the control circuit not only in the cars shown, but in all other cars similarly connected in the same train, since the horizontal control wires are the same through all cars linked in the train. The regulator 81 is shown with the plunger just beyond the extreme lower position in order to more clearly illustrate the connections.

The cut-out 76 is introduced in the lead 84 from the battery and is in operative relation to the sustaining coil of the converter. This cut-out serves the purpose of stopping the acceleration of the car by opening the circuit of the battery 83 whenever current from the converter 78 exceeds the amount necessary to operate the cut-out 76 which may be predetermined as desired.

The lever 81 carries four insulated blocks 85 upon the right hand end which lie in operative relation to a number of contacts, 163. These contacts are connected to different points in the auto-transformer 5 as shown in the figure and the lever 81 carrying the blocks 85 is just off the highest voltage position. At the start the blocks 85 rest upon the two lower blocks 163 and voltage is impressed from the lowest taps of the auto-transformer upon the two right hand and the two left hand main positive terminals 60 as shown. On moving to the next position the outer large blocks 85 pass to the next higher taps thus conducting the current flowing away from the inner blocks 85 which remain connected to the original transformer taps. This results from the fact that the current will, of course, flow from the points of highest potential. In this case two of the four main positive electrodes 60 are carrying current; the other two remaining idle. The next movement of the four blocks 85 connects the two inner blocks to the third taps of the transformer and withdraws the current flowing away from the outer blocks 85 and the corresponding positive electrodes 60, and so on throughout the operation. The circuit in the initial position is evidently from either the right or the left first tap in the auto-transformer 5, according to which half of the transformer 5 has a positive electromotive force through two of the contact blocks 85 and connecting wires to the main positive electrodes 60 and the negative electrode 15 and the sustaining coils and motors back to an intermediate point of the auto-transformer 5. Similarly for other positions. The converter 78 is kept alive by coils 87, 87, connected with the resistances, 88, 88, and the supplementary electrode 63. It is thus evident that from any switch 89 in the train, which may be connected up to the horizontal control wires, the levers 81 may be operated through the coil 82 by causing the battery 83 to pass current through different sections of the coil 82, thus drawing the arm 81 into different positions. The different positions of the arm 81 cause the contact blocks 85 and consequently the positive electrodes of the converter to be connected to different taps of the auto-transformer of the supply giving a variation in voltage upon the motors. This arrangement is adaptable to any number of similarly equipped cars having the proper connections as shown between the horizontal bus wires in the several cars.

In Fig. 4 is illustrated a method of operating direct current motors shown at 17, 17, from a three-phase source of supply connected with two-trolley wires 1^a and 1^b, and with a return earth or metallic conductor, 2. The means of control are illustrated at 90, the same consisting essentially of choke-coils, 91, 92 and 93, acting cumulatively and surrounding a common core, 94. The controller, 90, is regulated by means of a piv-

oted arm, 99, which can be operated for lifting and lowering the core, 94, and thereby adjusting the current delivered. The voltage in the receiving circuit is adjusted by means of transformers, 95, 95, interposed between the supply-circuit, 1^b and 2, and the receiving circuit. The vapor converters transmitting the supply to the several motors are shown at 96, 97, and 98. Each converter is supplied with an inductance, 101, for keeping alive purposes and for starting purposes each converter is provided with a resistance, 102, and with a snap or quick-break switch, 103, already well-known in the art. Each converter is also supplied with a starting band, 104, near the negative electrode 15 which starting band is joined by a wire, 105, to one of the leads to a positive electrode within the converter. The leads to the positive electrodes are themselves supplied with inductances 106, as shown, partly for purposes of regulation and partly for preventing short-circuiting between the positive electrodes. In connection with the system I also supply inductances, 107, 107, 107, for obtaining the neutral point of the system.

In Fig. 5 I illustrate a method of supplying direct current bus-bars from a polyphase or single-phase current source, the method consisting broadly in providing each converter or group of converters with a transformer of its own, as distinguished from an auto-transformer. In illustration, the source is assumed to be three-phase. From each phase a primary, 123, is taken, the several primaries being provided with secondaries, 124, 125 and 126. The terminals of the secondary 124 are connected to the positive electrodes, 127, 127 in the vapor converter 128; the terminals of the secondary 125 are connected to the positive electrodes 129, 129, in the vapor converter 130 and the terminals of the secondary 126 are connected to the positive electrodes 131, 131, 131, 131, in the converters 132 and 133. The negative electrodes 15, 15 of the converters, 128 and 130, are connected through inductances 134, 134, to the bus-bar, 112, while the middle points of the secondaries, 124, and 125 are connected by conductors, 135 and 136, to the bus-bar, 113. At the same time, the middle point of the secondary 126 is connected by conductor, 137, to the bus-bar 113 while the negative electrodes 15 of the converters 132 and 133 are connected through inductances 139 and 140 to the bus-bar 112.

It is evident that each of the three-phases supplied by the source of three-phase current is provided with its own transformer, the current from which is applied through suitable secondary circuits to the converters illustrated in Fig. 5. It is also evident that the bus-bars 112, 113, receive direct current which may be applied in any suitable way to car motors or other translating devices.

Any of the methods of starting or control or acceleration that have been already described in connection with this invention or which are known in the art may be used as found convenient or desirable. The impedances shown in this figure serve the same purpose as similarly located impedances in the previous figures.

The method of acceleration and control shown and described in connection with various figures of this application as applying to single-phase circuits are not intended to be limited to single-phase but may be utilized wherever suitable in connection with polyphase circuits and converters.

In another application filed on the 22nd day of January 1913, Serial Number 743,480 claims are made covering certain other features of the invention described herein.

I claim as my invention:—

1. The combination with a vapor converter having an hermetically sealed and completely exhausted container, and a vaporizable electrode therein, a direct current circuit fed therefrom, connections for supplying alternating current to said converter and means for applying increasing voltages, step by step, to the converter, of an impedance for cushioning the steps of voltage.

2. The combination with a direct current circuit, a plurality of vapor converters each comprising an hermetically sealed and completely exhausted container and a vaporizable reconstructing cathode and connections for supplying alternating current to said converters, of means for applying to one converter a voltage higher than the voltage applied to another similarly operating converter, and means for subsequently connecting the other similarly operating converter to the higher voltage step, and means for dividing the current between the converters.

3. The combination with a direct current circuit, a plurality of vapor converters each comprising an hermetically sealed and completely exhausted container and a vaporizable reconstructing cathode and connections for supplying alternating current to said converters, of means for applying to one converter a voltage higher than the voltage applied to another similarly operating converter, and means for subsequently connecting the other similarly operating converter to the higher voltage step, and multiple coil inductances for dividing the current between the converters.

4. The combination with an alternating current supply, and a direct current receiving circuit, of a plurality of parallel connected vapor converters each comprising an hermetically sealed and completely exhausted container, and a vaporizable recon-

structing cathode therein, and means for raising the voltage by steps through one of the parallel connected converters and alternately raising the voltage in the other.

5. The combination with an alternating supply circuit and a receiving circuit provided with several groups of translating devices, of separate vapor converters for the several groups, and means for simultaneously and equally raising the voltage applied to the several groups of vapor converters and translating devices.

6. In a system of electrical distribution in which current from an alternating source is utilized for supplying direct current, the combination with an alternating source of supply, a direct current work circuit, a rectifying apparatus comprising a plurality of exhausted containers, anodes and a cathode in each and connections for said system, normally placing corresponding anodes of the several rectifiers in parallel, of means for increasing the potential in the direct current work circuit including means for disconnecting an anode in one rectifier and connecting it to a point of higher potential in the alternating source and for subsequently disconnecting the corresponding anode of another rectifier from the source and connecting it in parallel with the first named electrode at the point of higher potential and repeating this operation through successive steps, in combination with means for automatically securing a division of current between the rectifiers at such times as both are connected in circuit.

7. The combination with an alternating current supply circuit having its neutral point naturally above or below ground potential and a direct current receiving circuit, of a vapor converter receiving energy from said supply circuit and supplying said direct current circuit, and means for impressing upon the anodes of the converter alternately positive and negative potentials having equal values above or below the potential of the earth.

8. The combination with an alternating constant potential supply, of a plurality of vapor converters connected in parallel to said supply, each comprising an hermetically sealed and completely exhausted container, anodes and a cathode therein, means for causing a division of current flow between the individual converters and means for varying the potential applied upon the parallel rectifiers as a system, said last named means consisting of a voltage absorbing device traversed by all currents flowing in the converters.

Signed at New York, in the county of New York, and State of New York, this 31st day of July, A. D. 1905.

PERCY H. THOMAS.

Witnesses:
WM. H. CAPEL,
GEORGE H. STOCKBRIDGE.