No. 877,144. PATENTED JAN. 21, 1908.

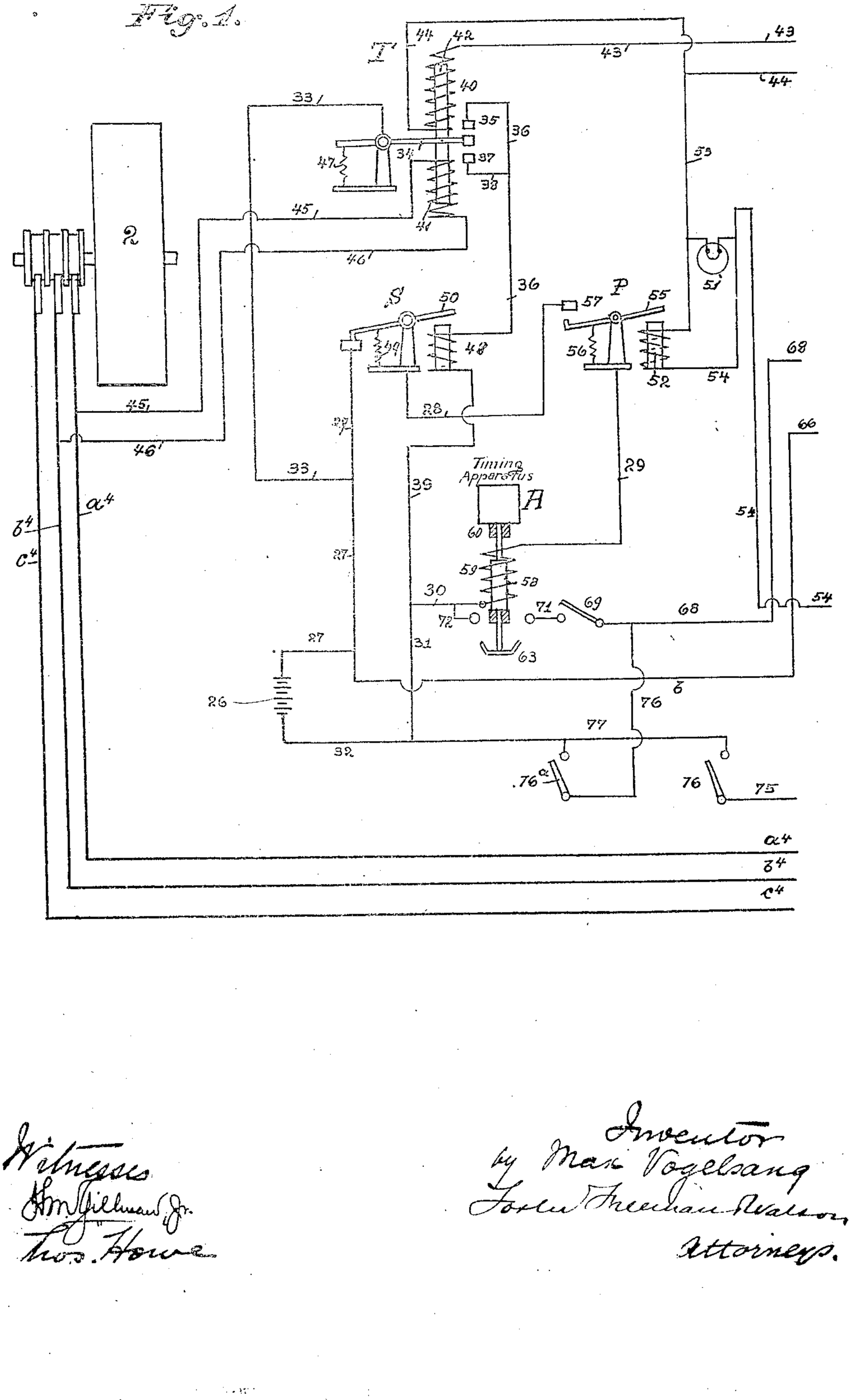
M. VOGELSANG.

SYNCHRONIZING APPARATUS FOR ALTERNATORS.

APPLICATION FILED FEB. 2, 1905.

5 SHEETS—SHEET 1.

Fig. 1.



Witnesses
Wm. Gilman Jr.
Thos. Howe

Inventor
by Max Vogelsang
Foster Freeman Watson
Attorneys.

No. 877,144. PATENTED JAN. 21, 1908.

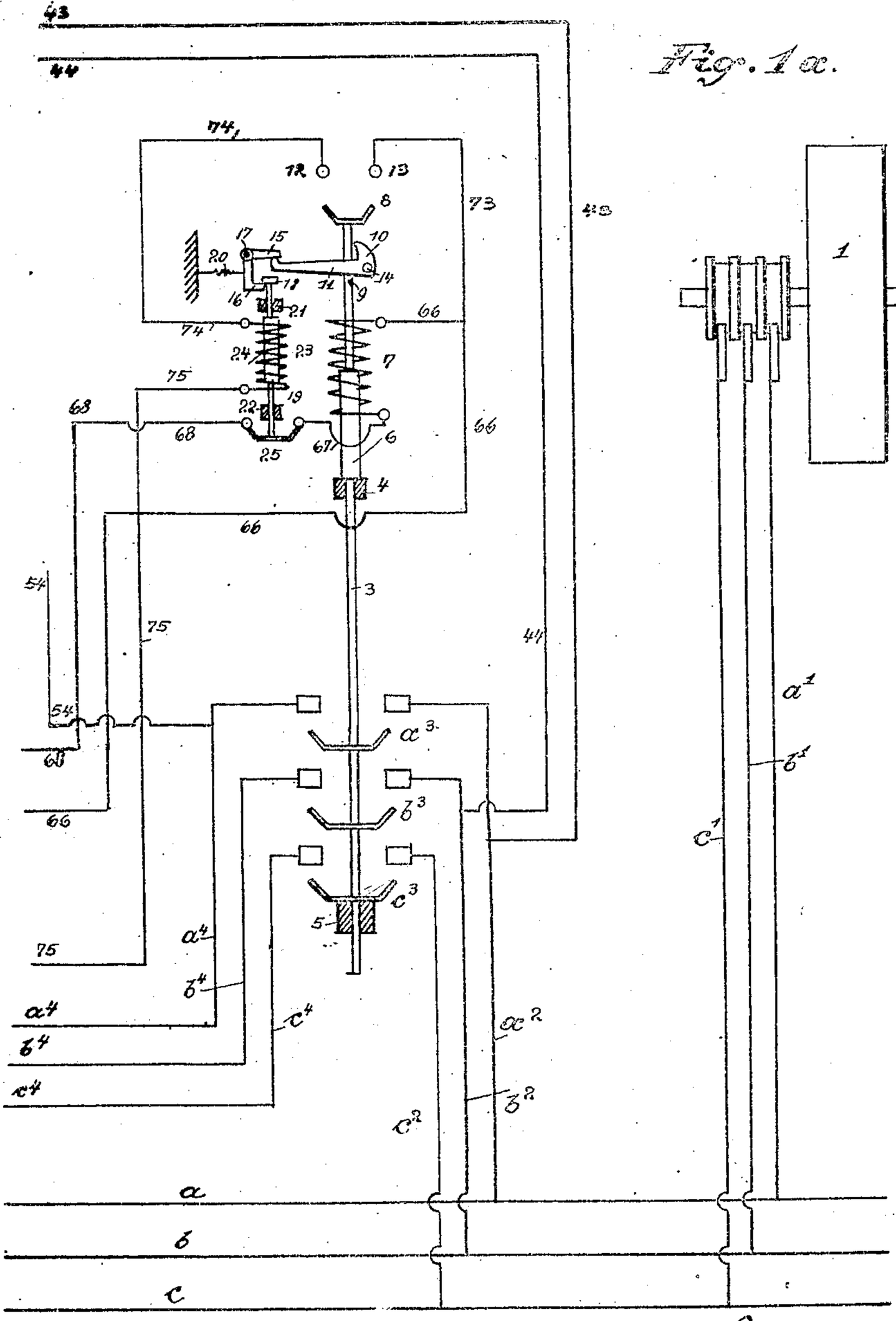
M. VOGELSANG.

SYNCHRONIZING APPARATUS FOR ALTERNATORS.

APPLICATION FILED FEB. 2, 1905.

5 SHEETS—SHEET 2.

Fig. 1a.



Witnesses
Wm. Gilman, Jr.
Thos. Howe

Inventor
Max Vogelsang
by Paul Freeman Walden
Attorney

No. 877,144. PATENTED JAN. 21, 1908.

M. VOGELSANG.

SYNCHRONIZING APPARATUS FOR ALTERNATORS.

APPLICATION FILED FEB. 2, 1905.

5 SHEETS—SHEET 3.

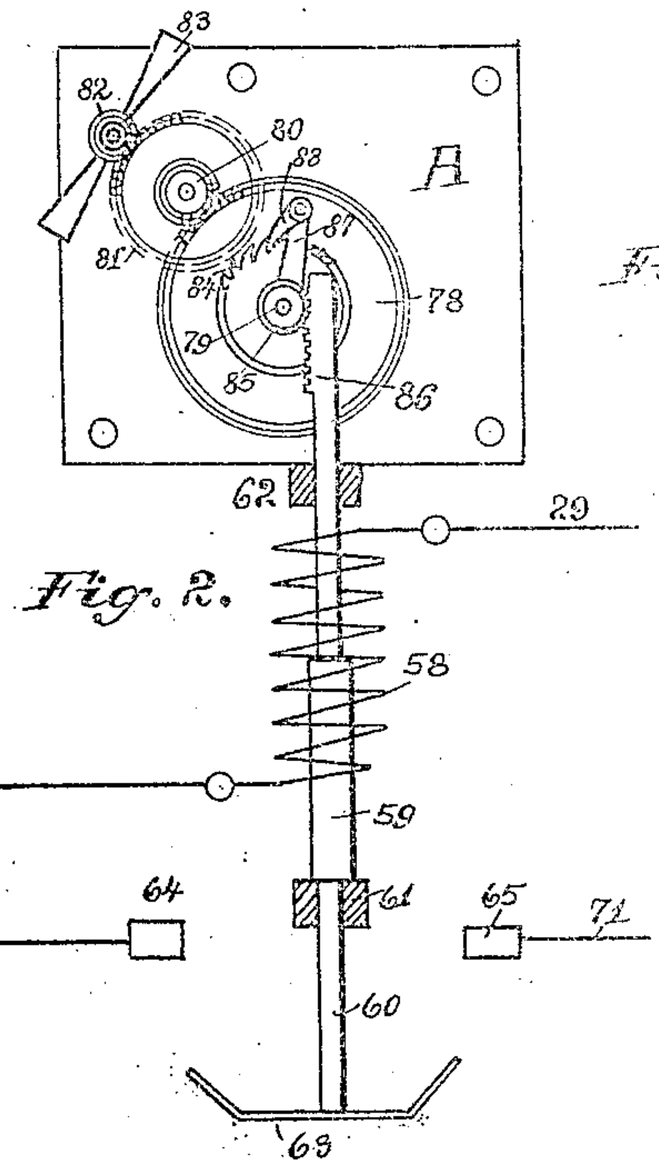


Fig. 2.

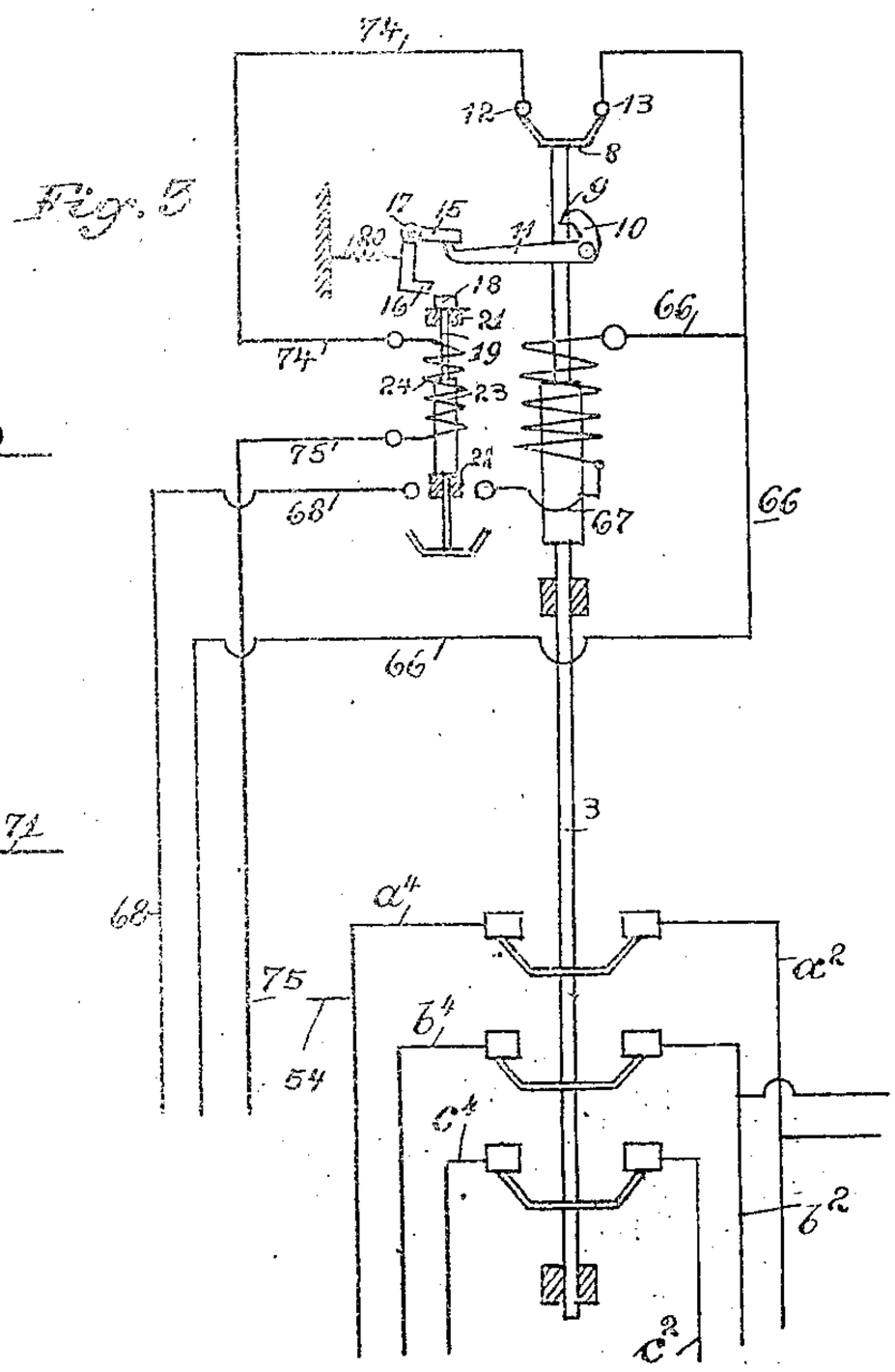


Fig. 5

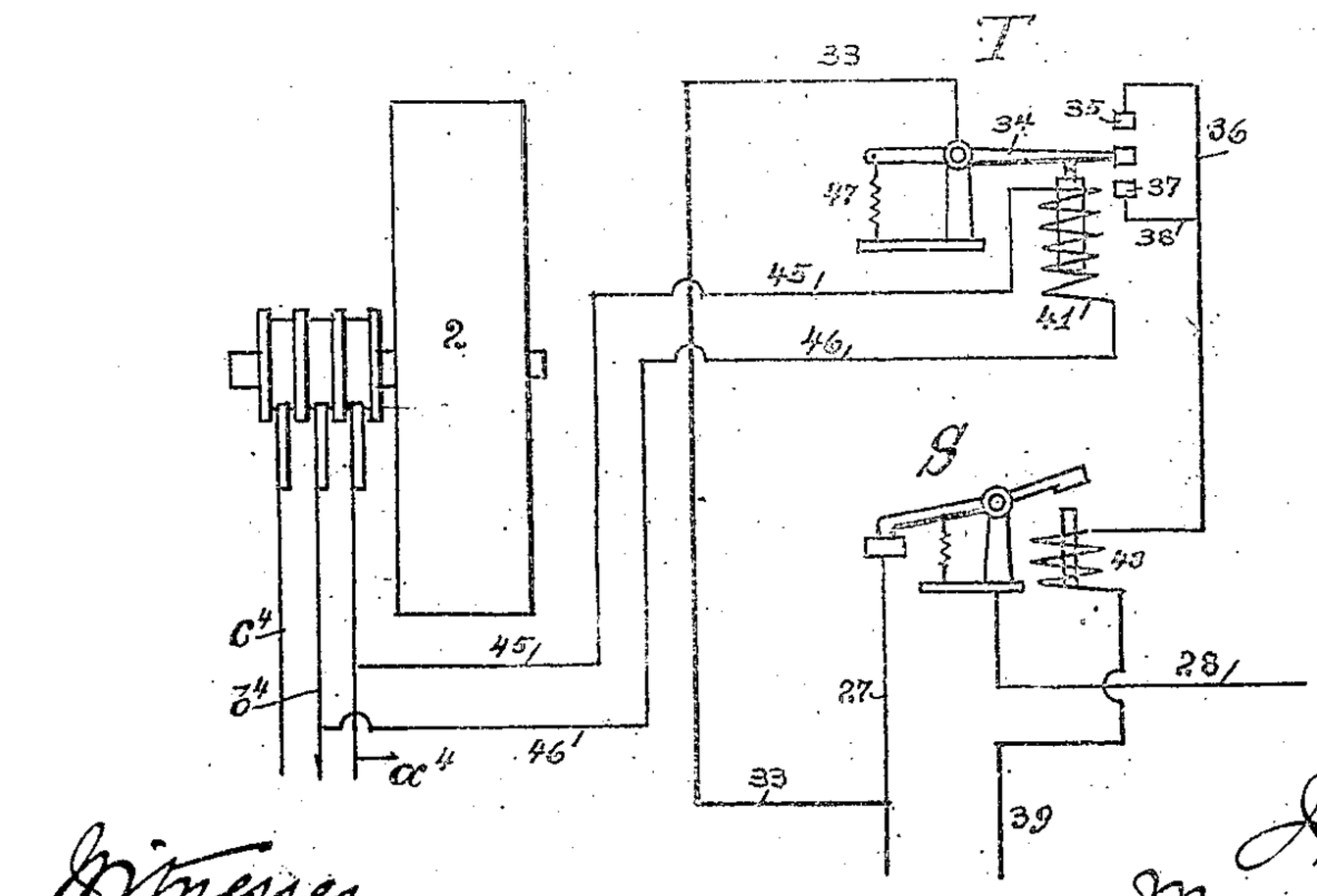


Fig. 4

Witnesses
Thos. Gillman Jr
Thos. Howe

Inventor
Max Vogelsang
by Lacey Freeman & Watson
Attorneys

No. 877,144. PATENTED JAN. 21, 1908.

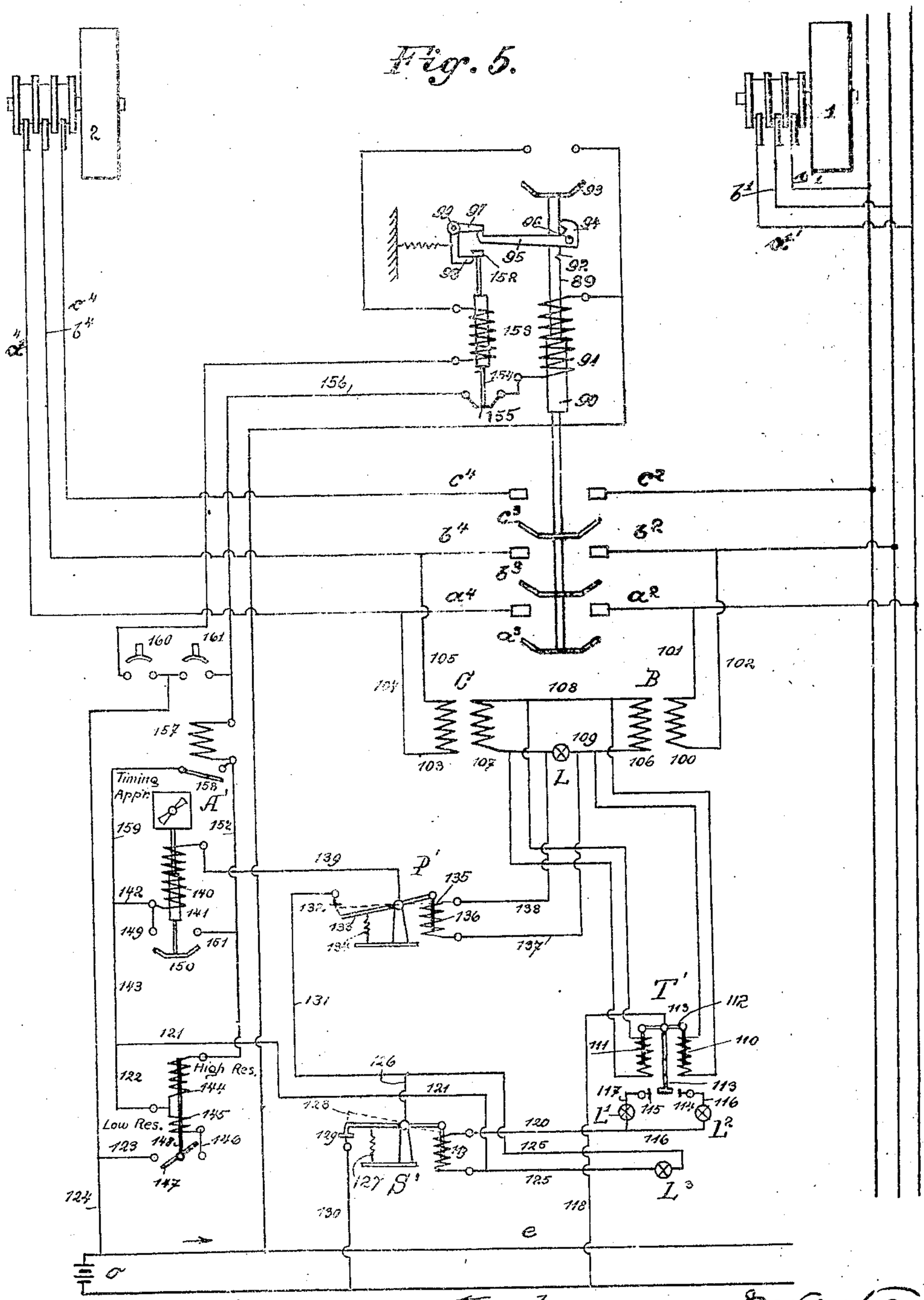
M. VOGELSANG.

SYNCHRONIZING APPARATUS FOR ALTERNATORS.

APPLICATION FILED FEB. 2, 1905.

5 SHEETS—SHEET 4.

Fig. 5.



Witnesses
Thos. Gillman Jr.
Thos. Howe

Inventor
Max Vogelsang.
by Foster Freeman Watson
Attorneys.

No. 877,144. PATENTED JAN. 21, 1908

M. VOGELSANG.

SYNCHRONIZING APPARATUS FOR ALTERNATORS.

APPLICATION FILED FEB. 2, 1905.

5 SHEETS—SHEET 5

Fig. 6

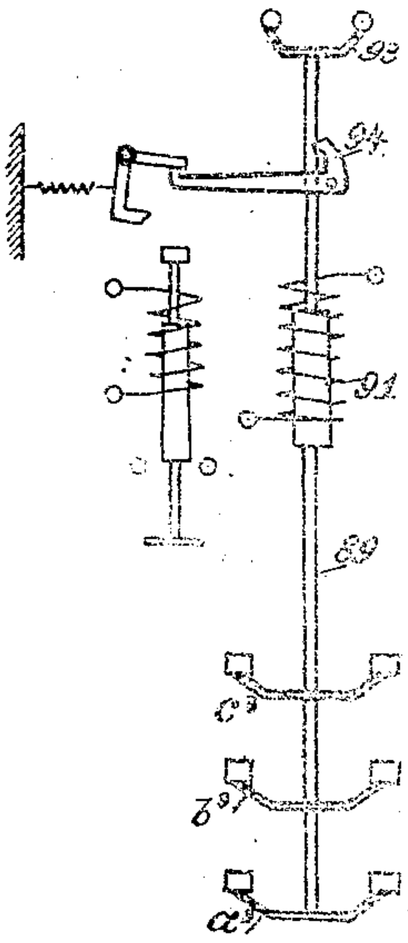
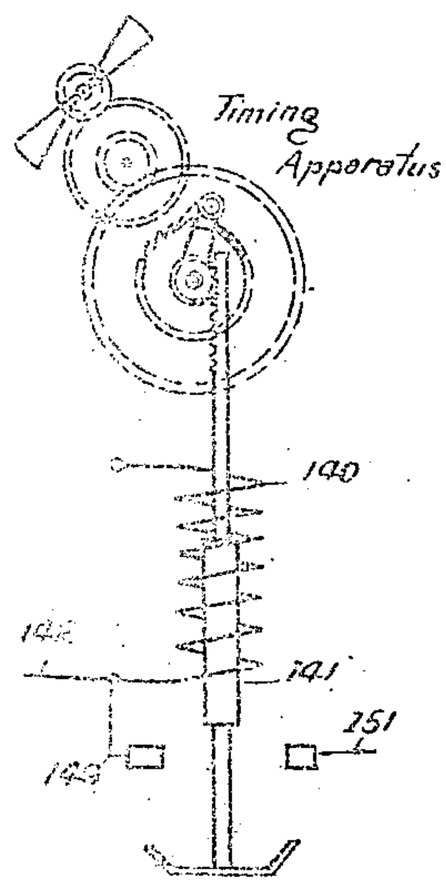


Fig. 7



Witnesses
H. M. Gillman, Jr.
Thos. Howe.

Inventor
Max Vogelsang
by Fred Freeman Wales
Attorneys

UNITED STATES PATENT OFFICE.

MAX VOGELSANG, OF FRANKFORT-ON-THE-MAIN, BOCKENHEIM, GERMANY, ASSIGNOR TO THE FIRM OF VOIGT & HAEFFNER, AKTIENGESELLSCHAFT, OF FRANKFORT-ON-THE-MAIN, GERMANY.

SYNCHRONIZING APPARATUS FOR ALTERNATORS.

No. 877,144. Specification of Letters Patent. Patented Jan. 21, 1908.

Application filed February 2, 1905. Serial No. 243,897.

To all whom it may concern:

Be it known that I, MAX VOGELSANG, a subject of the German Emperor, residing and having my post-office address at 50 Parkstrasse, Frankfort-on-the-Main, Bockenheim, Germany, have invented certain new and useful Improvements in Synchronizing Apparatus for Alternators, of which the following is a specification.

Alternating current machines of every description require to be synchronized before they may be safely connected in multiple with the distributing conductors. However, the operation of connecting the several alternators with the conductors requires careful attention and great caution for determining the proper moment at which they may be switched on, as otherwise serious disturbances and injury to machines and electrical apparatuses might follow.

My invention relates to an apparatus, which is so arranged as to automatically connect in multiple the respective alternator with the distributing conductors at the proper moment and at the same time it permits the disconnection of the alternator at will from the system. As is well known, heavy shocks with serious disturbances might follow the improper connection of an alternator, not only, in case the alternator is excessively energized, but also in case it is insufficiently energized.

The automatic apparatus according to my invention comprises a tension relay controlled by the tension of the respective alternator, a phase-indicator and a relay thereby controlled, a timing apparatus and a relay thereby controlled, a sychronizing circuit connecting the said three relays, a subsidiary relay controlled by the tension relay and normally closing the synchronizing circuit, a plurality of switches for connecting and disconnecting the respective alternator with the distributing conductors, a switching-on solenoid in connection with the plurality of switches, a switch actuating circuit connecting the switching-on solenoid with the solenoid of the timing apparatus, a switching-off solenoid for opening the switch actuating circuit, an independent source of electrical current, either direct or alternating, arranged for supplying the current to either the synchronizing circuit or the switch actuating circuit, and where so preferred also several safety devices. The tension relay is so arranged, that it permits the subsidiary relay to close the synchronizing circuit, the moment the tension of the alternator is approximately equal to that of the distributing conductors, but it causes the subsidiary relay to open the synchronizing circuit, when the tension either decreases or increases beyond certain limits. The relay controlled by the phase-indicator closes the synchronizing circuit the moment the phase of the alternator is equal to that in the distributing conductors, but this relay again opens the circuit on the phase varying. Thus there are two break-points in the synchronizing circuit, so that the latter can be closed only in case both the tension and the phase of the alternating current produced by the alternator are equal to those of the current in the distributing conductors. Then the solenoid controlled by the timing apparatus will be energized, but it can connect the synchronizing circuit with the switch actuating circuit only after a time in correspondence with the frequency of the current in the distributing conductors. Should either the tension or the phase of the alternator meanwhile vary, the synchronizing circuit will be again opened, when the timing apparatus will stop. When both the tension and the phase remain correct and the synchronizing circuit remains closed, the solenoid controlled by the timing apparatus will at last by a switch connect the synchronizing circuit with the switch actuating circuit, when the switching-on solenoid will be energized for causing the plurality of switches to connect the alternator with the distributing conductors and for locking the several switches. Immediately afterwards the switching-off solenoid will be energized for again opening the switch actuating circuit. The above mentioned safety devices will be referred to later on.

I will now proceed to fully describe my invention with reference to the accompanying drawings, in which the alternating current is assumed to be a three phase current.

Figures 1 and 1ª are diagrams of the three distributing conductors, an alternator already connected therewith, a second alternator and the automatic apparatus for connecting the latter with the distributing conductors, Fig. 2 is a vertical longitudinal section on an enlarged scale through the timing apparatus, the solenoid therewith connected being shown diagrammatically, Fig. 3 is a

part of Fig. 1, showing the position of the three switches when connecting the second alternator with the distributing conductors, Fig. 4 shows a modification of a part of Fig. 1, Fig. 5 is a modification of the diagram shown in Fig. 1, Fig. 6 is a part of the same, and Fig. 7 is a part of the same on an enlarged scale and corresponds to Fig. 2.

Similar characters of reference refer to similar parts throughout the several views.

a, b and c in Fig. 1[a] denote the three distributing conductors, a^1, b^1 and c^1 are conductors, which already connect the former with the first alternator 1, a^2, b^2 and c^2 are branch conductors connected with the distributers a, b and c, a^3, b^3 and c^3 denote three switches and a^4, b^4 and c^4 the conductors leading from the second alternator 2.

The three switches a^3, b^3 and c^3 are preferably secured on a vertical rod 3 and insulated therefrom in any known manner. The rod 3 is mounted in suitable guides 4 and 5 to move longitudinally and forms a part of an armature 6 of the switching-on solenoid 7. A switch 8 is shown as secured on the upper end of the rod 3 and is insulated therefrom. The rod 3 is provided with a notch 9, Fig. 3, in which the upper end of the vertical arm 10 of a bell-crank lever can engage, when the rod 3 occupies its uppermost position so that the three switches a^3, b^3 and c^3 bear from below against their respective contact pieces and thereby connect the conductors a^2, b^2 and c^2 with a^4, b^4 and c^4 respectively. At the same time the upper switch 8 will bear against its two contact pieces 12 and 13. The bell-crank lever 10, 11 is mounted to rock on a stationary pin 14 and its horizontal arm 11 is adapted to act upon the horizontal arm 15 of another bell-crank lever. The latter is mounted to rock on a stationary pin 17 and its vertical arm 16 is hooked at the lower end for snapping beneath the head 18 of a vertical rod 19. A spring 20 tends to withdraw the arm 16 from the head 18. The said rod 19 is longitudinally guided in suitable guides 21 and 22 and may be in one piece with the armature 23 of the switching-off solenoid 24. A switch 25 is secured on the lower end of the rod 19 and insulated therefrom. In the uppermost position of the rod 19 shown at Fig. 1[a], this switch 25 bears against its two contact pieces and thereby closes the switch actuating circuit, which will be referred to later on. When the rod 3 of the switching-on solenoid 7 occupies its lowest position shown at Fig. 1[a], it brings the bell-crank lever 10, 11 into the position shown, so that the hooked arm 16 of the other bell-crank lever snaps beneath the head 18 and thereby locks the switch 25 in its closed position. The hooked end 16 is so beveled off on its lower face, that on the armature 23 being attracted by the energized solenoid 24, its head 18 is enabled to rise and move aside the hooked end while overcoming the tension of the spring 20.

An independent source of electricity 26 of any known kind is disposed for supplying either direct current or alternating current, which may be used for exciting the several alternators or for other purposes. This source of electricity 26 is shown as connected with the synchronizing circuit 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, in which a tension relay T, a subsidiary relay S and a phase indicator relay P are inserted. It will be observed that the synchronizing circuit referred to comprises two branches one of which, 33, 44, 36 and solenoid 48 contains the solenoid 48 of the subsidiary relay and is controlled by the tension relay T while the other branch of the synchonizing circuit 27, 28, 29, 30, 31 and 32 includes the subsidiary relay S, the phase-indicating relay P, and the solenoid 58 controlling the switch actuating circuit and governed by the timing apparatus A.

The tension relay T may be of any known construction, the only condition being, that it may be controlled by the tension of the current furnished by the alternator 2 to be connected with the distributing conductors. In Fig. 1 I have assumed the tension relay T to be a well-known differential relay, that is one with two solenoids 40 and 41 and a common armature 42. The one solenoid 40 is connected on the one hand by a line 43 with one branch a^2 of the distributing conductor a and on the other hand by a line 44 with one branch b^2 of the distributing conductor b. Thereby the solenoid 40 is placed under the control of the tension in the distributing conductors. The other solenoid 41 is connected on the one hand by a line 45 with the conductor a^4 and on the other hand by a line 46 with the conductor b^4. Thereby the solenoid 41 is placed under the control of the tension of the alternator 2. The spring 47 of the relay T is so adjusted, that it balances the weight of the armature 42 and brings it into its middle position, so that the lever 34, to which it is linked, touches neither the upper contact 35, nor the lower contact 37. The subsidiary relay S is so arranged, that when its electromagnet 48 is not energized, its armature 50 is detached by a spring 49, so that its rear arm normally connects the lines 27 and 28 of the synchronizing circuit. The phase indicator comprises an incandescent lamp 51 and an electromagnet 52, which are both connected in multiple on the one hand by a line 53, 44 with a branch b^2 of the distributing conductor b and on the other hand by a line 54 with the conductor a^4 of the alternator 2. It will be seen, that the current circulating in the lines 44, 53, 54 will be a maximum, when the phases and frequencies of both alternators 1 and 2 are alike, so that at this moment the incandescent lamp will give the brightest

light. This will be clear, when it is taken into consideration, that two conductors b^2 and a^4 are connected, which correspond to two different distributing conductors b and a respectively.

When the electromagnet 52 of the relay P is without current, the armature 55 is normally detached by a spring 56, so that the lever 57 does not connect the lines 28 and 29 of the synchronizing circuit. The electromagnet 52 will be more or less energized by the circulating current according to the strength of the latter and the lever 57 with the armature 55 will oscillate in correspondence therewith. Only on the current attaining its maximum will the lever 57 touch its contact piece and thereby connect the lines 28 and 29.

In the synchronizing circuit is inserted a solenoid 58, the armature 59 of which is placed under the control of a timing apparatus A and arranged for closing the switch actuating circuit in the following manner. The armature 59 may be made in one piece with a vertical rod 60, which is longitudinally movable in two suitable guides 61 and 62, see Fig. 2. A switch 63 is secured on the lower end of the rod 60 and insulated therefrom. In the uppermost position of the armature 59 the switch 63 will bear from below against both contact pieces 64 and 65 and thereby connect the two lines 71 and 72. The timing apparatus A may be of any known construction. In the drawings it is assumed to be a clockwork comprising two gear wheels 78 and 81, two pinions 80 and 82, a fly 83, a ratchet 84 fastened on the shaft 79 of the gear wheel 78, a pinion 85 loose on the shaft 78 and a lever 87 rigidly connected with the pinion 85 and carrying a pawl 88. The upper part of the rod 60 is formed with a rack 86, which meshes with the pinion 85. It will be evident from an examination of Fig. 2, that on the solenoid 58 being energized it will attract its armature 59 and press the rod 60 upward. Thereby the clockwork will be put into motion and the fly 83 permits the rod 60 to move upwards only slowly, so that the switch 63 may touch the two contact pieces 64 and 65 only after a certain time, which corresponds to the frequency of the current in the distributing conductors. The moment the current is broken from any cause, the solenoid 58 is no longer energized but drops its armature 59, which is permitted by the pawl 88 moving in the opposite direction under the action of the weight of the rod 60 and armature 59 and sliding over the teeth of the ratchet wheel 84. Then the timing apparatus A will stop. Of course the timing apparatus A is preferably made adjustable in any known manner in accordance with the said frequency.

69, 76 and 76^a denote ordinary switches.

The automatic apparatus described is operated as follows: The first alternator 1 is assumed to be already connected with the three distributing conductors a, b and c by the three conductors a^1, b^1, c^1. The latter are shown as simple, but it will be understood, that the first alternator 1 may be provided with a similar system as the second alternator 2. The switch 69 is closed, to connect the parts 68 and 71 of the switch actuating circuit, while the two switches 76 and 76^a remain open as shown. The upper solenoid 40 of the tension relay T is energized by the current derived from the distributing conductors a and b by means of the circuit 43, 44, so that the armature 42 is attracted upwards and causes the lever 34 to touch the upper contact 35. Then a current supplied by the source of electricity 26 and circulating in the circuit 27, 33, 34, 35, 36, 39, 31, 32 will energize the electromagnet 48, so that the latter attracts its armature 50 and thereby causes its rear arm to break the connection between the lines 27 and 28 of the synchronizing circuit.

On the second alternator 2 starting, it will produce a current, a part of which circulates in the circuit 45, 46 and energizes the lower solenoid 41 of the tension relay T. The moment the tension of this current is equal to that in the upper solenoid 40, the armature 42 will be brought into its middle position shown at Fig. 1, so that the lever 34 does not touch either the upper contact 35 or the lower contact 37. Then the electromagnet 48 of the subsidiary relay S will be without current, so that the spring 49 detaches the armature 50 and causes its rear arm to connect the lines 27 and 28 of the synchronizing circuit. Meanwhile another part of the current from the alternator 2 will pass over to the distributing conductor b through the phase indicator circuit 54, 53, 44. b^2, in which both the incandescent lamp 51 and the electromagnet 52 act as resistances. The electromagnet 52 being thereby energized will more or less attract its armature 55, which will oscillate. When the lever 57 touches its contact pieces, it thereby connects the lines 28 and 29 of the synchronizing circuit. At the same time the incandescent lamp 51 will give a light and indicate to the machinist the condition of the system. The synchronizing circuit 27, 28, 29, 30, 31, 32 being now closed, the solenoid 58 of the timing apparatus A will be energized and attract its armature 60 upwards. Thereby the clockwork is put into motion, so that the switch 63 slowly rises and approaches to the contacts 64 and 65. As is well known, the frequency of the alternator 2 may not always be at once equal to that in the distributing conductors a, b and c, so that the current circulating may soon decrease and the spring 56 will overcome the attraction of the electromagnet 52 and detach its armature 55, whereby the syn-

chronizing circuit is again opened. The strength of the current circulating in the circuit 54, 53, 44, b^2 may repeatedly increase and decrease and the armature 55 will keep oscillating. Also the tension of the alternator 2 may increase beyond that of the distributing conductors a, b, and c, so that the lower solenoid 41 will be able to move the common armature 42 downwards and cause the lever 34 to touch the lower contact 37, when in a similar manner as described above the electromagnet 48 of the subsidiary relay S will be energized to attract its armature 50 and thereby to open the synchronizing circuit. Thus the latter can never be closed, if the tension of the alternator 2 is higher or lower than that in the distributing conductors a, b and c. This is of special importance, as all shocks and injury to machines and apparatuses are thereby avoided. When both the tension and the frequency of the alternator 2 become equal to those of the distributing conductors a, b and c, the timing apparatus A will be put into motion for a sufficient time to enable the switch 63 to touch its contact pieces 64 and 65 and to connect the lines 71 and 72. Thereby the switch actuating circuit 27, 66, 67, 25, 68, 69, 71, 63, 72, 30, 31, 32 will be closed, so that the switching-on solenoid 7 is energized and attracts the vertical rod 3 upwards and causes the three switches a^3, b^3 and c^3 to touch their respective contact pieces and thereby to connect the alternator 2 with the distributing conductors a, b and c. At the same time the upper end of the vertical arm 10 of the bell-crank lever 10, 11 will engage in the notch 9 of the rod 3 and thus lock the three switches a^3, b^3 and c^3. The dropping arm 11 of the bell-crank 10, 11 releases by means of the spring-pressed bell-crank lever 15, 16 the head 18 of the rod 19, whereupon with the armature 23 the switch 25 falls and opens the switch actuating circuit. The upper switch 8 on the rod 3 touches its two contact pieces 12 and 13 and thereby connects the lines 73 and 74.

If it is desired at any time to disconnect the alternator 2 from the distributing conductors a, b and c, the switch 76 is switched on to connect the parts 75 and 77 of the switch actuating circuit. Then the current supplied from the source of electricity 26 and circulating in the switch actuating circuit 27, 66, 73, 13, 8, 12, 74, 75, 76, 77, 32 will energize the switching-off solenoid 24, so that it attracts its armature 23 upwards. The head 18 of the rod 19 will reach its uppermost position and strike against the horizontal arm 11 of the bell-crank lever 10, 11, so that the vertical arm 10 withdraws from the notch 9, whereupon the rod 3 with the armature 6 and the three switches a^3, b^3 and c^3 drops to disconnect the alternator 2 from the distributing conductors a, b and c.

When it is desired to connect the alternator 2 with the distributing conductors a, b and c, in case no current is in the latter, the switch 76^a is switched on, while the other two switches 69 and 76 remain switched off. Then the current supplied from the source of electricity 26 will circulate in the switch actuating circuit 27, 66, 67, 25, 68, 76^b, 76^a, 77, 32 and energize the switching-on solenoid 7, so that it attracts its armature 6 upwards and causes the three switches a^3, b^3 and c^3 to touch their respective contact pieces. Thereupon the rod 3 is locked by the arm 10 engaging in its notch 9 and immediately afterwards the switching-off solenoid 24 is energized for opening the switch actuating circuit in the manner described above.

Where so preferred, the tension relay T may be simplified as is shown at Fig. 4, in which case the upper solenoid 40 of Fig. 1 and the circuit 43, 44 are omitted. Then the spring 47 is so adjusted, that normally it presses the lever 34 upwards against the upper contact 35 with such a force, that only on the tension of the alternator 2 becoming equal to that of the distributing conductors a, b, and c, the solenoid 41 will be sufficiently energized to detach the lever 34 from the upper contact 35 and to bring it into its middle position shown. Otherwise the operation of the automatic apparatus remains substantially the same as before.

In the system shown at Fig. 5 the conductors a^2, b^2 and c^2 are connected with the distributing conductors much in the same manner as in Fig. 1. The conductors a^4, b^4 and c^4 are also connected with the respective alternator. The three switches a^3, b^3 and c^3 are secured on the vertical rod 89 and insulated therefrom. The latter is shown only diagrammatic, but it may be constructed in the same manner as the rod 3 in Fig. 1 described above. The rod 89 is connected with the armature 90 and the upper switch 93 and provided with the notch 92. The bell-crank lever 94, 95 rocking on the stationary pin 96 and the other spring-pressed bell-crank lever 97, 98 rocking on the stationary pin 99 are substantially the same as levers 10, 11 and 15, 16 in Fig. 1. In this modified system is a tension relay T′, a phase-indicator relay P′, a timing apparatus A′ and a subsidiary relay S′ and other apparatus as will appear hereinafter.

Two transformers B and C have their respective primaries 100 and 103 respectively connected by conductors 101, 102, with the conductors a^2 and b^2 respectively which are connected with the alternator 1, and by the conductors 104 and 105 with the conductors a^4 and b^4, connected with the alternator 2. The secondaries 106 and 107 are connected in a closed circuit by the lines 108 and 109, in the latter of which a lamp L is inserted.

The tension relay T′ is constructed as a

differential relay and comprises two solenoids 110 and 111, whose armatures are suspended from a horizontal balance 112 which is rigidly connected with a suspending contact lever 113. The solenoid 110 is connected across the terminals of the secondary 106, while the coil 111 is connected across the terminals of the secondary 107. It will now be apparent that the voltage impressed upon the coil 110 will be equal to the voltage of the terminals of the secondary 106, while the voltage impressed upon the coil 111 is that at the terminals of the secondary 107. As the voltages of these secondaries are proportional on the one hand to that of the machine to be connected and on the other hand to that of the system to which it is to be connected, it will be apparent that the energizing of the coils 110 and 111 will be equal and the lever 113 will be vertical when the voltage of the machine to be connected and that of the system to which it is to be connected are the same. It follows that if one voltage is greater than the other contact lever 113 will be deflected to one side or the other according to which voltage is the greater. If that of the machine to be connected is greater the lever will be thrown to the right and will come in contact with the contact 114. If the voltage of the system to which the machine is to be connected is greater the lever will be thrown towards the left and will come against contact 115. The contact 114 is connected through the lamp L^2 and conductor 116 with the conductor 120 while the contact 115 is connected through the conductor 117 and the lamp L' with the conductor 120. The coil 119 of the subsidiary relay is connected on one side to the conductor 120 and on the other side to the conductor 121 which is connected with the solenoid 144 by conductor 122. The conductor 125, in which is inserted the lamp L^3, is connected through the conductor 126 to the subsidiary relay contact lever 128. The conductor 125 is also connected to the conductor 131, while conductor 126 is connected through the conductor 131 and 132 to one contact of the relay P'. The solenoid 136 of the phase indicator relay P' is connected across the lamp L in the secondary circuit of the transformers by means of the conductors 137 and 138. It will thus appear that the voltage impressed upon the solenoid 136 is equal to the drop in potential across the lamp L. The contact lever 133 of the phase indicator relay is connected by means of a conductor 139 with the one terminal of the solenoid 140 which actuates the plunger 141 controlling the switch element 150 to connect the conductors 149 and 151, the said plunger being controlled in its movement under the action of its solenoid, by means of the timing apparatus A'. The other terminal of the solenoid 140 is connected through conductors 142, 143, 122, low resistance solenoid 145 to conductor 146 whence circuit may be closed by the switch member 147 through the conductors 123 and 124 to the conductor *d* which is connected with the other terminal of the electric source (corresponding to source 26 of Fig. 1) to which the conductor *d* is connected. From the conductor 122 circuit passes through the solenoid 144, the solenoids 144 and 145 being differential and acting upon the same plunger 148, thence through conductor 152, solenoid 157 having armature 158 which is adapted to connect conductor 159 with one terminal of the solenoid 157, thence through conductor 156 and switch 155 to the switching on solenoid 91.

It will now appear that when the relays S' and P' are closed that the solenoid 140 will be energized through a circuit as follows: From the conductor *d* through conductor 180, contact piece 129, lever 128, conductors 126, 131 and 132, lever 133, conductor 139, solenoid 140, conductors 142, 143 and 122, high-resistance solenoid 144, conductor 152, solenoid 157, conductor 156, switch 155 and conductor 154, to one terminal of the switch-on solenoid 91, the other terminal of that solenoid being connected to the conductor *e*. The solenoid 144 being thus energized the armature 148 will be attracted and the switch 147 will be closed. Thus far the solenoid 91 has not been energized owing to the fact that the high-resistance coil 144 is in series with it. The solenoid 140 however, being energized, after a certain time has elapsed, depending upon the adjustment of the timing apparatus A', causes the switch 150 to connect the conductors 149 and 151, thereby short-circuiting the high-resistance coil 144 through conductors 122, 143, 142, 149 and 151. Circuit is then made from the conductor *d* through conductors 124 and 123, switch 147, conductor 146, low-resistance solenoid 145, conductors 122, 143, 142 and 149, switch 150 and conductor 151 to the conductor 152 whence circuit passes through the solenoid 91 to the conductor *e* as before traced. The high-resistance solenoid having thus been removed from the circuit of the solenoid 91, sufficient current flows to energize that solenoid whereby it operates to connect in the machine in a manner as described in connection with the previous figures. The whole current for energizing the solenoid 91 passes through the low-resistance solenoid 145 and serves to maintain the switch member 147 in closed position after the solenoid 144 has been short-circuited. Upon the breaking of the circuit at the switch 155 after the connecting operation has been performed in a manner as described in connection with preceding figures, the solenoid 145 becomes deënergized and the switch member 147 opens. It now becomes necessary that synchronous condi-

tions shall be again reached before the solenoid 91 can be again energized to effect a connecting operation, so that if, after synchronization has been reached and the machine connected, to the system, it is necessary to disconnect the machine because of short-circuit or otherwise, it will be impossible to again connect in the machine by reason of the setting of the apparatus due to the synchronous conditions existing at the former connection, but it will be necessary to again reach synchronous conditions before a connection between the system and machine can be effected.

When the high-resistance solenoid 144 has been short-circuited as described and sufficient current to energize the switching-on solenoid 91 passes through the solenoid 157, the last mentioned solenoid will become energized, and attracting its armature 158, will connect together the conductors 159 and 152, thus providing a connection in addition to the switch 150, whereby the high-resistance solenoid is short-circuited. This is for the purpose of maintaining the operative circuit of the solenoid 91 closed after it has once been closed by the switch 150 until the connecting operation has been completed. It would be undesirable for the operation of the connecting means to be arrested before completion, after it had once been started. It will be seen that this undesirable occurrence is avoided by the use of the solenoid 157 which is supplied with current through its own armature and therefore remains energized until its circuit is broken at the switch 155 upon the completion of the connecting operation. Without the use of this solenoid 157 the switch 150 might be only momentarily in engagement with its coöperating contacts as, after coming into the position indicated, the conditions of synchronism might be slightly varied from, whereby the switch 150 would leave its contact and the connecting operation which had been begun would be arrested. With the use of this solenoid however, the operation of connecting, after once having been started by the attainment of synchronous conditions, is carried to completion.

It has been observed that in order for connections to be established as just described that the contacts of the phase-indicator relay P′ and those of the subsidiary relay S′ must be simultaneously closed. This can only occur when the voltages of the apparatus to be connected and the conductors to which connection is to be made are at the same voltage, and also they must be in phase. It will be obvious that the greatest fall of potential across the lamp L will occur when there is coincidence in the phases of the voltages in the conductors a^4, b^4 and a^2, b^2, and the spring 134 is so adjusted that the armature 133 will come in contact with the terminal of the conductor 132 only when there is this maximum fall of potential across the lamp L and therefore the application of a maximum potential to the solenoid 136.

The lever 128 of the subsidiary relay S′ can only come against its contact 129 when the solenoid 119 is deënergized. This can only occur when the contact lever 113 is not in engagement with either of the contacts 114 and 115 for, if the lever engages with either of the contacts referred to, circuit may be traced from the conductor *d* through the conductor 118 lever 113, conductor 120, solenoid 119, and conductors 121 and 122, to the high-resistance solenoid 144, whence circuit may be traced through the solenoid 91 to the conductor *e*. As before pointed out, if the voltage of the lines a^4 and b^4, is too small, the lever 113 will come against the contact 115 so that connection is made with the conductor 120 through the lamp L′ and the burning of this lamp will indicate that the voltage of these lines is too small. If, on the other hand the voltage of these lines is too high, connection with the conductor 120 will be made through the lamp L^2 and the burning of this lamp will indicate this condition of the voltage. When, however, the voltage of the machine to be connected and the distributing conductors are equal and, therefore, the lever 113 is not in engagement with either of the contacts 114 and 115, the solenoid 119 will be deënergized and the lever 128 will come in contact with the contact piece 129. This contacting of the lever and contact piece not only serves to close the synchronizing circuit at this point but it also closes a circuit through the lamp L^3 which may be traced as follows: From the conductor *d* through conductor 130 contact piece 129, lever 128, conductor 126, conductor 125 containing the lamp L^3, conductor 121 and conductor 122 to the high-resistance solenoid 144 whence circuit may be traced as hereinbefore through the solenoid 91 to the conductor *e*. The lamp L^3 will then be lighted and afford an indication of the fact that the voltages of the lines to be connected together are equal.

The switches 160 and 161 correspond to those 76 and 76^a respectively in Fig. 1. The operation of the automatic apparatus shown at Fig. 5 is otherwise similar to that of the apparatus shown at Fig. 1.

The automatic apparatus may be varied in many respects without deviating from the spirit of my invention. In some cases the regulator for exciting the alternator may be provided with adjustable contact pieces on that place, which corresponds to the correct tension, and these contact pieces may be connected with the tension relay T′ for controlling the same.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. The combination with an alternating current machine and its distributing conductors, of a second alternating current machine, connections between said conductors and said second alternator provided with switches, a tension relay controlled by the tension in said alternators, a phase indicator, a solenoid with a timing apparatus, a synchronizing circuit containing said solenoid and adapted to be closed by said tension relay on there being the correct tension and by said phase indicator on there being the correct phase, and a switch actuating circuit adapted to be closed by said solenoid on there being the correct frequency and to close the switches in said connections.

2. The combination with the distributing conductors of an alternating current machine, of a second alternating current machine, connections between said conductors and said second alternator provided with switches, a tension relay controlled by the tension in said alternators, a phase indicator, a solenoid with a timing apparatus, a synchronizing circuit containing said solenoid and adapted to be closed by said tension relay on there being the correct tension and by said phase indicator on there being the correct phase, a switch actuating circuit adapted to be closed by said solenoid on there being the correct frequency and adapted to close the switches in said connections, and means for locking the switches and afterwards opening said switch actuating circuit.

3. The combination with current conveying distributing conductors, of an alternating current machine, connections between them provided with switches, a tension relay controlled by the tension in said alternator, a subsidiary relay controlled by said tension relay, a phase indicator, a relay controlled by said phase indicator, a solenoid with a timing apparatus, a synchronizing circuit containing said solenoid and adapted to be closed by said subsidiary relay and said relay, a switch actuating circuit adapted to be closed by said solenoid and to close the switches in said connections, and means for locking these switches and afterwards opening said switch actuating circuit.

4. The combination with main current conveying distributing conductors, of an alternating current machine, connections between them provided with switches, an independent source of electrical current with two distributing conductors, a tension relay controlled by the tension in said alternator, a subsidiary relay controlled by said tension relay, a phase indicator, a relay controlled by said phase indicator, a solenoid with a time apparatus, a synchronizing circuit joined to said two distributing conductors and containing said solenoid and adapted to be closed by said subsidiary relay and said relay, a switch actuating circuit joined to said synchronizing circuit and adapted to be closed by said solenoid and to close the switches in said connections, and means for locking these switches and afterwards opening said switch actuating circuit.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

MAX VOGELSANG.

Witnesses:
FRANZ HASSLACHER,
ERWIN PIPPEL.