

May 8, 1928.

1,668,615

P. M. G. TOULON
DEVICE FOR CONTROLLING AND ADJUSTING THE CURRENT PASSING THROUGH AN ARC FED
WITH ALTERNATING CURRENT
Filed June 29, 1926

3 Sheets-Sheet 1

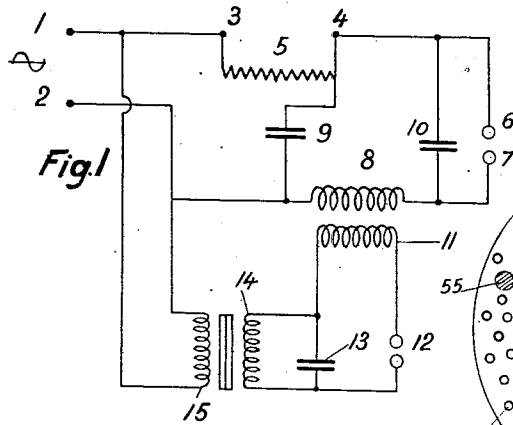


Fig. 1

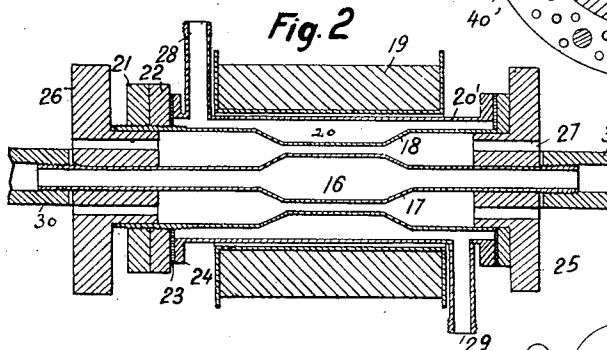


Fig. 2

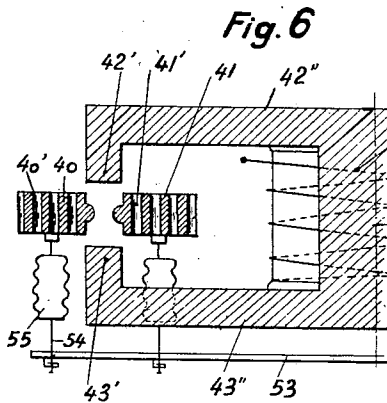


Fig. 6

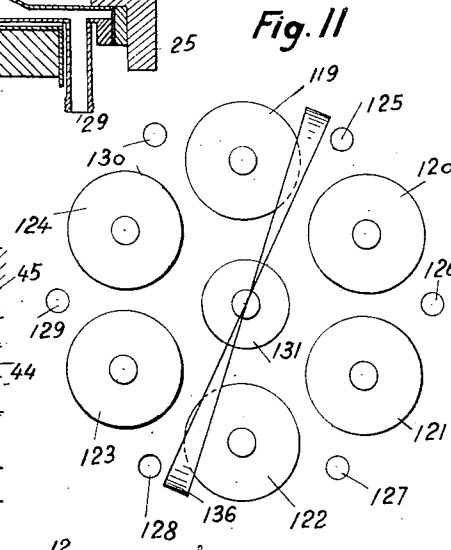
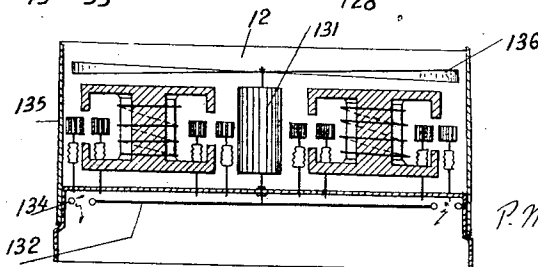


Fig. 11

Fig. 12



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Fig. 3

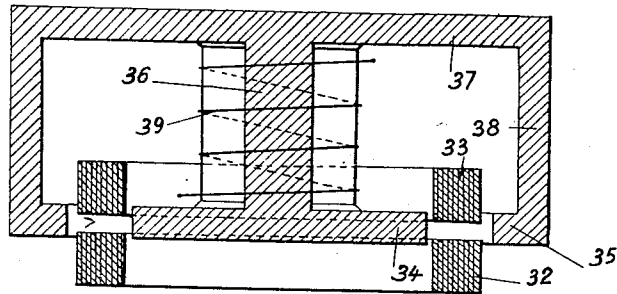


Fig. 4

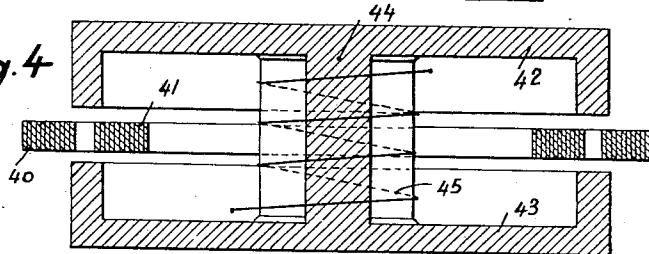


Fig. 5

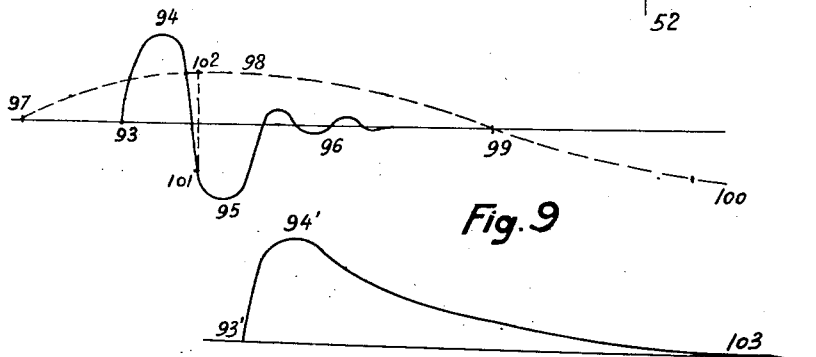
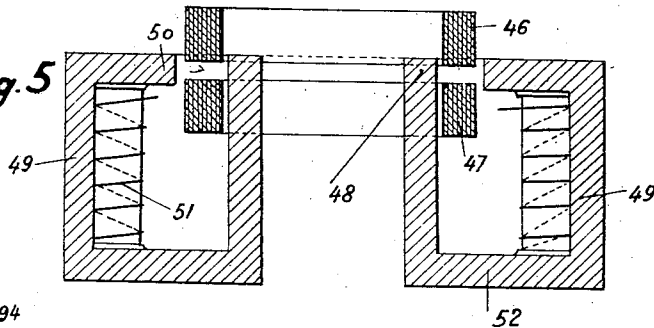


Fig. 9

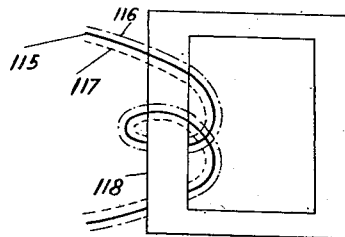


Fig. 10

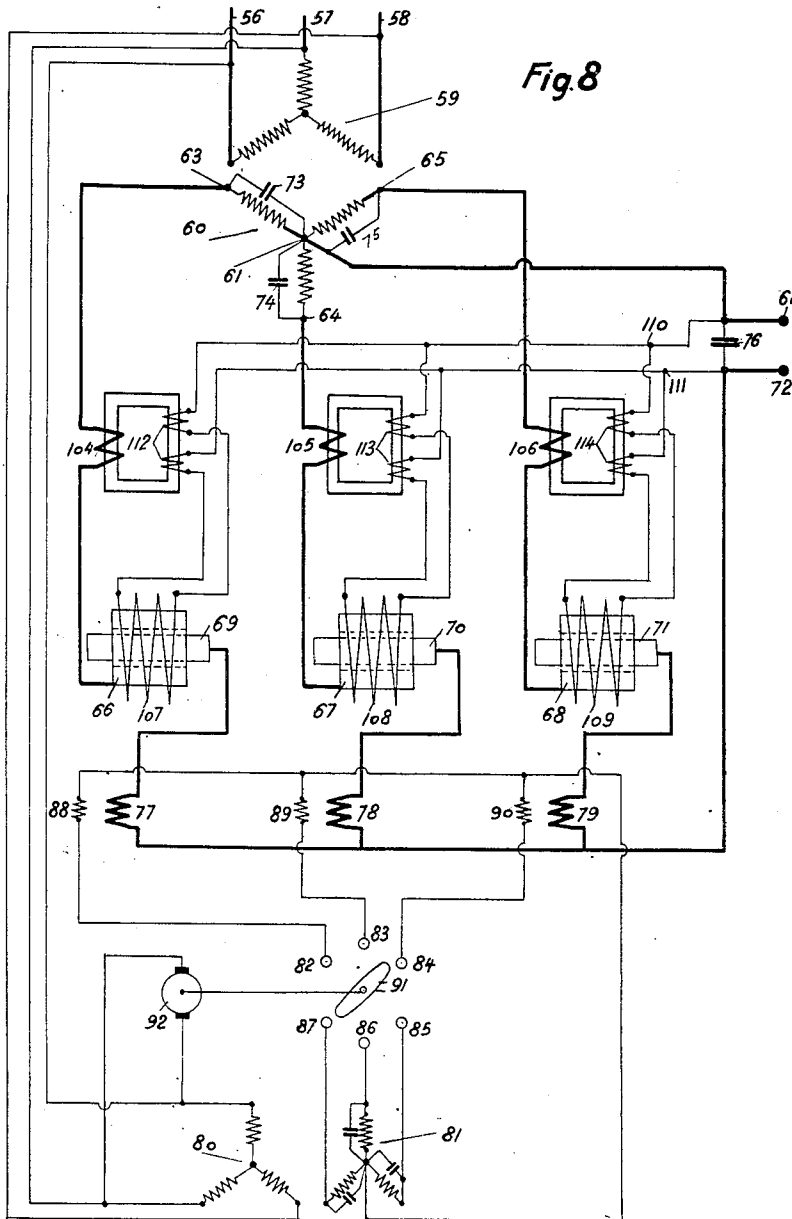
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE.

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DEVICE FOR CONTROLLING AND ADJUSTING THE CURRENT PASSING THROUGH AN ARC FED WITH ALTERNATING CURRENT.

Application filed June 29, 1926, Serial No. 119,511, and in France July 3, 1925.

My invention has for its object a device which allows the control and the adjustment of the current passing through an arc fed with alternating or polyphase current.

It is known that if two conducting electrodes placed at a certain distance one from the other are fed by an electric supply, an arc can be ignited between the said electrodes only when the voltage between them is sufficient and the arc will be extinguished as soon as this voltage falls below a given value. However if the electrodes are fed with alternating or polyphase current, of industrial frequency for instance, the arc can remain ignited at the end of each half period because, though the voltage has fallen at this moment to zero, the electrodes remain at a high temperature and continue producing ions and electrons which ensure the maintenance of the arc from one half-period to the next.

The device according to my invention must satisfy the three following requirements:

(a) The arc cannot be ignited automatically.

(b) The arc is extinguished each time the intensity of the current passes through zero or becomes lower than a given value.

(c) The arc is ignited by a "pilot-spark" flashing, according to a process known per se, between the two electrodes.

If the pilot-spark flashes at the moment where the alternating voltage between the electrodes is sufficiently great, the arc is ignited and will be extinguished towards the end of the half period.

According to my invention the flashing of the pilot-spark is adjusted with reference to the period or phase of the current feeding the arc and at a moment chosen according to the result which is desired.

For instance the following results can be obtained:

If a pilot-spark flashes at the beginning of all the half periods of same polarity, a rectified current is obtained. The adjustment of the mean intensity of this rectified current can be obtained by making the pilot-spark flash with a lesser or greater delay with reference to the beginning of each of the half periods considered.

The current fed by the arc is suppressed by suppressing the pilot-spark.

The frequency of the current can be altered by making the pilot-spark flash only for certain half-periods.

An amplifying relay can be obtained by adjusting according to the modulation to be amplified, the phase-lag of the pilot-sparks with reference to the beginning of the half periods.

Such an arrangement is of particular interest for controlling and adjusting industrial alternating or polyphase current by means of arcs burning in the open.

For preventing the arc from being ignited automatically, it is sufficient that the distance between the electrodes should be properly adjusted according to the maximum voltage of the feeding current.

According to my invention, for extinguishing the arc each time the intensity passes through zero or through the minimum value adopted and for preventing its automatic reignition after its extinction, I prevent the formation of ions or electrons by the electrodes during the periods wherein the feeding current between these electrodes is nil or very small.

This result can be provided by different means amongst which I may mention:

(a) At least one of the electrodes is powerfully cooled; for instance the electrodes are hollow and constituted by a metal, such as copper, which is a good conductor of heat; a suitable refrigerating fluid circulating through them to cause intensive cooling.

(b) The electrodes move quickly one with reference to the other.

(c) The arc is constantly shifted and cooled. The shifting is preferably provided along an annular path between two concentric electrodes disposed near each other, the cooling being obtained by a gaseous current.

(d) The movement of the arc along the annular path between the electrodes is obtained by a magnetic or electrostatic blow-out.

The phase-lag between the pilot-spark and the beginning of the half periods or phases can be obtained and adjusted by a number of devices amongst which I may mention.

(a) The circuit of the arc is coupled with

an oscillating circuit provided with a discharge device producing the sparks.

(b) The spark of the oscillating circuit is produced by one or more static transformers providing an alternating non-symmetrical voltage whereby the spark can flash only for one direction of current and consequently only during the half-periods of a given polarity.

(c) The spark flashing in one direction only and produced by the discharge circuit is caused by non-symmetrical electrodes fed with alternating voltage.

(d) The spark of the discharge circuit is provided by a mechanical rupturing device such as a vibrator or a rotating discharge disk.

(e) The adjustment of the phase lag of the pilot-spark with reference to the feeding current is made, by condensers, induction coils, polyphase transformers and the like disposed so as to modify the phase of the transformer feeding the discharge device.

The execution of an apparatus with electrodes allowing the arc to be ignited in the manner disclosed hereinabove can be provided in a number of manners.

For instance, the two electrodes can show between each other an annular space; when the voltage is sufficient, the arc will be ignited at one point and will move speedily along the annular path provided under the influence of a suitable magnetic field.

Magnetic circuits are advantageously disposed so as to localize and to reinforce the magnetic field between the electrodes of the arc.

If the apparatus is intended for the control and adjustment of a polyphase current, it can comprise as many pairs of electrodes of the type disclosed hereinabove as there are phases. These apparatus form a whole each of which is fed by a phase of the current: the pilot-sparks corresponding to each pair of electrodes will be produced in succession for instance by a rotating discharge disk controlled by a synchronous motor. Thereby each pair of electrodes will be fed by one phase; the arc will be ignited through the corresponding pilot-spark and will remain ignited the whole half-period of the corresponding phase.

In some cases it is necessary to take special care for preventing the oscillating pilot-spark from extinguishing the arc after having ignited it. This might happen if the negative voltage of the oscillating spark is at a given moment equal in value and of opposite polarity to that of the phase of the feeding current. This drawback is avoided by disposing in the circuit of the pilot-spark plug circuits, chiefly comprising one or more induction-coils with or without condensers whereby the oscillating spark is transformed into a spark having only one direction.

The magnetic circuits which reinforce the magnetic field created between the electrodes of the arc in view of producing the rapid movement of this arc along the annular path provided between the electrodes, as also disposed near the said electrodes whereby they can be given, at the moment of the flashing of the pilot-spark, a high voltage which might break through the windings of the excitation coils of these magnetic circuits. To avoid this drawback, the circuit of the pilot-spark is coupled with the excitation circuit of the magnetic cores, so that at every moment, the excitation winding is at the same potential as the corresponding electrode near which it is placed.

By way of example, I have described hereinbelow and shown on appended drawings several forms of execution of my invention.

Fig. 1 is a general diagram of the connections.

Fig. 2 shows a first form of execution of the electrodes between which the arc is to flash; these electrodes are constituted by two concentric tubes in copper provided with a water cooling device.

Figs. 3, 4 and 5 show diagrammatically three different electrode arrangements constituted each by two circular rings leaving between each other a circular interval wherein the magnetic field is reinforced by a magnetic circuit excited by a winding disposed near by.

Figs. 6 and 7 are a sectional side and a plan view of details of execution of a pair of electrodes of the type shown in Fig. 4.

Fig. 8 is a diagram of the connections used for rectifying a three-phase current by means of three couples of electrodes of the type shown in Fig. 2.

Fig. 9 shows the curves giving the compared voltage of the pilot-spark in the case where the said spark is oscillating and in the case where it has been suitably altered so as to flow, always in the same direction.

Fig. 10 illustrates a special form of execution of the coupling means between the circuit of the pilot-spark and that exciting the magnetic cores.

Figs. 11 and 12 are a diagrammatical plan and a sectional side view of the arrangement for rectifying 6-phase current comprising six pairs of electrodes of the type shown in Figs. 6 and 7.

According to Fig. 1 an alternating supply feeds the terminals 1 and 2. The terminal 1 is connected at 3 with the utilization circuit 5 of the rectified current. This circuit connected at 4 with the remainder of the feed circuit is diagrammatically shown as a resistance. A pair of electrodes 6, 7 for the arc is disposed in series with the circuit 5 and with the winding 8 which as described hereinafter is the secondary of a

transformer allowing the pilot-spark to flash between 6 and 7. The utilization circuit 5 is protected against high tension currents due to the pilot-sparks by the condenser 9. A condenser 10 bridging the electrodes 6, 7 allows an easy flashing of the pilot-spark.

The same alternating supply feeds through the same terminals 1, 2 the primary 15 of an iron core transformer, the secondary 14 of which loads at each half period a condenser 13 which forms with the coil 11, an oscillating circuit including a spark gap 12. The coil 11 is the primary of the above-mentioned transformer the secondary of which is the winding 8 of the electrode circuit.

The working of this device is as follows:

The adjustment is such that the maximum voltage caused by the alternating supply and existing at each half period between the electrodes 6 and 7 is not sufficient to make a spark flash between the electrodes. The transformer 15, 14, loads the condenser 13 at the beginning of each half-period. When the condenser is sufficiently loaded an auxiliary spark flashes in the spark-gap 12 and makes the oscillating circuit 11, 13, oscillate at a high frequency. The secondary 8 of the transformer 11, 8, is then the seat of a high alternating voltage which makes the pilot-spark flash between the two electrodes 6, 7 so that the alternating current supplied through 1, 2 can pass from one electrode to the other, thus igniting the arc until the end of the half-period considered.

When the current is to be rectified, the arc 6, 7 must flash only during the half-periods of a given polarity.

As stated hereinabove this result can be provided by several means, for instance by the following:

The transformer 15, 14 can provide a dissymmetric alternating voltage: or else the spark-gap 12, can be constituted by two dissymmetric electrodes, such as a point and a disk disposed perpendicularly thereto, this latter arrangement constituting a discharge device allowing the auxiliary spark to pass only in one direction. The flashing of the auxiliary spark at 12 can also be adjusted by constituting the spark-gap by a mechanical rupturing device: This device can consist of a vibrator or a rotating discharge disk adjusted according to the phases of the feed current from 1, 2 and allowing the spark to flash only at predetermined moments.

Fig. 2 shows how the pair of electrodes can be constituted: Outside and around a copper tubular electrode 16 showing in its middle a cylindrical swelling 17, is disposed a second copper tubular electrode 18 showing in its middle a depressed part disposed opposite and very near the swelling 17. The tube 18 is surrounded by a water jacket 20.

Inside the inner tube water is also made to run; the entrance of the water in the water jacket is made through the tube 28 and its exit through the tube 29. Round the outer tube 20' surrounding the water jacket 20 is mounted in an insulated manner a coil 19 fed preferably with D. C. The outer tube 20' bears at one end a collar 24 against which bear two nuts 21, 22, screwed on the left hand side of the tube 18, a packing 23 being provided between 22 and 24. At each end of the outer electrode 18, is fitted an insulating plug 25 or 26, through which is fitted the inner electrode 16, threaded at both ends whereby it is held by two threaded sleeves 30, 31 which press the two insulating plugs 25, 26, against the ends of the outer electrode 18.

This pair of electrodes 16, 18, works in the following manner: The two electrodes are connected with the feed circuit in the same manner as the electrodes 6, 7, in the diagram shown on Fig. 1. The pilot-spark starts at a predetermined moment of a half period of the current at a given point of the tubes 16, 18 between the central portions of the tubes which are close to each other. By reason of the feeding voltage at this moment, this pilot-spark ignites the arc which remains ignited until the end of the half-period. During the whole time the arc remains ignited, the magnetic field created by the coil 19 has for its effect to make the said arc move rapidly along the circular path afforded between the two electrodes.

The apparatus described hereinabove requires an intense water circulation and, in spite of this, if the intensity of the current is great, the two walls between which the arc flashes may become very hot. The reason of this is that, by reason of the small diameter of these parts the arc passes many times per second back through the same spot. Thus the arc may be reignited at an undesirable moment that is shortly after it has been normally extinguished, towards the end of the half period during which it has been extinguished. Moreover the metallic surfaces can be damaged when heated near the melting point.

The forms of execution of the arc electrodes shown on Figs. 3 to 7 are adapted for greater intensities.

According to Fig. 3 the two arc electrodes are constituted by two superposed metallic rings 32, 33, having the same diameter, and placed very near each other. These two rings leave between them a circular space wherein the arc is to move after ignition. The sides of this circular space are closed by a plate 34 and a circular flange 35 forming the two extremities of a magnetic circuit comprising a central core 36, to which are secured the plate 34 and the flange 35, this latter forming the inner end of a cyl-

inder 38 held by the top plate 37, directly secured to the core 36. The coil 39, is wound round the core 36. The working of this device is the following:

5 The two electrodes 32, 33, are fed like 6 and 7 on Fig. 1. The exciting coil 39 is fed preferably with D. C. and the two armatures 34, 35 provide in the annular path which separates the two electrodes 32, 33, an intense magnetic field which obliges the arc to rotate rapidly along this comparatively long annular path from the moment it is ignited by the pilot-spark to the moment it is extinguished at the end of the half-period.

15 According to Fig. 4 the two electrodes 40, 41, can be two flat concentric rings disposed in the same plane and the magnetic circuit can be constituted by two plates 42, 43, connected through a central armature 44 bearing the magnetizing winding 45.

20 According to Fig. 5 the two electrodes are two superposed flat rings 46, 47, having the same diameter and the magnetic circuit is constituted by a central cylinder 48, secured to an outer cylinder 49, ending with a flange 50. The magnetizing winding 51 is placed over posts connecting the top and the bottom of the armature. This latter device has the advantage over those shown on Figs. 3 and 4 of allowing a great diameter for the circular electrodes 46, 47, without increasing in proportion the size of the magnetic circuit considered in its diametrical section and constituted by the inner cylinder 48, the lower ring 52, the outer cylinder 49 and the flange 50. On the contrary in the types of magnetic circuits shown in Figs. 3 and 4 which comprise a central core, the length of the magnetic circuit is always substantially equal to twice the radius of the electrodes.

40 A detailed form of execution of a pair of electrodes according to Fig. 4 is shown on Figs. 6 and 7. The two electrodes 40, 41, are constituted each by a copper ring where-through are bored a certain number of vertical holes 40', 41'. Each of these electrodes is supported by a number of radial bars 53 on which they rest by means of the rods 54 and of the insulating blocks 55. The central core 44 of the magnetic circuit is connected with the two circular flanges 42', 43', disposed on either side of the path between the electrodes, by means of radial arms 42'', 43''. The outer electrode 40 projects widely beyond the magnetic field. Thanks to this arrangement the air heated by the working of the apparatus can move freely upwards and downwards through the spaces between the lower arms 43'', through the vertical holes 40', 41' in the two electrodes and through the spaces between the higher arms 42''. The working of such electrodes is very secure even for high power.

55 The diagram of Fig. 8 shows an arrangement comprising three couples of electrodes

of the type disclosed with reference to Fig. 2 and used for rectifying a three-phase current. The feed wires 56, 57, 58 feed the primary 59 of a three-phase transformer. The secondary 60 of this transformer has its neutral point 61 connected with one of the terminals 62 of the utilization circuit and each of its phases 63, 64, 65 is connected with one of the electrodes 66, 67, 68 of the three couples of electrodes of the type shown on Fig. 2. The other electrodes 69, 70, 71 are connected with the other terminal 72 of the work circuit. Each of the phases 63, 64, 65 of the secondary circuit of the three-phase transformer is short-circuited by one of the condensers 73, 74, 75. A condenser 76 bridges the terminals 62, 72 of the circuit using the rectified current. The three-circuits passing through the three couples of electrodes comprise the coupling coils 77, 78, 79. On the other hand the same line 56, 57, 58 feeds the primary 80 of a three-phase transformer the secondary 81 of which has its phases bridged by condensers and is connected through its neutral point with the three contact pieces 82, 83, 84 of a rotating switch; the three phases of 81 are connected with the complementary contact pieces 85, 86, 87. These three circuits comprise three primary windings 88, 89, 90, coupled with the abovementioned secondary windings 77, 78, 79, inserted in the three electrode circuits. The rotating arm 91 controlling the switch is actuated by a synchronous motor 92 fed by the same supply as the three-phase transformers.

This device works for each of its phases in the same manner as the A. C. device shown on Fig. 1. For instance, for the position shown on the drawing of the rotating switch acting as a discharge device, the spark-gap 84, 87 is used for allowing the auxiliary spark to pass. This spark causes through the coupling 90, 79, a pilot-spark to pass in the circuit of the electrodes 68, 71, by reason of the high alternating voltage provided. At this moment, the corresponding phase 65 of the three-phase transformer 59—60 is excited and the arc is ignited between the electrodes 68, 71, for the remainder of the half-period of the phase considered.

I have noticed that with the device shown in Fig. 1 the intensity of the rectified current is not constant. This can be explained by the fact that (see Fig. 9, top curve drawn in full lines), the voltage of the oscillating pilot spark starting from zero at 93 reaches a certain positive value at 94, then a substantially equal negative value at 95 and finally is rapidly damped towards 96. The dotted line shows the corresponding voltage of the feeding current, which begins at zero at 97 passes through its positive maximum at 97, becomes again equal to zero at 99 and

reaches its negative maximum at 100. Between 93 and 94, the pilot-spark ignites the arc; the voltage due to the feeding current whilst the arc is ignited could be represented by a curve very near the curve 98—99. When the voltage of the oscillating pilot-spark approaches 95, it may happen that for a point such as 101, the said voltage will exactly counterbalance the voltage reached simultaneously at 102, by the feed current, whereby the arc may be caused to fail.

In order to remove this drawback any device can be used which will give the voltage of the spark values all above zero as shown (Fig. 9) in the lower curve in full lines 93', 94', 103; thus no accidental reason can extinguish the arc before the feed voltage reaches zero at 99.

In view of this I may use as stated hereinabove several arrangements such as an induction coil or a combination of induction coils and condensers. In the diagram shown on Fig. 8, are shown induction coils 104, 105, 106, adapted to allow the spark to flow only in one direction.

As stated with reference to Fig. 2 each pair of electrodes bears on its outer electrode a magnetizing coil 107, 108, 109, (Fig. 9) adapted to make the arc rotate. When the pilot-spark flashes, this outer electrode 66, 67, 68, is brought to a high voltage whereby a current is induced in the corresponding coil 107, 108 or 109 which surrounds it and the difference of voltage between two adjacent coils or between these coils and the electrode can be strong enough to puncture the coil. In order to prevent this, I dispose (Fig. 8) in series with each coil 107, 108, 109, fed with D. C. through the terminals 110, 111, coils such as 112, 113, 114, wound over the same magnetic core as the induction coils 104, 105, 106. Thereby the potential in the windings 107, 108, 109 is at all times substantially equal to that of the electrodes 66, 67, 68.

According to Fig. 10, a practical form of execution of such windings consists in forming in one cable the three wires viz; the heavy wire 115 of the arc circuit and the two wires 116, 117, leading D. C. to and from the magnetizing coil. This cable is then wound over the magnetic core 118.

The six pairs of electrodes forming the 6-phase rectifier shown on Figs. 11 and 12, is constituted as follows: Six couples of electrodes (Fig. 11), 119, 120, 121, 122, 123, 124, are disposed side by side along a circumference. They are connected with the secondary of a 6-phase transformer as stated hereinbefore for the three pairs of electrodes of the device shown on Fig. 8. The pilot-sparks adapted to ignite the six arcs are provided by six high tension transformers 125, 126, 127, 128, 129, 130 for instance of the Tesla or of the Oudin type i. e., the pri-

mary of which is a short coil of heavy wire without an iron core. These six high tension transformers are disposed between six pairs of electrodes. At the center of the circumference formed by these electrodes, is a small synchronous motor 131, actuating the arm 132 (Fig. 12) of a rotating discharge disk the extremity of which moves in front of the contacts 134, and as explained with reference to Fig. 8 provides in predetermined succession the closing of the circuits producing the pilot sparks. Thereby the six arcs are ignited in succession at a predetermined moment of the corresponding phase. The whole apparatus is contained in a circular tube 135 forming a kind of a chimney through which the air heated by the pairs of electrodes can circulate thus ensuring a proper cooling of the electrodes. This air circulation is enhanced by a fan 136, disposed at the top of the apparatus and driven by the motor 131.

What I claim is:

1. In an A. C. rectifier the arc of which is adapted to be ignited by a pilot spark at an adjustable moment of each half period and to be extinguished at the end thereof, the combination of two electrodes affording parallel closed paths for the ends of the arc and means for moving rapidly the ends of the arc along their respective paths.

2. In an A. C. rectifier the arc of which is adapted to be ignited by a pilot spark at an adjustable moment of each half period and to be extinguished at the end thereof, the combination of two electrodes affording parallel closed paths for the ends of the arc, a magnetic core provided with poles the edges of which are parallel to, disposed on either side of, and very near the above mentioned paths and windings round said core adapted to create a strong uniform magnetic field perpendicular to the arc.

3. In an A. C. rectifier the arc of which is adapted to be ignited by a pilot spark at an adjustable moment of each half period and to be extinguished at the end thereof, the combination of two annular concentric electrodes having a large diameter, a magnetic core the poles of which are disposed on either side of and near the space between the said electrodes, D. C. windings round said core, and means whereby air is allowed to pass and is caused to circulate through the electrodes.

4. In an A. C. rectifier the arc of which is adapted to be ignited by a pilot spark at an adjustable moment of each half period and to be extinguished at the end thereof, the combination of two electrodes affording parallel closed paths for the ends of the arc, means for moving rapidly the ends of the arc along their respective paths, an oscillating exciting circuit fed with the A. C. feeding the rectifier and coupled with the

arc circuit, and a discharge device in the said oscillating circuit.

- 5 5. In an A. C. rectifier the arc of which is adapted to be ignited by a pilot spark at an adjustable moment of each half period and to be extinguished at the end thereof, the combination of two electrodes affording parallel closed paths for the ends of the arc, means for moving rapidly the ends of the
10 arc along their respective paths, an oscillating exciting circuit fed with the A. C. feeding the rectifier and coupled with the arc circuit, a discharge device in the said oscillating circuit, and damping circuits inserted
15 in the arc circuit and adapted to prevent the oscillating pilot spark from reaching a voltage liable to cause the extinction of the arc.

6. In an A. C. rectifier the arc of which is adapted to be ignited by a pilot spark at an adjustable moment of each half period 20 and to be extinguished at the end thereof, the combination of two electrodes affording a parallel closed path for the ends of the arc, a magnetic core provided with poles the edges of which are parallel to, disposed on 25 either side of, and very near the above mentioned paths, windings round said core adapted to create a strong uniform magnetic field perpendicular to the arc, and a second winding disposed in series with the 30 said circuit and coupled with the arc circuit.

In testimony whereof I affix my signature.

PIERRE MARIE GABRIEL TOULON.