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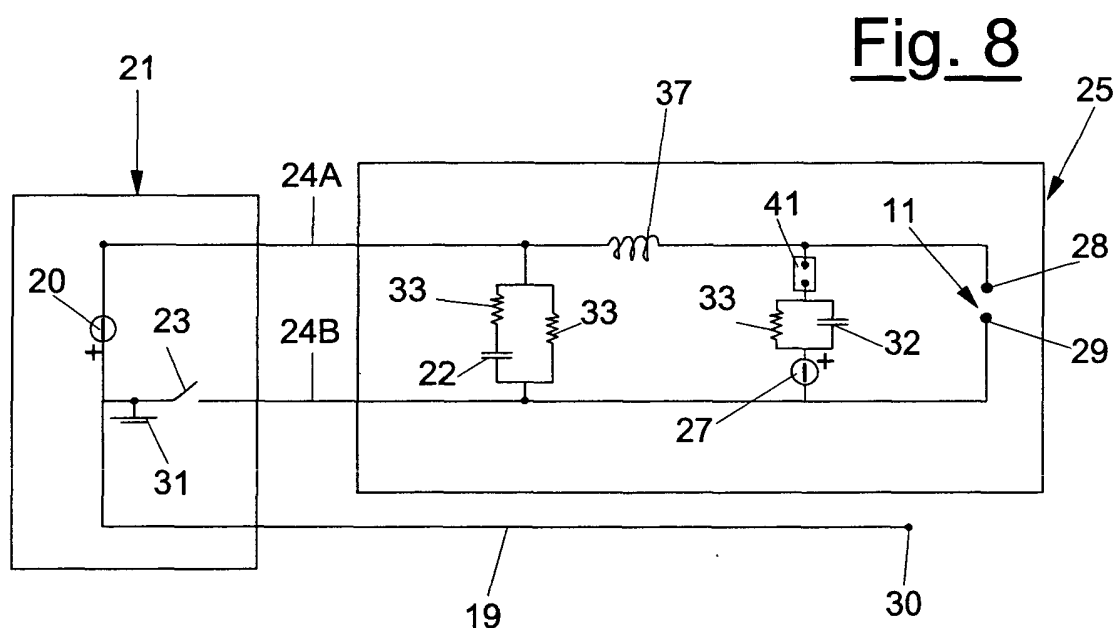
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(54) **Striking circuit of the pilot arc for plasma arc torches**

(57) A striking circuit of the pilot arc for plasma arc torches (25), comprising a low power impulse generator (27), suitable for striking the pilot arc between the cathode (28) and auxiliary anode (29), which is positioned inside the torch body (25) and kept separate from the direct current generator (20), which feeds both the pilot arc and the main arc, until the arc has been permanently struck; the separation of the part of the circuit in which the low power impulses are present is obtained by using an insulated inductor (37), with a ferrite separation nu-

cleus between the feeder (21) and the torch body (25), and a discharger (41), situated in series with the impulse generator (27), associated with an oscillator and an amplifier, so as to obtain, between the high voltage outlet of the impulse generator (27) and the earth (31), high voltage impulses, having a frequency of about 250 kHz. The electromagnetic emissions are thus reduced during the functioning of the torch (25) and the whole system is more compact, reliable and functional, with respect to the known art.



Description

[0001] The present invention falls within the general context of plasma arc torches and the cutting processes obtained therewith.

[0002] In particular, the invention relates to a specific circuitry, obtained after modeling the present high frequency striking system of plasma arc torches, to develop an alternative striking system which does not use high frequency impulse generators.

[0003] One of the major problems arising in the development of the plasma arc torch technology for the cutting of materials consists in the striking and relative transfer of the plasma arc.

[0004] In this specific case, it is quite difficult to strike an arc transferred between the electrode of the torch and the piece being processed, mainly due to the relative distance existing between them, when at a stand-still.

[0005] Most of the plasma cutting systems are consequently based on the striking of a pilot arc between the electrode of the torch and the nozzle, elements separated by a substantially lesser distance with respect to that indicated above; said pilot arc induces the formation of an arc between the electrode and the piece being processed.

[0006] A widely-used mode currently adopted for striking the pilot arc uses a high voltage and high frequency signal generator, coupled with a direct current generator and with the torch; the high frequency generator sends a signal which causes a sudden discharge in a plasma which flows, following a typically spiral path, between the electrode and a nozzle of the torch.

[0007] The discharge causes a preferential course for the current which, therefore, forms the pilot arc between the electrode and the nozzle, between which a power difference is created.

[0008] The direct current generator is directly connected to the electrode and to the piece being processed and the gas flow at the outlet of the nozzle is ionized by the pilot arc so that the electric resistance between the electrode and piece becomes small.

[0009] Furthermore, the nozzle is connected to the piece being processed by means of a pilot resistor and a pilot relay, connected to each other in series, creating a high power difference between the nozzle and the piece; this induces the transfer of the arc to the material being processed following the complete ionization of the surrounding space.

[0010] The relay is closed before the formation of the pilot arc and opened at a pre-established moment, after the arc has been transferred to the piece and consequently the time which passes between the formation of the pilot arc and the transfer of the arc to the material being processed is in relation to the distance between the torch and the piece being processed, the current value of the pilot arc and the flow rate of the gas.

[0011] In the striking systems currently adopted, of

the type described above, it can also be observed that 20-30% of the energy supplied by the high frequency generator is dispersed in the environment by the torch wire which, by functioning as an aerial, can negatively influence all the surrounding electronic equipment and also cause failed ignition of the arc, above all in the presence of humidity conditions (especially during the winter and/or in Northern Countries).

[0012] This can be clearly demonstrated by carrying out specific functioning characterization tests of said high voltage and high frequency impulse generator, which is normally used in striking circuits; a spark gap is normally used for the tests, consisting of two metal electrodes at an adjustable distance and a probe oscilloscope, with pre-established division ratios, for measuring the voltage and current.

[0013] The scheme of this test circuit is illustrated in the enclosed figure 1, in which 10 indicates the high frequency impulse generator, 11 generically indicates the adjustable spark gap, 12 the measuring oscilloscope and 13 and 14 the current and high voltage probes, respectively.

[0014] From the measurements described, it can be observed that the impulse generator 10, which is normally assembled in series on the striking circuits for plasma arc cutting torches, produces a voltage impulse every 20 ms approximately and that the impulse has extremely rapid rise and fall times, with a spectrum containing quite high frequencies (up to about 1 MHz); in the absence of current (idle), the impulse consists of a voltage peak having a certain sign, followed by a opposite sign peak and with approximately the same amplitude (7-8 kV).

[0015] The equivalent circuit (schematically shown in figure 2) is therefore substantially represented by the direct current voltage generator V, which feeds both the main arc and pilot arc, situated in series with a resistor R and a network LC, equivalent to the high voltage and high frequency impulse generator, comprising an inductor L and a condenser C; the condenser C is charged to about 1 kV and is brusquely discharged (through the diodes 15, of the SCR type) onto the primary circuit of an impulse transformer 16, thus inducing the voltage VI of the required level onto the secondary circuit of the transformer 16.

[0016] The discharge can take place during the first or second peak; in any case, if the discharge takes place in the spark gap 11, the current describes a sinusoid with a basic frequency of 300 kHz approximately (with a period of about 3 μ s), it has a peak value of about 40 A and diminishes with a time constant of about 10 μ s.

[0017] Neglecting the losses of the transformer 16, the maximum voltage measured reaches 8 kV and the charge corresponding to a current semi-wave, measured at the secondary circuit of the transformer 16, is equal to about 40 μ C; the energy corresponding to an impulse is therefore equal to about 160 mJ.

[0018] A hypothesis for the development of an alter-

native striking system to the high frequency system, was initially based on the possibility of using Paschen curves for finding an optimal condition of the values relating to the pressure and distance between the torch elements, in order to minimize the voltage necessary for the striking of the arc.

[0019] A more detailed study of the phenomenon, together with technological and operative restrictions of plasma arc torches indicated, however, that this could only be possible using a torch with lower pressures than atmospheric value.

[0020] Other studies were effected using a piezoelectric generator, instead of high voltage in high frequency impulse generators, with feeding at 220 Volt, described above and normally adopted in striking circuits of plasma arc torches.

[0021] On effecting the measurements with the circuit of figure 1, it can be immediately observed that, in this case, the current absorbed by the high voltage probe 14, is such as to cause a significant voltage drop inside the piezoelectric generator, which has a very high internal impedance; the voltage supplied by the generator is therefore reduced by the consumption due to the measurement probe, to such an extent that, at times, the striking does not even occur.

[0022] In order to reduce the current absorbed by the probe 14, it is alternatively possible to provide a compensated divider RC with a prefixed ratio and increased inlet impedance, in order to obtain qualitatively acceptable measurements.

[0023] From the oscillograms obtained under these conditions, it can be observed, however, that, during the compression of the crystal, the piezoelectric generator produces a sequence of 3-4 voltage increases with a very slow growth (lasting several tens of ms); each increase is brusquely interrupted when the discharge takes place in the spark gap 11, which brings the voltage practically back to zero and, during the release of the pressure on the crystal, a sequence of completely analogous negative increases arises.

[0024] The discharge voltage of the spark gap 11 proves to be slightly higher than 4 kV, lower therefore than that measured with the high voltage and high frequency impulse generator, with the same distance between the electrodes; this is coherent with the fact that a very short voltage impulse has a lower probability of producing the strike with respect to a continuous voltage.

[0025] In this case, the current reaches 20 A and the charge supplied is equal to about 0.1 μC , whereas the voltage is equal to about 4 kV and the energy corresponding to an impulse is equal to about 1 mJ, or 160 times lower than that supplied by the high voltage and high frequency generator.

[0026] Within the range of requirements specified above, an objective of the present invention is to provide a circuit for plasma arc torches which allows the striking of a pilot arc using a low power generator, instead of a

high frequency impulse generator which, according to the known art, is normally situated inside the main generator.

[0027] A further objective of the invention is to provide a striking circuit for plasma arc torches which drastically reduces electromagnetic emissions, with respect to the techniques so far used, during the functioning of the torch, thus limiting the risks of exposure to these radiations during the processing of materials.

[0028] Another objective of the present invention is to provide a striking circuit for plasma arc torches, in which the low power generator used for striking the pilot arc can be situated inside the torch, thus limiting the overall hindrances of the equipment necessary for the processing (cutting) of plasma arc materials.

[0029] Yet another objective of the invention is to provide a striking circuit for plasma arc torches which is extremely functional and reliable, under any condition and/or in any application, which is also simple to use and relatively economical with respect to the techniques traditionally adopted, in virtue of the advantages obtained.

[0030] These and other objectives, according to the present invention, are achieved by providing a striking circuit of the pilot arc for plasma arc torches, according to claim 1, to which reference should be made for the sake of brevity; other embodiment variants are described in the subsequent claims.

[0031] The striking circuit according to the present invention uses, as impulse generator for the striking of the pilot arc, an impulse generator which produces a sequence of impulses consisting of a positive peak and a negative peak, with a typical frequency of about 100 kHz; the impulses are repeated at intervals of about 100 ms and are approximately sinusoidal with a variable peak value (up to about 8 kV).

[0032] The current reaches a value of 20 A and the charge is equal to about 0.5 μC , whereas the energy of an impulse can be estimated as being around 2 mJ, i.e. about 80 times lower with respect to that emitted by a high voltage and high frequency impulse generator.

[0033] By using the high voltage and low power impulse generator described in the present invention (inside the torch), it is therefore possible to strike a pilot arc between the cathode and auxiliary anode; this avoids the use of the traditional high voltage and high frequency impulse generator which is normally positioned inside the main direct current generator.

[0034] Further characteristics and advantages of a striking circuit of the pilot arc for plasma arc torches, according to the present invention, will appear more evident from the following description relating to an illustrative but non-limiting embodiment, and referring to the enclosed schematic drawings, in which:

- figure 1 shows a scheme of the test circuit adopted for the various measurements effected;
- figure 2 shows a circuitry scheme equivalent to the high voltage and high frequency impulse generator,

used in striking circuits for plasma arc torches, according to the known art;

- figure 3 shows a principle scheme of the striking system of the pilot arc in plasma arc torches not using a high frequency generator;
- figure 4 illustrates a first embodiment of a test circuit used for testing the functioning principle of the striking system of figure 3;
- figures 5-7 show other embodiment variants of a test striking circuit scheme which can be used for testing the functioning principle of the striking system of figure 3;
- figure 8 shows a principle circuitry scheme of a striking circuit of the pilot arc for plasma arc torches, which can be inserted in the torch body, according to the present invention.

[0035] The principle of the striking system of the pilot arc without the use of any high frequency generator is schematized in figure 3.

[0036] According to this system, it is possible to advantageously use a torch feeder 21, comprising a direct current low voltage generator 20 (equal to a maximum of 250 V), suitable for the formation of the pilot arc and main arc, connected in parallel to a condenser 22 and to a switch 23 of the pilot arc; the feeder 21 is electrically connected, by means of the connection cable 24A, 24B, to the plasma arc torch 25, which includes a protection diode 26, connected in parallel to a high voltage impulse generator 27 (about 5 kV) for the striking of the pilot arc and to a negative electrode 28 (cathode) of the torch 25.

[0037] The cathode 28 is coupled with the hood of the torch 25, which acts as auxiliary anode 29, whereas the main anode 30 consists of the piece to be processed, which is connected, as also the generator 20 and switch 23, to the earth potential 31, by means of the wire 19 of the main anode 30.

[0038] According to the invention, the generator 27 is an impulse generator which produces a sequence of impulses consisting of a positive peak and a negative peak, with a typical frequency of about 100 kHz; the impulses are repeated at intervals of about 100 ms and are approximately sinusoidal with a variable peak value (up to about 8 kV).

[0039] The current reaches a value of 20 A and the charge is equal to about 0.5 μC ; the energy of an impulse can be estimated as being around 2 mJ, about 80 times lower than that of the high voltage and high frequency impulse generator.

[0040] By using the high voltage and low power impulse generator 27, it is possible to strike a pilot arc between the cathode 28 and auxiliary anode 29.

[0041] In any case, in order to test the functioning principle of the system schematized in figure 3, as a diode such as that indicated with 26, capable of tolerating both the striking voltage and the current of the pilot arc, is not available at present, the test circuit of figure 4 was produced, in which two diodes are used in series (com-

ponent indicated with 36) with a maximum inverse voltage of 8 kV and a maximum current equal to 0.4 A.

[0042] In order to avoid destroying the diodes 36, a resistor 33 was also introduced, which limits the current to 0.4 A, whereas the condenser 32 is used to prevent a direct current from passing through the impulse generator 27 when it is switched off (the outlet of the generator 27, in fact, consists of an elevator transformer which would become overheated as a result of the direct voltage); finally, the condenser 22 protects the generator 20 from rapid overvoltages.

[0043] The spark gap 11, consisting of two metallic electrodes at an adjustable distance, was used for the tests, and voltages and currents were measured with the oscilloscope 12, using the probe for high voltages 14, the current probe 13 and a differential probe 34.

[0044] The high voltage probe 14 tolerates voltages up to 40 kV RMS and has a feed-through band of about 70 MHz, whereas the current probe 13 has a capacity up to 30 A and a feed-through band of 50 MHz; the differential probe 34 tolerates voltages up to 1.4 kV and has a band of about 10 MHz.

[0045] The oscillograms effected with the generator 20 switched off, show that the diodes 36 adequately protect the generator 20 without absorbing excessive current of the impulse generator 27, which is therefore able to tolerate the voltage and produce the striking.

[0046] Furthermore, when the generator 20 is switched on, the arc struck between the electrodes continues even after the impulsive voltage produced by the impulse generator 27 has become exhausted, as a result of the current supplied by the generator 20 through the diodes 36; as this current, however, is necessarily limited to 0.4 A, the phenomenon only lasts for a few tens of μs .

[0047] The effect of the greater energy due to the current created by the generator 20 is however well visible even to the naked eye and experimentally confirms that it is possible to strike a pilot arc (between cathode 28 and auxiliary anode 29) using a high voltage and low power generator such as the impulse generator 27 (which can be inserted inside the torch 25), instead of the high voltage and high frequency impulse generator which is traditionally placed inside the main generator 20.

[0048] The most critical point of the system, however, is represented by the fact that it only functions if the impulse generator 27 is kept separate from the direct current generator 20 until the arc has been permanently struck; this separation was initially obtained by means of a high voltage diode 26 as, in the absence of this, the voltage impulses would have propagated back along the wire 24A, 24B and would have caused considerable emissions of waves and electromagnetic disturbances, as well as damaging the direct voltage generator 20.

[0049] Furthermore, in the absence of separation, in order to sustain the voltage at the value necessary for producing the discharge, an impulse generator with a

much greater power than that strictly necessary for producing the striking of the arc between the cathode 28 and auxiliary anode 29, would have to be used.

[0050] By using only one diode 26, this can be connected to the cathode 28 conductor (as illustrated in figure 3), so that, during the functioning of the pilot arc, the auxiliary anode 29 is at earth potential 31, or to that of the auxiliary anode 29, in which case the auxiliary anode 29 is brought to a potential of various kV, with respect to the earth potential 31; in this latter case, it is possible to use a diode 26 with a lower current capacity.

[0051] Even if, however, the tests effected showed, as already mentioned above, that the system can clearly function, diodes 26 capable of tolerating the required voltages and current cannot easily be found on the market and can also be costly and bulky, whereas the use of a pair of diodes 36 causes a striking which has an extremely limited duration.

[0052] In alternative and preferred embodiments of the invention, the idea arose of using an inductor to separate the part of the circuit in which high voltage impulses are present (the torch 25) from the rest of the circuit (wire 24A, 24B and feeder 21), according to the circuitry scheme of figure 5.

[0053] The tests were carried out under the same conditions as the previous ones, using the spark gap 11, consisting of two metallic electrodes at an adjustable distance, to simulate the distance (gap) existing between the cathode 28 and the auxiliary anode 29, the oscilloscope 12, the high voltage probe 14, the differential probe 34 and the current probe 13, whereas the striking circuit was varied by connecting, instead of the diode 26 or series of diodes 36, an inductor 35, made with a ferrite nucleus with an openable casing of about 20 coils, having an inductance in the order of 50 μ H (this value was selected with the criterion of making the current absorbed by the inductor 35 low in percentage with respect to that supplied by the generator 20 when the discharge takes place in the spark gap 11).

[0054] All the other components were obviously redimensioned with respect to the previous embodiments and a resistor 33 in parallel with the condenser 32, was added.

[0055] The tests effected showed that the 50 μ H inductor 35 does not yet represent an optimal filtration, as, although the current absorbed by the inductor 35 is low in percentage with respect to that supplied by the generator 20 during the discharge, the voltage drop inside the generator 20 with this current is still sufficient however to prevent the formation of the discharge.

[0056] In practice, the inductor 35 still allows a current to pass which is such as to lower the voltage of the generator 20 before the discharge takes place; the problem could be solved by further increasing the inductance (by increasing the number of coils and the ferrite section), but it is believed that such an increase would not be easily compatible with the possibility of housing the striking circuit in the body of the plasma hand torch 25.

[0057] The idea then occurred to modify the circuit by introducing a second spark gap, indicated with 36 in figure 6, situated in series with the high voltage impulse generator 27; in this respect, it should be noted that electronic components having the same function with respect to those of figure 5 are indicated in figure 6 with the same references.

[0058] The circuit of figure 6 ensures that the electrode forming the cathode 28 remains at the potential set by the generator 20 of the pilot arc (-250 V) until the discharge has been effectively initiated inside the second spark gap 36; at this point, in fact, the potential of the cathode 28 is brought within a very short time interval (in the order of a few ns) to an intermediate level between the voltage of the impulse generator 27 and the earth potential 31 (about 5 kV, in any case sufficient for effecting the discharge between the auxiliary cathode 28 and anode 29).

[0059] The inductor with a ferrite nucleus 35 is then subjected to a voltage with a much shorter duration than that obtained with the circuit of figure 5 and this allows the striking circuit to be effectively separated from that of the generator 20, using a very small inductance; the period of time during which the inductor 35 must prevent the passage of current towards the generator 20 is in fact reduced by at least one 100 factor (from 5 μ s to less than 50 ns).

[0060] In further preferred but non-limiting embodiments of the invention, the inductor 35 consists of a series of high voltage insulated wire coils (Teflon insulation), wound around a toroidal ferrite nucleus having a diameter of about 25 mm.

[0061] The tests showed that the small impulse generator 27 is capable of striking an arc, which is then fed by the energy supplied by the generator 20 of the pilot arc.

[0062] The result is therefore extremely positive, both with respect to the energy of the discharge which is triggered, which is clearly greater than that previously obtained (according to the scheme of figure 3), which used the diode 26, and also as regards the much more reliable repeatability in the discharge itself.

[0063] Furthermore, the duration of the discharge improves when the transformer of the traditional striking system, which was left, even in the absence of feeding, inside the generator 20, is short-circuited.

[0064] In order to maintain the striking of the arc for a certain period of time, it is also necessary to ensure that the generator 20 of the pilot arc is sufficiently rapid to supply the current necessary for sustaining the discharge; in this respect, it has been observed that the extinguishing of the arc in short times is linked to the high inductance inside the generator 20 and that this problem can therefore be solved by reducing said inductance or by simply producing voltage impulses with more rapid time intervals than those currently obtained by the impulse generator 27 (as already occurs with the high frequency impulse generator inside the generator

20).

[0065] It has also been verified that the system also continues to function when the number of coils around the toroidal inductor is reduced.

[0066] In view of the encouraging results, it was decided to perfect the circuit by using a more powerful and reliable impulse generator.

[0067] The principle at the basis of this impulse generator is the Ruhmkorff principle, in which the secondary circuit with a small section wire ($\varnothing = \sim 0.2$ mm) with thousands of coils is wound onto a ferrite nucleus with primary winding with a large section wire ($\varnothing = \sim 1$ mm) and few coils, so that, by opening and closing the primary circuit, there are high potential differences at the ends of the secondary circuit.

[0068] The circuit illustrated in detail in the circuitry scheme of figure 7, where the same components as figure 6 have the same numerical references, uses an impulse generator 27 consisting of an ignition reel fed at 14 Volts in direct current and having an integrated circuit as oscillator.

[0069] The signal generated is amplified by one or more transistors which apply it to the primary circuit of the reel, and high voltage impulses are obtained between the high voltage outlet of the reel and mass 31.

[0070] Furthermore, as the apparatus is envisaged for an impulsive functioning, it is necessary to connect a switch in series to the direct current feeding at 14 Volts, so that with each pressure on the switch, a spark is generated in the spark gap 11.

[0071] The impulse generator thus conceived produces a voltage impulse with a frequency of about 100 Hz and the impulse has a rise and fall with frequencies in the order of 250 kHz.

[0072] A further improvement of the circuit of figure 7 is represented by the circuitry scheme of figure 8, in which the components of figure 7 having the same function, are indicated with the same numerical references; in the circuitry scheme of figure 8, in particular, in addition to the use of the discharger 41 instead of the second spark gap 36, the inductor with a ferrite nucleus 37 is installed inverted, i.e. it is connected in series to the auxiliary anode 29, where a maximum current of 20 A passes, so as to have an inductance with a limited value.

[0073] In the case, on the other hand, of figure 7, as the inductor 37 is situated in the cable of the cathode 24A, during the functioning of the torch 25 it must tolerate a maximum current of about 150 A and this parameter, which is not well tolerated by the inductor 37, can cause a critical point in the system.

[0074] From the tests effected, an extremely stable and intense arc is obtained on the spark gap 11, when very compact components are used; in the field of plasma arc torches, in addition to the possibility of using a high frequency impulse generator 27 (with consequently great advantages from the point of view of electromagnetic compatibility and low emissions), this also allows a structure with an extremely reduced hindrance to be

obtained, as all the circuitry necessary for the functioning of the striking system of the pilot arc can be contained inside the torch body 25.

[0075] From the above description, the characteristics as also the advantages of the striking circuit of the pilot arc for torches, which is object of the present invention, are evident.

[0076] Finally, numerous variants can obviously be applied to the striking circuit in question, which are all included in the novelty principles implied in the inventive concept. It is also evident that, in the practical embodiment of the invention, the materials, forms and dimensions of the details illustrated can vary according to the demands and can be substituted with other technically equivalent alternatives.

Claims

1. A striking circuit of the pilot arc for plasma arc torches (25), of the type comprising at least one high voltage signal generator (27), coupled with the torch (25) and at least one direct current low voltage generator (20), suitable for the formation of the pilot arc and main arc, said high voltage signal generator (27) being capable of sending a signal for inducing a sudden discharge into a plasma, which flows, according to a pre-established path, between at least a first electrode (28), connected to said direct current generator (20), and at least a second electrode (29) of the torch (25), in order to create a preferential course for a current signal, which forms the pilot arc between said electrodes (28, 29), maintained at a certain potential difference, **characterized in that** said high voltage signal generator (27) comprises an impulse generator which produces a sequence of frequency impulses, in order to strike the pilot arc between said first (28) and second (29) electrodes, situated at a variable distance, said direct current low voltage generator (20) being connected in parallel to at least one condenser element (22) and to at least one switch element (23) of the pilot arc and being kept separate from said impulse generator until the arc has been permanently struck.
2. The striking circuit according to claim 1, **characterized in that** said impulse generator (27) is situated in series with at least one spark gap (41) and is further connected to at least one electric separator, in order to obtain high voltage and high frequency impulses, between a high voltage outlet of said impulse generator (27) and the earth potential (31).
3. The striking circuit according to claim 2, **characterized in that** said electric separator comprises at least one diode (26, 36) or at least one inductor (35, 37).

4. The striking circuit according to claim 1, **characterized in that** said impulse generator (27) is situated in series with first resistor elements (33), which allow the current to be limited to pre-established values, and/or to first condensers (32), which are used to prevent a direct current from passing through said impulse generator (27) when it is switched off. 5
5. The striking circuit according to claim 1, **characterized in that** said direct current generator (20) is connected in parallel to second resistor elements (33) and/or second condensers (22), which allow the direct current generator (20) to be protected from rapid overvoltages. 10 15
6. The striking circuit according to claim 1, **characterized in that** said impulse generator (27) is inserted inside the torch (25) or positioned close to it.
7. The striking circuit according to claim 3, **characterized in that** said inductor (35, 37) is produced with a ferrite nucleus with an openable casing or comprising coils of high voltage insulated wire, insulated and wound around a ferrite toroidal nucleus. 20 25
8. The striking circuit according to claim 1, **characterized in that** said impulse generator (27) consists of a reel or insulated inductor, in which a secondary winding is situated on a ferrite nucleus with primary winding, so that, upon the opening and closing of the primary circuit, there are high potential differences at the ends of the secondary circuit, said reel being coupled with an integrated circuit which acts as oscillator and with one or more transistors which act as amplifiers of the signal applied to the primary circuit. 30 35
9. The striking circuit according to claim 8, **characterized in that** said inductor (35, 37) with a ferrite nucleus is electrically connected to at least one discharger (41) and is connected in series to said second electrode (29), which forms an auxiliary anode of the torch (25), so as to have an inductance with a limited value and thus obtain a stable and intense arc between said first electrode (28), which forms a cathode of the torch (25) and said auxiliary anode. 40 45 50 55

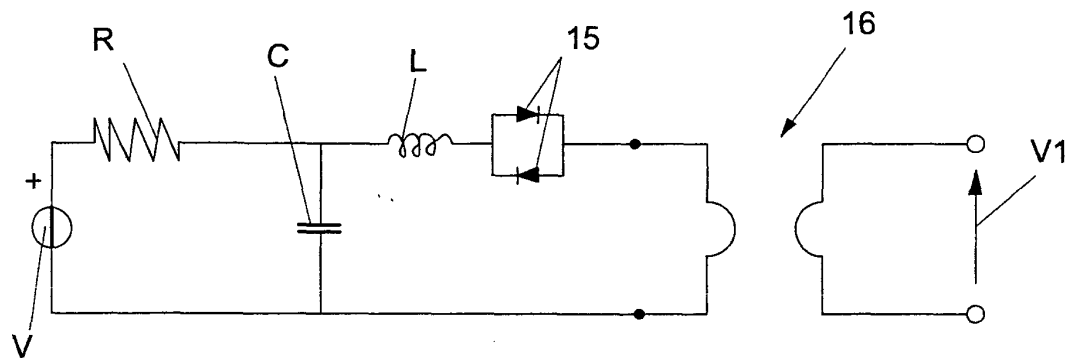
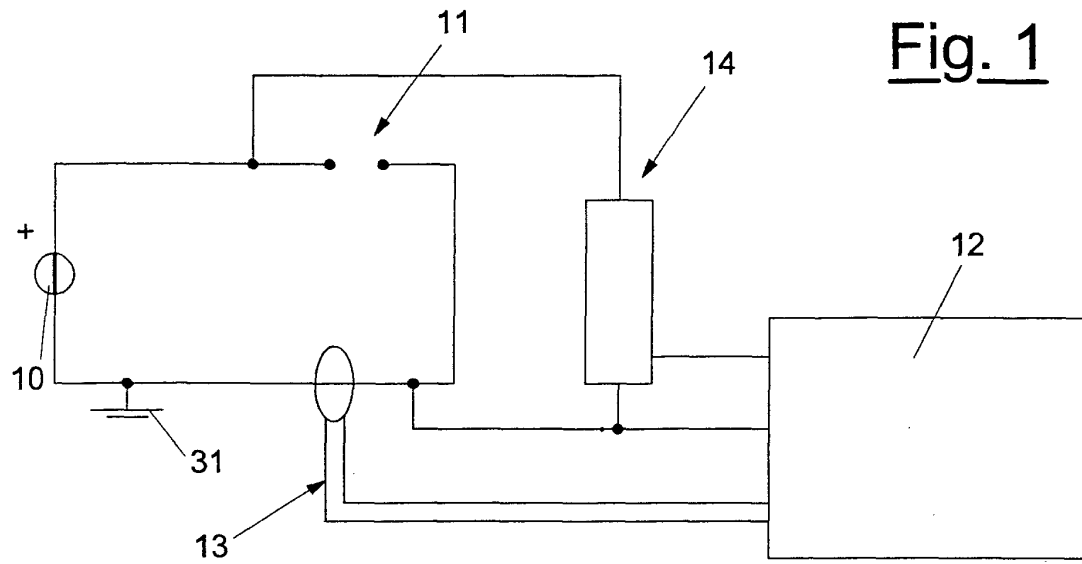


Fig. 3

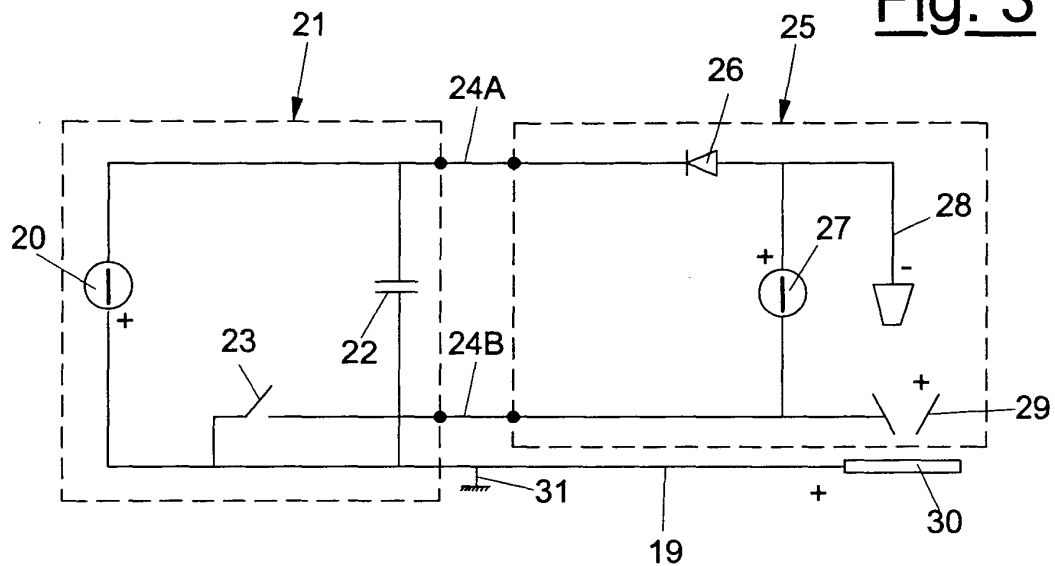


Fig. 4

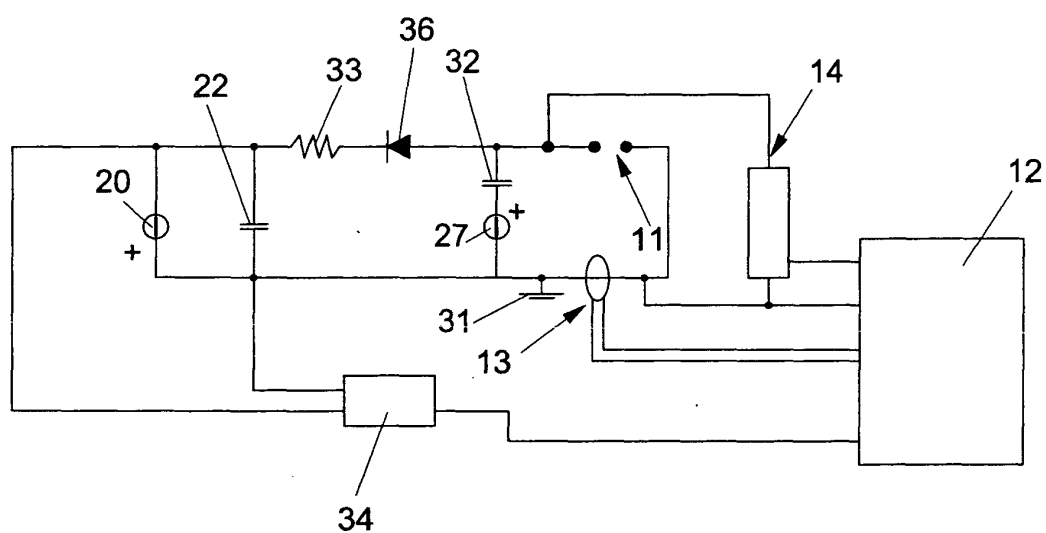


Fig. 5

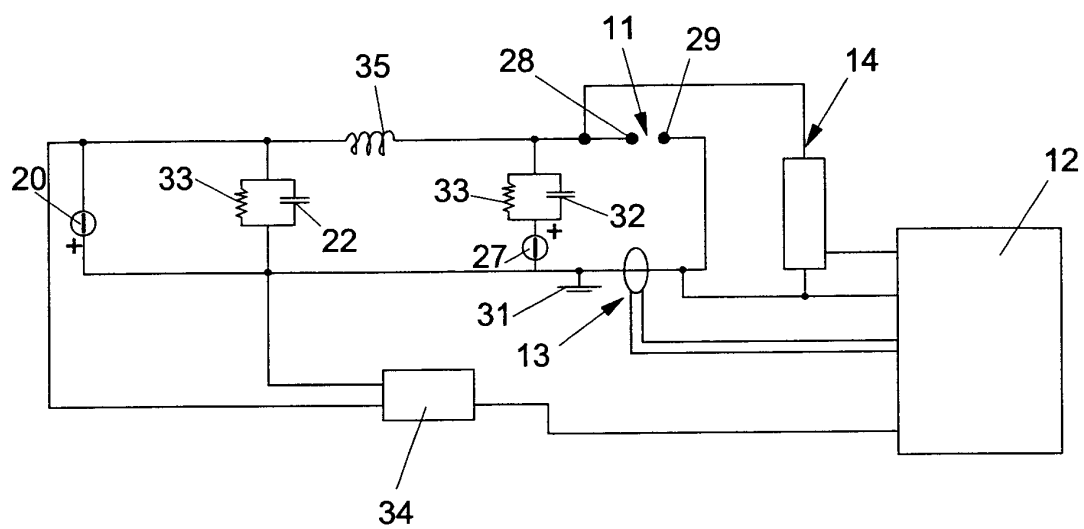


Fig. 6

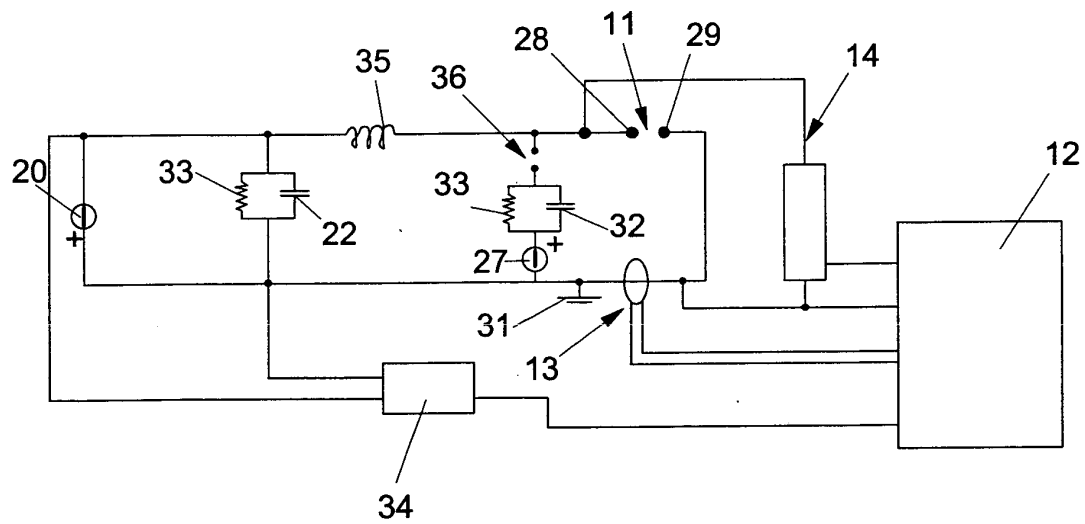


Fig. 7

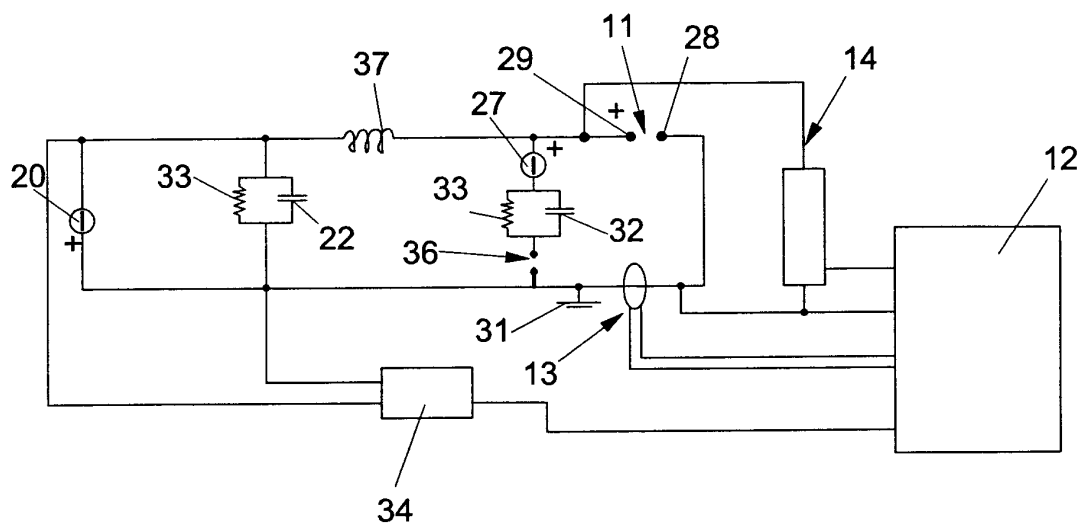


Fig. 8

