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SPARK EROSION WITH NON-DISTORTED IMPULSES

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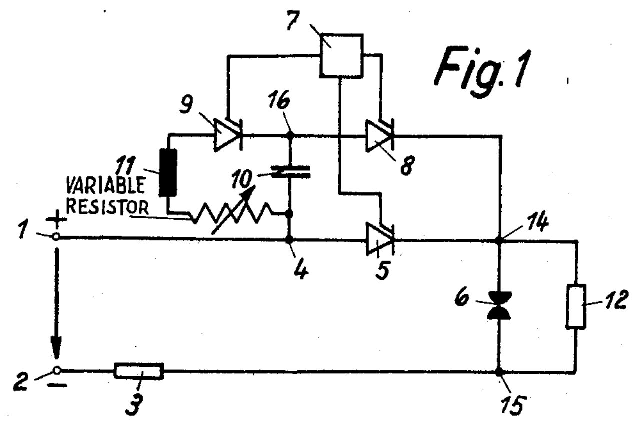

Fig. 1

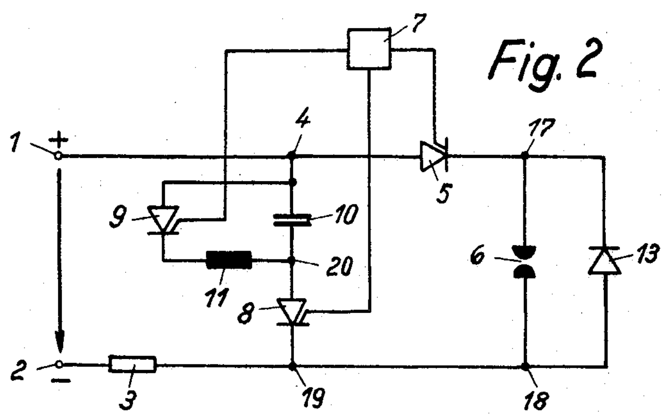

Fig. 2

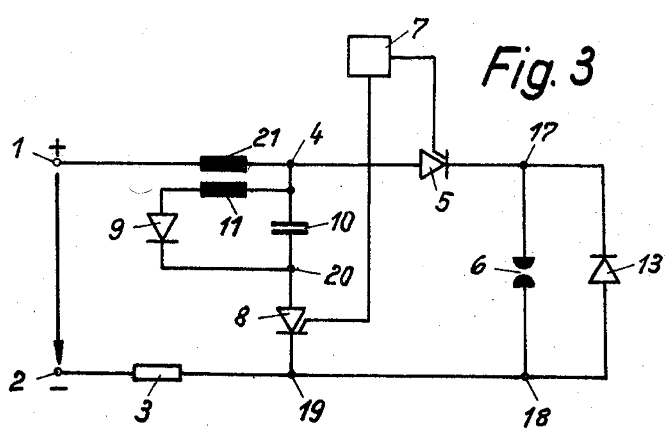

Fig. 3

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SPARK EROSION WITH NON-DISTORTED IMPULSES

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6 Claims. (Cl. 315—200)

The present invention relates to a circuit for spark erosion and includes provision of distortion free adjustment of the duration, frequency and amplitude of the impulses conveyed to the erosion gap. The invention, furthermore, relates to the provision of a particular storage free working circuit with a control switch therein adapted to be controlled by an impulse generator.

The circuit according to the present invention also comprises a circuit for blocking or quenching the working switch and including a condenser for storing energy for this purpose and, furthermore, including therein a quenching or blocking switch also adapted to be controlled by an impulse generator. The circuitry also includes means for charging the condenser through the quenching switch.

In a heretofore known circuit of the type involved, with a control working switch designed for instance as four-layer triode, sometimes referred to as a gated semi-conductor, the condenser is charged with energy for quenching or blocking the working switch or, in other words, for making the working switch non-conductive. Thereupon the quenching switch which may, for instance, likewise be designed as a four-layer triode, or gated semiconductor, is triggered whereby the condenser is discharged through the quenching switch and working switch while a blocking counter voltage occurs on said working switch. As a result thereof, the working switch is quenched, or made non-conductive. Immediately thereafter, the condenser is through the still conductive quenching switch charged with blocking or quenching energy for the quenching switch. At the condenser there will now prevail a voltage which is opposite to the voltage which prevailed therein for the working switch following the charging of the condenser with energy for quenching the working switch. After another triggering of the working switch, the condenser is discharged through the working switch and quenching switch, while at the latter a counter or blocking voltage will occur. As a result thereof, the quenching switch is quenched. Such an arrangement has among others the drawback that quenching energy is required for quenching the quenching switch.

According to the present invention a greatly simplified circuit is provided including therein control elements in the nature of gated semi-conductors or gas filled grid controlled electron tubes known as thyratrons, so organized as to avoid the drawbacks of the heretofore known circuits.

A characteristic of gated semi-conductors, sometimes referred to as gated diodes and of grid controlled gas discharge tubes, is that these circuit elements, which conduct in one direction only, can operate as switches and can be triggered into a conductive state by an impulse supplied to the control element of the switch, namely, the aforementioned gate or grid and, thereafter, the switch will remain in a conductive state as long as there is a predetermined voltage impressed across the switch regardless of whether or not the control element of the switch is under any bias. A momentary impulse to the control element will thus trigger the switch into a conductive state.

A further characteristic of such switch-like circuit elements is that they become non-conductive when the voltage drop across them is reduced to a predetermined amount. Thus, the switch elements when non-conductive serve for blocking a circuit against flow in either direction and, upon being triggered by an impulse, will conduct in one direction only until the voltage drop there across is reduced to a certain amount, whereupon they cease to be conductive and resume their blocking function.

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The circuitry according to the present invention is concerned with a novel application of control elements of this nature and including the application of such a control element in a circuit involving the aforementioned condenser and an inductance in circuit therewith forming a sort of oscillatory circuit arrangement which is operable for effectively reversing the charge on the condenser.

The present invention employs the reversed charge on the condenser for establishing such counter voltage on at least the working control switch as to make it non-conductive or, in other words, to quench the working control switch, thereby to interrupt the flow of current in the working circuit.

With the foregoing in mind, it is, therefore, an object of the present invention to provide a circuit for spark erosion of the type set forth above which will overcome the above-mentioned drawbacks found in connection with prior art circuits.

It is another object of this invention to improve and simplify a circuit of the above-mentioned type.

It is still another object of the present invention to provide a circuit of the above-mentioned general type which will make it possible that the quenching of the quenching switch is effected automatically.

These and other objects and advantages of this invention will become more apparent upon reference to the following specification taken in connection with the accompanying drawing, in which:

FIG. 1 illustrates an arrangement in which the quenching circuit contains only a condenser, a quenching switch and a working switch while the charge changing circuit contains a controllable charge changing rectifier.

FIG. 2 represents an arrangement the quenching circuit of which comprises a condenser, a quenching switch, a working switch, and an erosion gap, while the charge changing circuit likewise comprises a controllable charge changing rectifier.

FIG. 3 illustrates an arrangement the quenching circuit of which comprises a condenser, a quenching switch, a working switch, and an erosion gap, while the charge changing circuit comprises a non-controllable charge changing rectifier.

With a circuit system of the above-mentioned general type, the invention consists primarily in that the charging of the condenser with quenching energy for the working switch is effected directly subsequent to the quenching of the working switch and that the condenser is located in a charge changing circuit which contains an inductance and a charge changing rectifier. The invention is thus primarily based on that the only condenser, immediately after its discharge, is, following the next impulse, again available for charging with quenching energy for the renewed quenching of the working switch, said condenser giving off the quenching energy for the working switch. With the circuit system of the present invention the charge changing circuit is necessary in order to convert the quenching energy which was first stored with the incorrect nature of the charge for quenching the working switch to the right nature of the charge. This is effected in the charge changing circuit by the inductance. For this purpose, the already prevailing or inherent inductance of the conductors in the charge changing circuit may suffice. Possible embodiments of the circuit system according to the invention are provided with a controllable rectifier as charge changing rectifier.

According to an advantageous embodiment of a circuit system according to the present invention, the quenching circuit contains only a condenser, a quenching switch and a working switch. In this connection it is advantageous parallel to the erosion gap to arrange an ohmic resistance when the resistance of the erosion gap is so great that a sufficiently quick charge of the condenser through the erosion gap will not be possible. The charge changing rectifier and the working switch are so controlled that the working circuit and the charge changing circuit are closed simultaneohsly. In this way, the charge changing of the condenser is effected simultaneously with the flow of the working current. The rather extremely short duration of the flow of the working current is thus limited to the duration of the charge changing of the condenser.

According to a preferred embodiment of the present invention, the quenching circuit comprises the condenser, the quenching switch, the working switch and the erosion gap. The charging of the condenser is effected directly from the voltage source so that the resistance of the erosion gap cannot affect the requirements for charging the condenser. With such a circuit, a rectifier, for instance a diode with blocking function in the direction of the working current may be arranged parallel to the erosion gap. In this way, the discharge of the condenser with quenching of the working switch will be accelerated, and the impulse at the erosion gap will not be affected. In particular, it is possible in this way to obtain impulses at the erosion gap with steep rear flank (rectangular impulse). The charge changing rectifier and the working switch are in this connection so controlled that the working circuit and the charge changing circuit are closed simultaneously with the above-mentioned results.

Advantageously, the charge changing rectifier may be uncontrollable, and an additional inductance may be provided in the working circuit. Consequently, the charge changing of the condenser starts automatically following the charging of the condenser with quenching energy for the working switch and prior to the working current starting to flow. As a result thereof, the very short duration of the flow of the working current is not limited to the duration of the charge changing of the condenser. Charging and discharging of the condenser as well as quenching of the working switch will in this instance be effected in the same manner as described in connection with the above mentioned embodiment. This circuit arrangement is advantageous over the above mentioned embodiment because instead of a controllable charge changing rectifier, a simpler non-controlled charge changing rectifier is employed.

In the charge changing circuit, additionally an ohmic resistance may be arranged which is preferably controllable and which permits a control of the charge changing operation. The working switch, the quenching switch, and as the case may be, the controllable charge changing rectifier, are electronic control elements and may for instance be thyratrons. Preferably, however, four layer triodes, or gated semi-conductors, are employed. Circuits according to the present invention may advantageously also be employed for spark erosion in an erosion gap under water.

Referring now to the drawing in detail, the control circuit is connected to the voltage source **1** (positive potential) and **2** (negative potential). In the working circuit there are arranged in series the branch point **4**, the working switch **5**, the erosion gap **6**, and the ohmic resistance **3**. The resistance **3** serves for limiting the working current. Connected to the branch point **4** is the charge changing circuit which comprises a charge changing rectifier **9**, a condenser **10**, a variable resistor and an inductance **11**, said members being arranged in series in a closed loop. The charge changing circuit is furthermore connected to the working circuit through the intervention of a quenching switch **8**. The working switch **5**, the quenching switch **8**, and as the case may be, the charge changing rectifier **9**, are connected to a suitable impulse generator **7** for control purposes. Impulse generator **7** alternately conveys impulses on one hand to the working switch **5** and, as the case may be, to the charge changing rectifier **9** simultaneously and on the other hand to the quenching switch **8**. Switches **5** and **8** and, as the case may be, the charge changing rectifier **9**, are designed as four-layer triodes, or gated semi-conductors.

The operation of the circuit arrangement according to the invention as indicated in FIGS. 1 and 2 consists in the sequence of the following operations:

(a) The impulse generator **7** sparks the quenching switch **8**. As a result thereof, condenser **10** is charged through the intervention of quenching switch **8**. After condenser **10** has been charged, quenching switch **8** is automatically quenched.

(b) Impulse generator **7** simultaneously sparks working switch **5** and charge reversing rectifier **9**. As a result thereof, on one hand, the working current in the working circuit will flow, and on the other hand, condenser **10** will have its charge changed in the charge changing circuit by inductance **11**. After the charge changing operation has been completed, charge changing rectifier **9** will automatically be quenched.

(c) Impulse generator **7** again sparks quenching switch **8**. The quenching energy stored on the condenser **10** acts upon working switch **5** and quenches the latter while condenser **10** is partially discharged. Immediately thereafter, condenser **10**, if necessary, completes its discharge through quenching switch **8** and through the latter is again charged but with an opposite charge. After the charging of the condenser has been completed, quenching switch **8** is automatically quenched.

In the arrangement of FIG. 1, it will be noted that in the quenching circuit, the quenching switch **8** is at the branching point **16** connected on one hand to the charge changing circuit and on the other hand at the branching point **14** connected to the working circuit. At the branching points **14**, **15** of the working circuit there is arranged an ohmic resistance **12** in parallel to the erosion gap **6**.

According to the arrangement of FIG. 2, in the quenching circuit, quenching switch **8** is on one hand at branching point **20** connected to the charge changing circuit, and on the other hand at branching point **19** is connected to the working circuit. At the branching points **17**, **18** of the working circuit and in parallel to the erosion gaps **6**, there is connected a rectifier **13** formed by a diode.

In operation (a) according to the circuit of FIG. 1, the charging of condenser **10** (branch point **16** negative charge; branch point **4** positive charge) is effected through erosion gap **6** and resistor **12** respectively, whereas according to the arrangement of FIG. 2, the charging of condenser **10** (branch point **20** negative charge; branch point **4** positive charge) is effected directly from the voltage source **1**, **2**, i.e. independently of the erosion gap **6**.

According to operation (b), the charge changing of condenser **10** is with both circuit arrangements effected in the same manner (according to FIG. 1, branch point **16** positive charge, branch point **4** negative charge; according to FIG. 2, branch point **20** positive charge; branch point **4** negative charge).

According to operation (c), with the arrangement of FIG. 1, branch point **16** is practically connected to branch point **14**, whereas, according to the arrangement of FIG. 2, branch point **20** is practically connected to branch point **19**. According to the arrangement of FIG. 1, the residual discharge of condenser **10** and its immediately succesive renewed charging is effected through erosion gap **6** and/or resistor **12**. With the arrangement of FIG. 2, the discharge of condenser **10** is effected primarily through diode **13** and the possible residual discharging and the renewed charging of the condenser **10** is effected through voltage source **1**, **2**.

The structure and operation of the control circuit according to the invention, as shown in FIG. 3, differs from the structure and operation of the embodiment according to FIG. 2 merely in that the charge changing rectifier **9** is not controllable so that the connection thereof to the impulse generator **7** is missing, while an additional inductance **21** is provided in the working circuit between the positive terminal **1** of the voltage source of branch point **4**. This inductance **21** must be less than the inductance **11** in the charge changing circuit.

With regard to the operation of the arrangement of FIG. 3, after condenser **10** has been charged with quenching energy for working switch **5**, changing of the charge of condenser **10** in the charge changing circuit starts automatically through charge changing rectifier **9** and inductance **11**. Certain time control between the charging of condenser **10** and the change of its charge is possible and may be controlled by the magnitude of the inductances **11** and **21**.

In view of the fact that the charge changing rectifier **9** is not controllable, the automatic quenching of the quenching switch **8**, branching point **19** and ohmic resistance **3** acts in the manner of an oscillating circuit. As a result it will be evident that after condenser **10** has been discharged and subsequently charged from the voltage source **1**, **2** (branch point **4** positive; branch point **20** negative), a partial discharge of condenser **10** will occur in the above-mentioned circuit which contains the additional inductance **21**, which discharge will, in view of the direction of the current, quench the quenching switch **8**. In view of the impossibility of a further current flow through the quenching switch **8**, there will follow the above-mentioned change in the charge of condenser **10** in the charge changing circuit through charge changing rectifier **9** and inductance **11**. Condenser **10** will then, as mentioned above, be so charged (branch point **4** negative; branch point **20** positive) that after the sparking of quenching switch **8**, the discharge of condenser **10** can bring about the later quenching of the working switch **5**.

From the above operation of the arrangement of FIG. 3, it will be evident that in this instance, the inductance **11** in the charge changing circuit must be selected greater than the additional inductance **21** to such an extent that the change in the charge in the charge changing circuit will not overlap the quenching of the quenching switch **8**.

According to the arrangement of FIG. 3, the ohmic resistance **3**, in addition to limiting the working current, also serves the purpose of limiting the current flow through the additional inductance **21**, branch point **4**, inductance **11**, the non-controllable charge changing rectifier **9**, branch point **20**, quenching switch **8**, branch point **19** and ohmic resistance **3**, so that a minor partial discharge of condenser **10** can bring about the quenching of the quenching switch **8** in the manner described above.

It is, of course, to be understood, that the present invention is, by no means, limited to the particular arrangements set forth above and illustrated in the drawings, but also comprises any modifications within the scope of the appended claims.

What is claimed is:

1. A circuit for spark erosion having means for controlling at least the frequency of the impulses conveyed to the erosion gap by the circuit and comprising; a substantially storage free working circuit including an erosion gap, a working control switch in said working circuit adapted to be controlled by an impulse generator, a quenching circuit including a condenser for storing energy for quenching the working switch, a quenching switch in said quenching circuit also adapted to be controlled by an impulse generator, means for charging said condenser through said quenching switch, means for reversing the charge on said condenser, means for applying the reversed charge on said condenser via said quenching switch to said working circuit for quenching said working switch, and means for recharging said condenser via said quenching switch immediately following the quenching of said working switch, said means for reversing the charge on said condenser comprising an auxiliary charge reversing circuit connected in parallel with said condenser and including an inductance, and a rectifier in series, said quenching circuit comprising said condenser, said quenching switch, said erosion gap and said working control switch in series.

2. A circuit according to claim **1** which includes a rectifier connected in parallel with said erosion gap and operable for conducting current in a direction opposite to the direction of the working current across the gap.

3. A circuit according to claim **1** in which said working circuit includes an inductance.

4. A circuit according to claim **1** in which said quenching and working switches are in the form of gated semiconductors.

5. A circuit according to claim **1** which includes an impulse generator connected to said quenching switch and said working switch in controlling relation thereto.

6. A circuit according to claim **1** in which said impulse generator is also connected to said rectifier in controlling relation thereto.

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