Aug. 24, 1965 A. BARDÓCZ 3,202,874

SPECTROSCOPIC LOW VOLTAGE SPARK SOURCE AND INTERRUPTED ARC SOURCE

Filed June 28, 1961

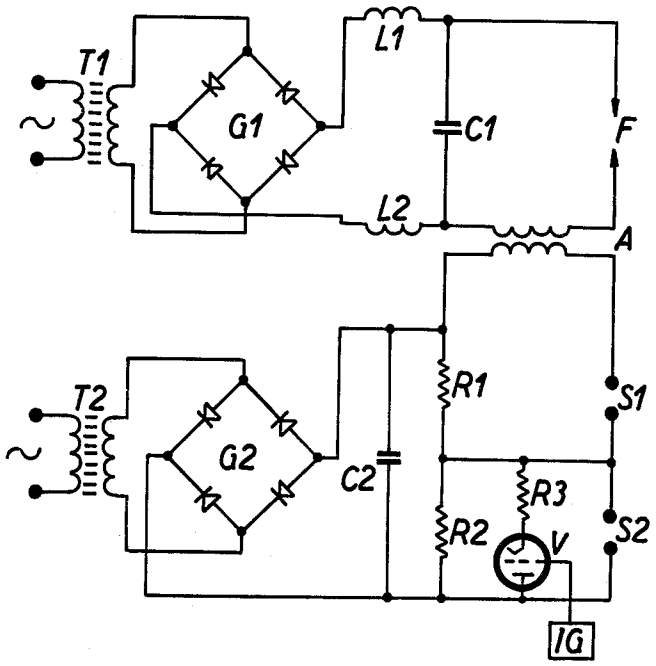


Fig. 1

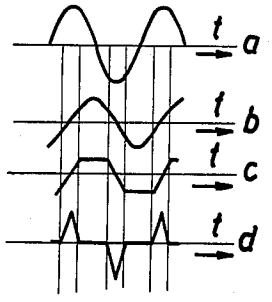


Fig. 2

INVENTOR.
ARPAD BARDOCZ
BY Blum, Moscovitz, Friedman and Blum
Attorneys

United States Patent Office 3,202,874 Patented Aug. 24, 1965

3,202,874

SPECTROSCOPIC LOW VOLTAGE SPARK SOURCE AND INTERRUPTED ARC SOURCE

Arpád Bardócz, 4 Orlay Utca, Budapest XI, Hungary

Filed June 28, 1961, Ser. No. 146,025
8 Claims. (Cl. 315—232)

In spectroscopic research work and spectrochemical analysis the separately ignited spark, or low voltage spark, and the interrupted arc are frequently employed as light sources. The ignitor spark generator is an important component for separately ignited spark as well as for interrupted arc sources. The term "separately ignited spark" connotes an electric discharge of a condenser charged to a relatively low voltage, said discharge being incapable to break down a gap between two electrodes spaced several millimeters apart, and with the spark gap being ionized by a high voltage, high frequency ignitor discharge between said electrodes. In producing an A.C. interrupted arc, a relatively low A.C. voltage is connected across the two electrodes formed of the substance to be investigated. As the spacing of the two electrodes is of the order of several millimeters, there will be no arc between the electrodes due to the low voltage A.C. source. An arc between the two electrodes is established with the assistance of high voltage high frequency currents generated in a so-called ignitor circuit. If the A.C. arc thus created does not have a high current, the arc will be extinguished at the end of each half cycle of the A.C. voltage. The term "A.C. interrupted arc" is used to describe an arrangement of this type.

The production of low voltage sparks is carried out, in the case of spectroscopic light sources, in such a manner that condensers (working condensers) are charged from the A.C. mains and then discharged through the analytical spark gap. Igniting sparks are discharging in general through a controlling spark gap or controlling tube. To obtain correct operation of the spark source the charging and discharging processes of the condenser should be separated from one another. This is necessary because if, during the spark discharge and immediately after it, the supply voltage remains on the analytical and controlling spark gaps, in the case of higher excitation energies and greater spark frequencies the deionization of the spark gaps is incomplete, and consequently the network will be short circuited through them and a regular controlling of the spark discharges cannot be maintained. In other words the spark source has to be formed in such a manner that during charging of the condenser no discharge shall occur, while during the discharge the condenser shall be completely separated from the network.

Recently, a further requirement consists in that in spark sources the starting of spark discharges shall take place with a small time scattering (jitter) of the order of magnitude of a microsecond relative to the moment of a given control signal, so that spark sources may be applied for the production of time resolved spark spectra. This can be realized by means of electronically controlled spark sources operating with high precision in time. In connection with the problem, the following should also be noted.

In order to perform spectroscopic analysis or investigations, and primarily spectrochemical analysis, a single spark discharge is not sufficient to produce a satisfactory

spectrum on a photographic plate. To produce a satisfactory spectrum, many hundreds or even many thousands of successive discharges are necessary. These successive discharges must be resolved in time. That is, the particular time, during each discharge, in which a given spectrum occurs must be the same for each successive discharge. Thus, if it is desired to use that portion of the discharge occurring between 0.0 and 0.1 microsecond of a given spark discharge, the successive discharges must also be analyzed within the 0.0 to 0.1 microsecond range of the discharge. Thereby, the successive discharges being analyzed will always be coincident in time with respect to the portion of the period of a single discharge during which they occur.

The procedure by which corresponding time periods of successive discharges appear at the same position on the photographic plate is known as time resolution. One manner in which the time resolution may be effected is by using a rotating mirror to direct the image of the arc or spark discharge to the admission slit of the spectrograph. With such an arrangement, each respective position along the slit will be illuminated with light originating from the same respective time periods during the radiation of each successive discharge. Correspondingly, every particular position on the spectrum line of a spectrum plate will be indicative of detection of the radiation of the radiation arising from the same particular period during the discharge of each successive spark or arc. It is thus imperative that a high time resolution must be effected so that corresponding time portions of successive discharges will always appear at the same position on the spectrum line as photographed on a spectrum plate. In other words, to obtain a high time resolution, the superposition of the spectrum from successive discharges must be effected with a very high precision timewise. If this is done, corresponding increments of successive sparks or arc discharges will appear exactly on the same place on the slit of the spectrograph, and every successive corresponding spectrum will appear exactly on the same place on the photographic plate. It will therefore be apparent that a high time resolution is necessary when using a multitude of successive spark or arc discharges to produce a photographic spectrum on the photographic plate of a spectrometer.

The production of time resolved interrupted arcs as well as the investigation of processes taking place in them are of equal importance. A high precision ignition is needed for the time resolution, which might be ensured by an ignitor spark operating with high precision.

The above-mentioned requirement, namely that the condenser charging and discharging processes be separated from one another, can be relatively easily met if a number of sparks per second equal to the frequency of the network has to be produced. In this case, by inserting a rectifier before the working condenser, the charging of the condenser takes place during one half cycle of the A.C. network, whereas the discharge takes place during the other half cycle when the charged condenser is completely isolated from the mains by the rectifier. Hitherto the separation of charging and discharging processes was solved in this manner in the case of some spark sources.

In practical and scientific spectroscopic practice, however, in general a spark frequency higher than the frequency of the supply network is desirable. A higher spark frequency results in shorter exposition times and in

a higher analytical precision. Moreover, it is experimentally proved that the higher the sparking frequency, the higher is the stability of the discharge, and consequently, the smaller is the time scattering in the production of time resolved spectra. Further, it should be noted that the time-resolved spectroscopy for routine operation may only be, in general, possible by a spark frequency higher than the mains frequency. In the majority of cases it is already sufficient if the frequency of the spark discharges is twice the frequency of the A.C. mains.

The subject of the invention consists in such separately ignited spark and arc sources which are also suitable for the production of time-resolved spectra, with the aid of which the realization of spark frequencies higher than the mains frequency is feasible in such a manner that the charging and discharging processes of the condenser supplying the excitation energy are completely separated from one another. Self ignited spark sources suitable for the production of ignitor sparks are included in the invention. The appended drawings diagrammatically illustrate some embodiments of, and best ways for, carrying out the invention which is not limited to such embodiments. In the drawing:

FIG. 1 illustrates application of the principle of the invention to separately ignited spark sources and interrupted arc sources, and

FIG. 2 shows the voltage, current, and magnetic induction relations of the transformers T1 and T2 in FIG. 1.

An example of the invention for the production of separately ignited sparks and interrupted arcs is illustrated in FIG. 1. The upper part of FIG. 1, consisting of components T1, G1, L1, L2, C1, and F, is the low voltage spark circuit or working circuit. The lower part of FIG. 1, consisting of components T2, G2, C2, R1, R2, R3, V, S1, S2 and IG, is the high voltage, high frequency ignitor circuit. The common component of both of the circuit parts is the coupling means A which in the present case is an air cored transformer. The part of the figure at the left of condenser C1 is the charging circuit of the low voltage spark part of the source, and the part at the right is the discharge circuit. C1 is the working condenser storing the excitation energy. Condenser C1 is charged from the A.C. network through a suitable transformer T1 and the full wave rectifier G1. F denotes the analytical gap. The discharging of the working condenser C1 with the aid of the air-cored transformer A is carried out by means of the high voltage high frequency currents induced by the ignitor circuit into the circuit C1–A–F. L1 and L2 are filter coils, which prevent the high frequency current circulating in circuit C–A–F from entering the supply mains.

The operation of the charging circuit of the spark source illustrated in FIG. 1 is as follows: the core of the secondary coil of transformer T1 is preferably of a material of low magnetic saturation. Moreover, its cross section is relatively small, so that the saturation point is attained even with small field intensities. The further increase of the magnetic induction is taken off by a shunt magnetic circuit which may be provided with an air gap.

The voltage, current, and magnetic induction relations of transformer T1 are illustrated in FIG. 2.

Curve *a* illustrates the course in time of the primary voltage, curve *b* the primary current, *c* the magnetic induction appearing in the core of the secondary coil, and *d* the voltage on the secondary terminals of the transformer.

The working condenser C1 of FIG. 1 is charged by the voltage impulses of *d* in FIG. 2. It should be kept in mind that owing to the presence of the full wave rectifier G1, all the voltage pulses of *d* in FIG. 2 are unidirectional directly before condenser C1.

The ignitor circuit of FIG. 1 is built up as follows. The ignitor energy is stored in condenser C2 which is the working condenser of the ignitor circuit. T2 is a high voltage transformer with saturated core capable of delivering voltage pulses of short duration as compared with the duration of a half sine wave of the A.C. supply voltage. G2 is a full wave rectifier. Condenser C2 is charged by rectified high voltage pulses of short duration. Condenser C2 discharges through the controlling spark gaps S1 and S2 and through the primary of the air-cored transformer A.

The discharge of condenser C2 takes place as follows: The charging voltage of condenser C2 is distributed by resistances R1 and R2 uniformly over the symmetric twin controlling spark gaps S1 and S2. The twin controlling spark gaps S1 and S2 are set so that, in the charged state of condenser C2, no breakdown occurs. By applying a positive voltage signal from pulse generator IG to the grid of electron tube V, which tube is otherwise blocked by a negative bias, tube V will conduct and the total charging voltage of condenser C2 will appear across the controlling spark gap S1, under the influence of which it will break down. Condenser C2 begins to discharge after the breakdown takes place through the path: primary of the air-cored transformer A–S1–R3–V. During the discharge, the total charging voltage of condenser C2 will appear on the terminals of resistor R3, and thus on the terminals of S2. Consequently this will break down, too. As a result of this, condenser C2 will discharge freely through the path: primary of the air-cored transformer A–S1–S2, and supplies the ignition energy.

If, under the above mentioned circumstances, condenser C2 is charged by voltage pulses appearing after the rectifier G2, and the controlling of electron tube V is performed in such a phase position that the discharge takes place in the neighborhood of the zero value of the descending voltage pulses, for a time no voltage will be present on the terminals of condenser C2. Thus, the conditions will be favorable for the deionization of the spark gaps S1 and S2. The conditions are similar in the charging circuit. Condenser C1 should be discharged in the neighborhood of the zero value of the descending voltage pulses, so that for a time no voltage will be present on the terminals of condenser C1. Thus, the conditions will be favorable for the deionization of the spark gap F.

Since FIG. 2 illustrates, to a fairly good approximation, the effective conditions, the object of separating the charging and discharging phases of working condensers C1 and C2 from one another is practically attained even with a spark frequency corresponding to twice the frequency of the network or even higher.

The electron tube V of FIG. 1 may be replaced by a synchronous mechanical interrupter. In this case the circuit works just as in FIG. 1, but the control of the twin spark gaps S1 and S2 will be performed by the rotating interrupter instead of the tube V.

If the aim set is that the voltage pulses illustrated by curve *d* in FIG. 2 be as perfect as possible, this can be realized, for instance, by using controllable rectifiers, which are somewhat biased, instead of the rectifying element G1. No current will then flow through the controllable rectifiers until a certain voltage threshold is attained, which threshold is, however, higher than the eventual remainder voltage between the voltage pulses. The situation is more simple if, in the circuit of FIG. 1, instead of the bridge rectification, a full wave rectification is present, because in the latter case only two controlled rectifiers have to be used. Another possibility for producing more perfect voltage free intervals between the voltage pulses with a very small residual voltage consists in using for the transformers one or more auxiliary coils. The auxiliary coil in question may be short-circuited, connected in series with the primary, or fed separately from a separate supply.

Applying the saturated core transformers described, the reactive (wattless)) current uptake from the network may be high with respect to the effective consumption. This might be reduced by applying, in the usual way, a

power factor condenser on the network-part of the system.

The application of polyphase transformers for the production of the voltage pulses in question is considered as self-evident and will not be dealt with here.

In spectrochemical analysis and other spectroscopic investigations interrupted arcs of a very short duration are often desirable. The shorter the arcs, the smaller is the cratering in the samples so that the possibility of reproduction is greater and the precision is higher. In case of a sine wave voltage, if not too high voltages are used, the difficulty met with by producing individual arcs of very short duration is that the arc has to be ignited at the end of the sine wave, where the voltage is already very low, so that the ignition is rather cumbersome. Interrupted arcs of a very short duration may be produced, with the aid of the circuit illustrated in FIG. 1, by their safe ignition. In this case condenser C1 is a bypass condenser and is only so large that the high frequency and high voltage currents induced into the circuit C1–A–F shall pass through it. In this case, the excitation energy is applied directly across the analytical gap F to transformer T1, rectifier G1, and filter coils L1 and L2. Thus the higher ignition voltage and short arcing time is automatically insured.

If the circuit illustrated is used for producing interrupted arcs, unidirectionally polarized arcs are obtained. Omitting the rectifying element G1, the polarisation of the arc to be produced becomes bidirectional.

The pulse generator illustrated may be constructed so that the repetition rate per second of the control voltage pulses delivered by said generator is variable. In this way, the discharge repetition rate per second can be varied at will, which is advantageous in all the cases when the electrode samples to be analysed must be protected against excessive heating.

It is understood from what has been set forth above that this invention is not limited to the arrangements, devices, operations, conditions, and other details specifically described and illustrated, and can be carried out with various modifications without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. A spectroscopic low voltage spark and arc source comprising, in combination, a source of A.C. potential; a saturated core transformer having a primary winding connected to said source and a secondary winding and effective to produce in said secondary relatively sharp voltage pulses in one-to-one correspondence with half cycle voltage surges of said source and respectively of short duration in comparison with the duration of a half cycle of said source; rectifying means connected to said secondary; a charging circuit connected to the output of said rectifying means and including a low voltage energy storage means; a power circuit connected across said low voltage storage means and including an analytical spark gap in series therein; said rectifying means charging said low voltage storage means to peak voltage during each pulse and interrupting the charging current at the end of each pulse while maintaining the storage means charged to peak voltage, said peak voltage being insufficient to breakdown said analytical spark gap; a high A.C. potential ignitor circuit operatively coupled with said power circuit and operable, in synchronized relation with such pulse production, to ionize said analytical spark gap for discharge of said low voltage storage means across said analytical spark gap as the voltage of each pulse decays to substantially zero; each charge-discharge cycle of said low voltage storage means being effected during a period not exceeding the duration of a half cycle of said source; each of said charging and power circuits being inactive when the other is active.

2. A spectroscopic low voltage spark and arc source, as claimed in claim 1, said ignitor circuit comprising, in combination, a source of A.C. potential; a second device having an input connected to said source and an output and means producing, at its output, relatively sharp voltage pulses in one-to-one correspondence with half cycle voltage surges of said second mentioned source and respectively of short duration in comparison with the duration of a half cycle of said last-named source; second rectifying means connected to the output of said second device; a second charging circuit connected to the output of said second rectifying means and including a second energy storage means; said second rectifying means charging said second storage means to peak voltage during each of said last-named pulses and interrupting the charging current at the end of each of said last-named pulses while maintaining the second storage means charged to peak voltage; a second discharge circuit connected across said second storage means and including a coupling means in series therein and in series in said first-named discharge circuit; and circuit means operatively associated with said second discharge circuit and operable, in synchronized relation with the production of said last-named pulses, to trigger said second discharge circuit to discharge said second storage means across said coupling means as the voltage of each of said last-named pulses decays to substantially zero; each charge-discharge cycle of said second storage means being effected during a period not exceeding the duration of a half cycle of said last-named source; each of said second charging and second discharging circuits being inactive when the other is active.

3. A spectroscopic low voltage spark and arc source, as claimed in claim 2, in which said second device is an electromagnetic device.

4. A spectroscopic low voltage spark and arc source, as claimed in claim 3, in which said electromagnetic device is a saturated core magnetic transformer having its primary winding connected to said last-named source and producing said last-named pulses across its secondary winding output.

5. A spectroscopic low voltage spark and arc source comprising, in combination, a source of A.C. potential; a device having an input connected to said source, an output, and means producing, at its output, relatively sharp voltage pulses in one-to-one correspondence with half cycle voltage surges of said source and respectively of short duration in comparison with the duration of a half cycle of said source; rectifying means connected to the output of said device; a charging circuit connected to the output of said rectifying means and including a low voltage energy storage means; a power circuit connected across said low voltage storage means and including an analytical spark gap in series therein; said rectifying means charging said low voltage storage means to peak voltage during each pulse and interrupting the charging current at the end of each pulse while maintaining the storage means charged to peak voltage, said peak voltage being insufficient to break down said analytical spark gap; a high A.C. potential igniter circuit operatively coupled with said power circuit and operable, in synchronized relation with such pulse production, to ionize said analytical spark gap for discharge of said low voltage storage means across said analytical spark gap as the voltage of each pulse decays to substantially zero; each charge-discharge cycle of said low voltage storage means being effected during a period not exceeding the duration of a half cycle of said source; each of said charging and power circuits being inactive when the other is active, said igniter circuit comprising, in combinaton, a source of A.C. potential; a saturated core magnetic transformer having a primary winding connected to such further source of A.C. potential and a secondary winding and effected to produce in said secondary relatively sharp voltage pulses corresponding to each half cycle of said source and respectively of short duration in comparison with the duration of a half cycle of said last-named source; second rectifying means connected to the output of said secondary; a second charging circuit connected to the

output of said second rectifying means and including a second energy storage means; said second rectifying means charging said second storage means to peak voltage during each of said last-named pulses and interrupting the charging current at the end of each of said last-named pulses while maintaining the second storage means charged to peak voltage, a second discharge circuit connected across said second storage means and including a coupling means in series therein and in series in said first-named discharge circuit; and circuit means operatively associated with said second discharge circuit and operable, in synchronized relation with the production of said last-named pulses, to trigger said second discharge circuit to discharge said second storage means across said coupling means as the voltage of each of said last-named pulses decays to substantially zero; each charge-discharge cycle of said second storage means being effected during a period not exceeding the duration of a half cycle of said last-named source; each of said second charging and second discharging circuits being inactive when the other is active.

6. A spectroscopic low voltage spark and arc source comprising, in combination, a source of A.C. potential; a saturated core magnetic transformer having a primary winding connected to said source and a first low voltage secondary winding and a second high voltage secondary winding and effective to produce in said secondaries generally synchronized relatively sharp voltage pulses corresponding to each half cycle of said source and respectively of short duration in comparison with the duration of a half cycle of said source; first and second rectifying means respectively connected across said first and second secondaries; first and second charging circuits respectively connected to said first and second rectifying means and respectively including first, low voltage and second, high voltage energy storage means; first and second output circuits respectively connected across said first and second voltage storage means and respectively including an analytical spark gap in series in said first output circuit and a controlling spark gap means in series in said second output circuit; each said rectifying means charging its associated storage means to peak voltage during each pulse of its associated secondary and interrupting the charging current at the end of each pulse while maintaining its associated storage means charged to peak voltage; the peak voltage of said first storage means being insufficient to break down said analytical spark gap, the peak voltage of said second storage means being sufficient to break down said controlling spark gap; said second output circuit including circuit means normally impeding current flow from said second storage means to said controlling spark gap so as to prevent breakdown thereof; said circuit means being operative in the time interval between conclusion of charging of said storage means and resumption of charging thereof responsive to respective succeeding voltage pulses to permit current flow from said second storage means to said controlling spark gap for breakdown thereof; and means coupling said output circuits for transfer of energy of the resulting discharge of said second storage means to said first output circuit thereby to break down said analytical spark gap for discharge of said first storage means across same during said time interval.

7. A spectroscopic low voltage spark and arc source, as claimed in claim 1, said igniter circuit comprising, in combination, a source of A.C. potential; a second device having an input connected to said source and an output and means producing, at its output, relatively sharp voltage pulses in one-to-one correspondence with half cycle voltage surges of said source and respectively of short duration in comparison with the duration of a half cycle of said first-named source; second rectifying means connected to the output of said second device; a second charging circuit connected to the output of said second rectifying means and including a second energy storage means; said second rectifying means charging said second storage means to peak voltage during each of said last-named pulses and interrupting the charging circuit at the end of each said last-named pulses while maintaining the second storage means charged to peak voltage; a second discharge circuit connected across said second storage means and including first and second resistors in series across said second storage means; coupling means in series with first and second controlling spark gaps across said second storage means and also in series in said first-named discharge circuit; control means including a third resistor in parallel with said second resistor and said second controlling gap, operative to block current flow therethrough while said first and second storage means are being charged and then operative before resumption of charging of said first and second storage means to permit current flow therethrough to shunt said second controlling spark gap; the charged voltage of said second storage means insufficient for breakdown of both controlling gaps in series but effective to break down the first controlling gap when the second controlling gap is shunted and then to break down said second controlling gap; said coupling means effective to transfer energy of the resulting discharge of said second storage means to said first-named discharge circuit and thereby effective to break down said analytical gap for discharge of said first storage means across same.

8. A spectroscopic low voltage spark and arc source comprising, in combination, a source of A.C. potential; a saturated core magnetic transformer having a primary winding connected to said source and a first low voltage secondary winding and a second high voltage secondary winding and effective to produce in said secondaries generally synchronized relatively sharp voltage pulses corresponding to each half cycle of said source and respectively of short duration in comparison with the duration of a half cycle of said source; first and second rectifying means respectively connected across said first and second secondaries; first and second charging circuits respectively connected to said first and second rectifying means and respectively including first, low voltage and second, high voltage energy storage means; first and second output circuits respectively connected across said first and second voltage storage means and respectively including an analytical spark gap in series in said first output circuit and a controlling spark gap means in series in said second output circuit; each said rectifying means charging its associated storage means to peak voltage during each pulse of its associated secondary and interrupting the charging current at the end of each pulse while maintaining its associated storage means charged to peak voltage; the peak voltage of said first storage means being insufficient to break down said analytical spark gap; the peak voltage of said second storage means being sufficient to break down said controlling spark gap; said second output circuit including first and second resistors in series across said second storage means; coupling means in series with first and second controlling spark gaps across said second storage means and also in series in said first output circuit; control means including a third resistor in parallel with said second resistor and said second controlling gap, operative to block current flow therethrough while said first and second storage means are being charged and then operative before resumption of charging of said first and second storage means to permit current flow therethrough to shunt said second controlling spark gap; the charged voltage of said second storage means insufficient for breakdown of both controlling gaps in series but effective to break down the first controlling gap when the second controlling gap is shunted and then to break down said second controlling gap; said coupling means effective to transfer energy of the resulting discharge of said second storage means to said first output circuit and thereby effected to break down said

analytical gap for discharge of said first storage means across the same.

References Cited by the Examiner

UNITED STATES PATENTS

2,391,225	12/45	Clark	315—174 X
2,417,489	3/47	Hasler et al.	
2,480,681	8/49	Stiefel.	

OTHER REFERENCES

Bardocz: Electronically Controlled Spectrographic Spark Source, Nature Magazine, vol. 171, pages 1156 and 1157, June 27, 1953 (British edition).

DAVID J. GALVIN, *Primary Examiner.*

GEORGE N. WESTBY, *Examiner.*