Dec. 14, 1948. J. H. ENNS 2,456,116

STABILIZED CONTROL GAP FOR SPARK SPECTROSCOPES

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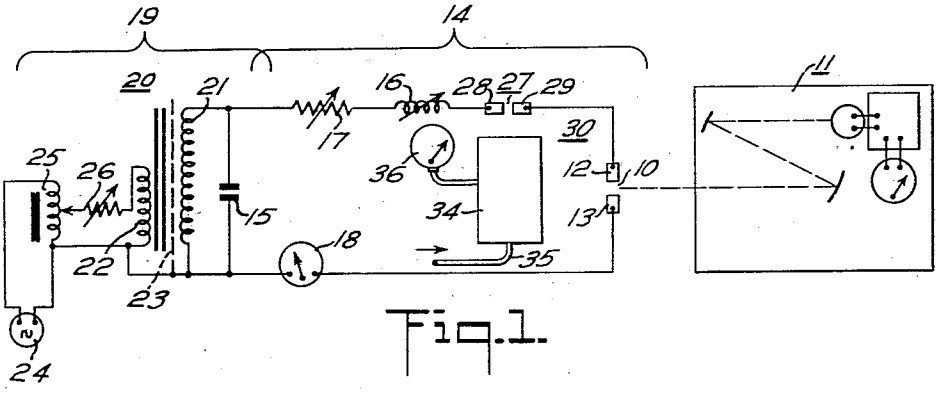


Fig. 1.

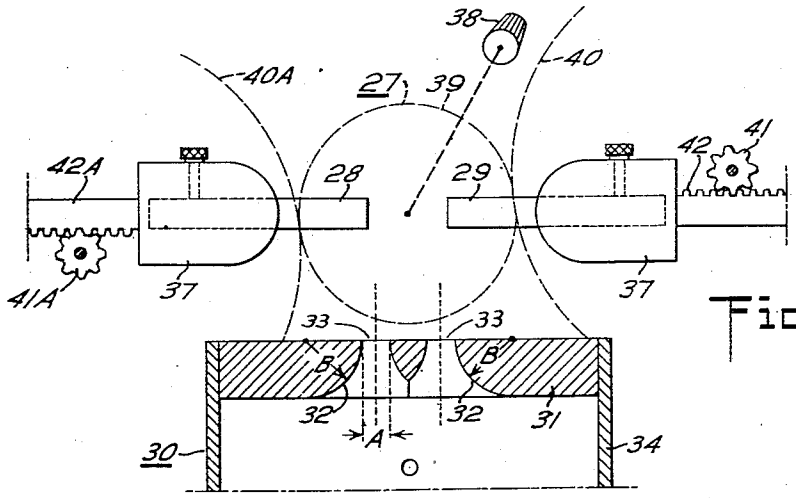


Fig. 2.

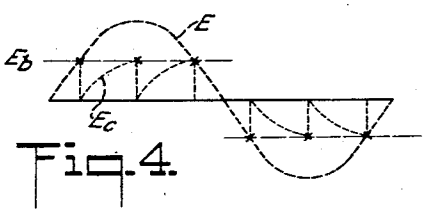


Fig. 4.

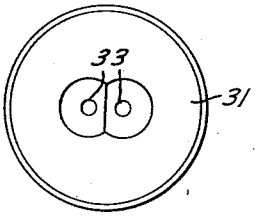


Fig. 3.

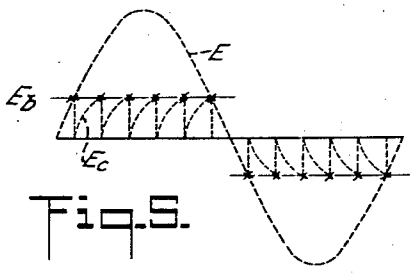


Fig. 5.

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STABILIZED CONTROL GAP FOR SPARK SPECTROSCOPES

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7 Claims. (Cl. 315—111)

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This invention relates to spectroscopy, and particularly to arrangements for stabilizing the light output of a spark-type spectrographic source.

In spark spectroscopy, an electric spark is used as a light source to provide a spectrum having emission lines characteristic of and identifying the various elements of material used as or included in the spark electrodes forming the analytical gap, or introduced in the gap. Especially in quantitative analysis where reproduceability and stability are needed, the intensity of the successive sparks must be held constant within narrow limits.

In accordance with the present invention, the light source is stabilized by a second spark gap, serving as a control gap in series with the analytical gap, against whose electrodes is directed a non-turbulent stream or streams of air or other suitable gas to remove electrically charged particles and so insure that the breakdown potential of the control gap remains constant, within narrow limits, for the successive sparks.

The invention further resides in features of construction, combination and arrangement hereinafter described and claimed.

For more detailed understanding of the invention, reference is made to the accompanying figures of the drawings, in which:

Fig. 1 schematically illustrates a spectrograph system;

Fig. 2, on different scale, illustrates the control gap assembly, Fig. 1, embodying the invention;

Fig. 3 is a bottom plan view, on reduced scale, of an orifice plate shown in Fig. 2; and

Figs. 4 and 5 are explanatory figures referred to in discussion of the operation of the control gap of Figs. 1 and 2.

Referring to Fig. 1 as exemplary of a spectrograph system ultilizing the invention, light from the analytical gap 10 is admitted into a spectrophotometer represented by the block 11 in which a prism or grating produces a spectrum having emission lines characteristic of the material to be analyzed, and for that purpose used as or included in the electrodes 12, 13 of the light source 10, or introduced into the spark gap between them. The spectrum may be photographed in whole or in part, or it may, in whole or in part, be viewed by a suitable radiation-responsive device, such as a bolometer, photocell, or the like, to determine the intensity of the radiation at various wavelengths, and thus quantitatively to determine the amounts in which various elements are present in the composition under analysis. As the particular nature of the spectrograph is not here of interest, it is not further described. It may be of any conventional type suitable for use in spark spectrographic analysis.

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The point here of significance is that unless the intensity of the light source is stable, the measurements obtained by the spectrograph 11 are subject to wide unknown variation.

The analyzing gap between the electrodes 12, 13 of the light source is included in a high-frequency discharge circuit including a capacitor 15, an inductor 16, a resistor 17, and preferably a radio-frequency ammeter 18.

The low-frequency charging circuit 19 of the capacitor 15 includes a voltage stepup transformer 20 capable of impressing high voltage, for example of the order of 10,000 to 40,000 volts upon the capacitor 15. To prevent undesired transfer of high-frequency energy from the discharge circuit 14 to the transformer 20, there is preferably provided an electrostatic shield 23 between the primary and secondary windings 21, 22, respectively, of the transformer. The low-frequency current excitation for the transformer 20 is provided by any suitable source of alternating current 24, such as an available 220 volt, 60 cycle power line. To provide for adjustment of the charging voltage for the capacitor 15, there is interposed between the primary winding 22 and the supply source 24 any suitable voltage-varying arrangement or device; preferably, and as shown, there is utilized an adjustable autotransformer 25 of the "Variac" type and an adjustable series resistance 26. As will hereinafter appear, by variation of the transformer voltage and the primary resistance 26, the operator may predetermine, other things remaining constant, the number of sparks which jump the analytical gap per alternation of the low-frequency supply voltage.

As above stated, it is essential that the light source be stable, as otherwise the spectroscopic measurements are of little value. To stabilize the light output of the analytical gap, there is included in series with it a control gap 27 comprising electrodes 28 and 29 of suitable metal; preferably tungsten, or of Dow metal, or like magnesium-aluminum alloys. To maintain the breakdown potential of this gap constant, it is kept continuously free of charged particles by a nonturbulent stream or streams of air directed across the end surfaces of the electrodes from the device 30.

As shown more clearly in Fig. 2, the air issues from an orifice plate 31, preferably of Bakelite, or other insulating material, which in the particular form shown in Fig. 2 has extending through it a pair of passages 32 each converging in direction towards its discharge opening 33. The orifice plate 31 forms the upper end of a reservoir 34 having volumetric capacity sufficient to reduce any turbulence arising from introduction of air therein from the inlet pipe 35. The pressure within the reservoir 34, as read from the gage 36, may be of the order of from five to six centimeters of mercury above atmospheric pressure. The discharge openings 33 are so located that the streams of air wash the electrode tips and clear the gap between them, particularly adjacent the electrodes, of charged or ionized particles.

It is important that the air streams be non-turbulent, as otherwise ionized particles removed from the gap are randomly re-introduced, and so lower and vary through wide limits the breakdown potential between the electrodes. In generally similar arrangements which do not provide for non-turbulent flow of air, the sparking potential between the electrodes varied by as much as plus or minus 25 per cent, with the result that the spectrograph readings were not reproducible for determination of the percentage composition of the material under analysis in the analytical gap 10. With the non-turbulent arrangement disclosed, and later more specifically described, the variation in breakdown potential of the control gap is within the limits of plus or minus two and one-half per cent, affording an accuracy satisfactory for most spectrographic analyses.

Preferably, and as shown, the jets are directed upwardly from below the gap, rather than downwardly or horizontally, so that air movement due to the streams from the orifices 33 is in the same direction as that due to any thermal effect of the sparks.

In the double orifice arrangement shown in Fig. 2, the diameter "A" of each discharge opening 33 is of the order of the diameter of the electrodes, which, for example, may be about one-quarter inch. To attain non-turbulence of the air stream issuing from the discharge end of the orifice, the radius of curvature "B" of the approach to it is of the order of twice the diameter of the discharge opening 33. Thus, each of the passages 32 is defined by a surface generated by rotation of a quadrant having the radius "B" about the axis of the passage. One radius of the quadrant is at right angles to the axis, and the other radius of the quadrant is parallel to the axis. Otherwise expressed, each passage 32 is of circular cross section having a radius R of magnitude, as measured at axial distance d from the discharge opening, which may be expressed as

$$R=B(1-\cos\theta)+\frac{A}{2}$$

wherein

$$\theta=\sin^{-1}\left(\frac{d}{B}\right)$$

The diameter of the orifice plate should be of the order of at least ten times the diameter of one of the discharge openings 33 to avoid or minimize turbulence of the air as it enters each orifice passage; in the specific example given, the diameter of the orifice plate 31 may be about three inches. The distance between the axes of the passages 32 depends upon the length of the air gap between the electrodes 28 and 29. Usually the gap length is within the range from about one-eighth inch to three-quarters inch, and with a gap length within this range, satisfactory constancy of the breakdown potential is maintained when the center to center spacing of the passages 32 is of the order of one-half inch. The distance between the top of the orifice plate and the center line of the electrodes may be within the range of from about three-quarters inch to one and one-quarter inch when the electrodes and passages are of the dimensions herein given. The reservoir 34 has sufficient capacity when, for the size orifices above discussed, the length of the reservoir is of the order of seven inches or so.

As the electrodes 28 and 29 are slowly consumed, it is necessary from time to time to readjust or replace them. As shown in Fig. 2, the electrodes may be detachably carried by holders 37—37 adjustable in unison away from or toward each other by a single control knob 38 coupled to a gear 39. Electrode 29 is coupled to gear 39 by the gears 40—41 and rack 42. The holder 37 for the other electrode 28 is similarly coupled to the gear 39 by gears 40A, 41A and rack 42A. By this arrangement, the electrodes are concurrently adjustable symmetrically with respect to the orifices 33. In a common plane, the axes of the electrodes are in alignment with each other and at right angles to the axes of the passages 32.

Referring to Fig. 4, in which the sine wave E represents the open circuit voltage across the secondary winding 21, as the voltage rises it charges the capacitor 15 until it attains a magnitude E_b at which a spark jumps across the control gap 27, whereupon the energy stored in the capacitor 15 is dissipated as an oscillatory high-frequency discharge in the discharge circuit 14 including the analytical gap 10. This reduces the voltage E_c across the capacitor substantially to zero, but as the secondary voltage is still higher, the capacitor again starts recharging at a rate determined by the time constant of the charging network and therefore the voltage E_c may again attain the potential E_b at which a spark jumps the control gap 27. This again initiates a high-frequency discharge, causing sparking in the analytical gap 10. This charging and discharging cycle repeats, in each half-wave of the secondary voltage, a number of times depending upon the setting of the control gap, the time constant of the charging circuit 19 and the available secondary voltage of the transformer. In spectrographic work, the number of spark breakdowns per alternation may range from 1 to 20; preferably, for most work, about three breakdowns of the control gap for each alternation is desirable.

For a given spacing of the control gap 27, the number of break-downs per cycle may be increased by increasing the transformer secondary voltage available for charging the capacitor or by decreasing the value of resistor 26. As shown by Fig. 5, when the secondary voltage E is higher, other factors remaining the same, the capacitor voltage E_c reaches the breakdown voltage of the control gap 27 a greater number of times per alternation because, of course, the rate at which the capacitor 15 recharges is higher when the secondary voltage is higher: Alternatively, other factors remaining the same, the number of break-

downs per alternation may be increased by decreasing the value of resistor 26. When the breakdown potential has been predetermined by the setting of the stabilized control gap and the number of sparks per alternation has been set by adjustment of the transformer voltage or resistance 26, the amount of the electrical energy dissipated per unit of time is to a high degree constant within about five per cent, whereas, with prior arrangements the variations were of the order of ten times as great.

The dual air stream is preferred over a single stream largely because of reduced consumption of air. To attain the same constancy of breakdown potential, for a given gap setting, with a single non-turbulent stream of air, the discharge opening must be materially increased so that its area is at least twice that of the combined areas of the two discharge openings shown in Fig. 2. However, the invention is not limited to the dual stream; a smaller or greater number of streams may be used provided the passages are so contoured and the openings are so disposed that the air at and adjacent the tips of the electrodes is non-turbulent.

It shall be understood the invention is not limited to the specific arrangements shown, and that changes and modifications may be made within the scope of the appended claims.

What is claimed is:

1. A control spark gap for spectrographic analysis comprising spaced sparking electrodes, and structure having a passage contoured to minimize turbulence in a stream of gas directed across the spark path between the tips of the electrodes to remove ionized particles from said path in the interval between successive sparks.

2. A control spark gap for spectrographic analysis comprising spaced sparking electrodes, and structure having a circular orifice with a radius of curvature of the approach to the discharge opening of the orifice of the order of twice the diameter of said opening for directing air across the spark path and against at least one of the electrodes to remove ionized particles from said path in the interval between successive sparks.

3. A control spark gap for spectrographic analysis comprising spaced sparking electrodes and an orifice plate structure having passages therethrough whose axes are parallel and spaced respectively to direct streams of air across the tips of the electrodes, the diameters of the discharge openings of said passages being of the order of the diameter of the electrodes and the cross sectional areas of said passages so decreasing towards their respective discharge openings that the air streams issuing therefrom are non-turbulent.

4. A control spark gap for spectrographic analysis comprising sparking electrodes and circular plate structure having a diameter at least ten times the electrode diameter and through which

extend passages whose axes are parallel and so spaced that air streams therefrom respectively clear the tips of the electrodes and the adjacent regions of charged particles, the diameter of the discharge end of each passage being of the order of the electrode diameter and the cross sectional area of each passage so decreasing towards its discharge end that the air stream issuing therefrom is non-turbulent.

5. A control spark gap for spectrographic analysis comprising spaced sparking electrodes, and structure having a passage for directing air against the tips of said electrodes, said passage decreasing in cross sectional area in direction of flow of the air therethrough and whose radius (R) at each distance (d) from the discharge opening of the passage may be expressed as

$$R=B(1-\cos\theta)+\frac{A}{2}$$

wherein

A = diameter of discharge opening

$B=2A$

$$\theta=\sin^{-1}\left(\frac{d}{B}\right)$$

6. The method of obtaining constancy of the potential at which successive sparks will form between the electrodes of the control gap for spectrographic analysis which comprises continuously directing across the electrode tips a non-turbulent stream of air to insure removal of charged particles from the control gap.

7. The method of predetermining the mean intensity of the light output of a spark source which comprises the step of selecting the peak magnitude for an alternating voltage used to charge a reactance, selecting the time constant of the charging circuit including said reactance, selecting the length of a control gap in circuit with said source and said reactance to predetermine its breakdown voltage for disruptive discharge of said reactance, and directing non-turbulent air across said control gap to maintain the breakdown voltage constant for successive sparks, said steps jointly determining the number and energy content of the sparks per alternation of the charging voltage.

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