

ELIMINATION OF "SELF-IGNITION" OF LOW-VOLTAGE A. C. ARC

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Low voltage a. c. arc generators, used for spectrochemical analysis, ignite the single discharges with a high voltage and high frequency current (*Tesla-current*). The control of arc discharge is possible, because the instance of discharging the ignitor spark is adjustable. Under some conditions, however, the control becomes ineffective, that is the a. c. arc becomes self-ignitioning ("Zischbogen" ROLLWAGEN, [1]). This failure can simply be overcome by a stabilizing arc gap, switched in series with the analytical arc gap.

The self-ignition of the a. c. arc occurs, if after a controlled discharge so much metal vapour evaporates into the electrode gap that the number of ions, produced by it, is sufficiently high for the beginning of the next discharge. The latter then occurs without any ignitor spark, that is, the discharges become non-controlled.

This state of the electrode gap is produced by the peak voltage and current of the working circuit of the generator, the size of the gap, the amount of substances volatilized from the electrodes and their ionization potentials, as well as by that of the surrounding gas atmosphere together exert their influence on the arc voltage. BARDÓCZ found at spectral pure carbon electrodes at 1000 V peak voltage, even with 10 A current, self-ignition [2]. At 220 V peak voltage, under other similar circumstances, there is no self-ignition, if, however, the substance transferred to the electrodes contains metals of low ionisation potentials (alkali and alkaline earth metals), then according to the experiments of ERDEY and GEGUS even at 4—5 A current self-ignition occurs [3]. TÖRÖK, SZAKÁCS and SZABÓ [4] found the same phenomenon in argon atmosphere on the analysis of aluminium alloys when using carbon counter electrodes, at 220 V peak voltage and 12 A current. Under similar circumstances, in air, there is no self-ignition.

The above-mentioned authors eliminated self-ignition by decreasing the frequency of the arc discharging, resp. by the interruption of the arc. This method is generally used. The use of interrupted a. c. arc excitation in the analysis of metals is advantageous, both with self- or counter electrodes, because it also prevents the heating up of the sample to a too high temperature.

However, if supporting carbon electrodes are used, the situation is completely changed. In such cases it is mainly necessary to quantitatively volatilize the substance on the electrodes. For this reason the supporting electrode must be sufficiently heated, which can be maintained only by a continuous arc. In the following the stabilizing arc is discussed.

Operation and construction of the stabilizing arc

It is obvious, if the analytical arc is inclined to self-ignition, such an arc is to be switched in series, in which self-ignition might not occur under the usual circumstances, there self-ignition will not occur in the analytical arc, either. The stabilizing arc, being free of self-ignition, serves as a "current valve" for the analytical arc, which "opens" only on the effect of the ignitor spark.

As an electrode substance, copper was found to be the most suitable for the stabilizing arc. Copper has a medium boiling point and ionisation potential among the metals. Its high heat conductivity and slight oxidation makes copper suitable for the mentioned roles. If the shape of electrodes is chosen suitably so, that conduction of heat should be convenient from the arc, volatilization of copper will not be too great, and therefore, self-ignition will not occur even at high currents. Because of the slight volatilization and small extent of oxidation, copper electrodes can be regarded as relatively stable.

Electrodes are made of technical copper rods, 10—15 mm in diameter. The lengths of the electrodes are 10—15 cm. Their working surface is similar to a chisel, so that the width of their edge should be 2—3 mm. The isolated electrodes must be horizontally fastened in such a way, that the edges should stand symmetrically, at a horizontal plane. The arc gap is 1.5 mm. The stabilizing arc must be closed into a box, on the bottom and upper side of which holes are cut for natural ventilation. The horizontally placed electrode edges are uniformly consumed. The stabilizing arc gap must be readjusted from time to time.

It is necessary to mention that the stabilizing arc gives a protection only against self-ignition, that is, against the extremely high changes in effective currents. Changes in the volatilization of the sample yield changes in the resistance of the analytical arc gap, and this leads to changes of current. The stabilizing arc, being switched in series, slightly increases these current-changes. This follows from the "reciprocal" Ohm's law, corresponding to arc discharges, which was first established by NOTTINGHAM [5].

$$V = A + \frac{B}{I^x}$$

where V is the voltage between the electrodes during the discharge (voltage

drop in arc), I is the current, x is a constant, which depends on the material of the electrode, while A and B are constants.

If the current increases, due to changes in the analytical arc gap in accordance to this equation, the voltage drop in the stabilizing arc gap, switched in series, is lower. This, on the other hand, further increases the current in the working circuit. The higher current fluctuation, however, due to the stabilizing arc, changes the excitation energy in the analytical arc to a negligible extent only.

Uses of stabilized, low voltage a. c. arc excitation

For substances containing larger amounts of alkali metals, mainly high voltage a. c. arc excitation is used [6, 7]. The high-voltage a. c. arc is a "self-controlling" excitation method. The low voltage a. c. arc, in continuous use, is not suitable for the analysis of the mentioned substances because of self-ignition. Self-ignition is not only dangerous, because control is impossible, but also because the arc strongly creeps in such cases. The arc remains at the end of the electrodes, on which the sample is taken up, only until alkali metals are volatilized. When the other components of higher boiling points should be volatilized, the arc moves towards the side of the electrodes on which the alkali vapours have been condensed, where the leaving energy of the electrons is smaller.

In case of stabilized a. c. arc excitation this creeping completely ceases. The high-voltage ignitor spark, namely, discharges between the nearest points of the electrodes and so localizes the arc on the electrode gap.

The problem of arc creepage emerges not only in cases of samples of high alkali contents. As is known, for the sake of increasing sensitivity, alkali salts are added as spectrochemical buffers to a wide range of samples. The use of low voltage, a. c. arc excitation can be considerably spread by the use of the stabilizing arc.

Summary

In low voltage a. c. arcs, at special samples, resp. excitation conditions, self-ignition occurs. The timely and irregular occurrence of the latter causes interferences at quantitative spectrochemical analyses. To eliminate this phenomenon a stabilizing arc is switched in series to the analytical arc. The electrodes of the stabilizing arc are made of copper.

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References

1. ROLLWAGEN, W.: Spectr. Acta **1**, 66 (1939).
2. BARDÓCZ, Á.: Acta Techn. Hung. **13**, 3 (1955).
3. ERDEY, L., GEGUS, E.: Acta Chim. Hung. **5**, 43 (1945).
4. TÖRÖK, T., SZAKÁCS, O., SZABÓ, Z.: Private communication.
5. NOTTINGHAM, W. B.: Phys. Rev. **28**, 764 (1926).
6. DUFFENDACK, O. S., WOLFE, R. A.: Ind. Eng. Chem. Anal. Ed. **10**, 161 (1938).
7. ASTM Methods for emission spectrochemical analysis (1953).

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