140. Ignition of Gas by Spark and Its Dependency on the Nature of Spark.

By Torahiko TERADA and Kiyohiko YUMOTO.
Institute of Physical and Chemical Research.
(Comm. by T. TERADA, M.I.A., Oct. 2, 1928.)

J.D. Morgan1) inferred from the results of his investigations regarding the spark ignition of some combustible gas mixtures that the "capacity spark" is in general more effective in igniting the gas than the "inductance spark," the total energy of the spark being the same. According to his "thermal theory" a heat source of short duration is more effective than one in which the heat is supplied over a large interval. The result of our recent experiment which we are going to describe, seems, however, to show that the above general statement may in some case lead to a misunderstanding, at least in the case of CO-Air mixture with low percentages of CO.

For the excitement of spark, a 100 V. 1 Kw. transformer (turn ratio 200) was used, a direct current through the primary being interrupted by a pendulum or different kinds of switch. Sparks of different nature could be obtained, firstly, by varying the conditions of the secondary circuit; viz. (I) with neither additional capacity nor high resistances, (II) with a large capacity (1, 2 or 3 Leyden jars, each 1270 cm.) in parallel with the spark gap,2) (III) with the above capacity in parallel and a high resistance (slate pencil or water tube) in series with the gap. Secondly, with a given circuit, the nature of the spark could be varied by varying the modes of making or breaking the primary current; viz. (a) the current cut off by a pendulum (length 115 cm. and the height of fall 50 cm.), (b) the current cut off, or (b') turned on by a single snap-switch on one side of the primary, (c) the current cut off, or (c') passed on by a double switch on both sides of the same. The spark gap was horizontal or vertical, kept constant at about 4 mm. or 2 mm.

The gaseous mixture used was of the composition 16% CO and 84% air, which is near the limit of inflammability, and was saturated with water vapour at room temperature (25°-27° C.). The combustion

2) The case (II) is therefore not that of the pure capacity spark.
chamber with the gap electrode is the same one as in the previous experiments.  

The results of the experiment may be summarised as follows.

With no additional capacity and resistance, i.e. the case (I), the ignition is completed when the primary current is greater than 2.0 A, with either mode of interruption above enumerated, i.e. (a) to (c'), though the luminosity of spark is rather faint. On the other hand, when a parallel capacity is inserted, i.e. the case (II), a primary capacity of 4.0 A is insufficient for ignition by either mode of interruption, notwithstanding the remarkable brightness of the spark in this case compared with the above case. In the case (III) above named, i.e. with a series resistance, the luminosity of spark becomes of course fainter, but the ignition takes place whenever a spark be passed.

The sparks were photographed on a rotating disc film (diam. 24 cm., 87 revolution per sec.) In the cases (I) and (III) the luminosity of spark is too faint to give a good image with ordinary lens. In the case (II) the spark is generally oscillatory, the interval and total number of sparks depending not only on the capacity but on the mode of making or breaking the circuit. Generally speaking, the larger the capacity, the greater is the primary current necessary for ignition. Thus, with a single jar the ignition cannot be effected by either mode when the primary current is below 5 A. With three jars more than 8–9 A is required. On examining the photograms of different sparks, it may be said that the "incendivity" generally increases with the total number of sparks passed in the single discharge and ceteris paribus on the total duration of the oscillatory discharge, though the data are still wanting for establishing any quantitative relation.

To obtain a photographic impression of spark in the case (I) or (III), the glass windows of the combustion vessel were removed and the spark, excited in free air, was photographed by means of a quartz-fluorite lens on a rotating film. In the case (I), a train of 3 or 4 sparks in 5/100,000 sec. may be discerned which is then followed by a faint glow near the electrodes lasting for a duration of about 1/100 sec. It may be remarked that the glow is always more conspicuous near the cathode than near the anode. In the case (III), using slate pencil (2–6 pieces, each 2 cm. length, in parallel) for the resistance, a single spark is generally photographed which is followed by an after-glow of a sensible duration (order of 1/100 sec.). Here also the cathode glow is much


2) It may be oscillatory with a very high frequency.
more conspicuous than the anode one, as far as may be judged from the photogram. With the water resistance, the result seems to be essentially similar.

The actual mode of propagation of flame in the same mixture has already been studied by K. Yumoto\(^1\) by kinematographical method. His result shows that the flame started by a single spark is subjected to a conspicuous retardation at a distance of several mm. after which it is either restarted with a nearly uniform velocity or thence extinguished. Instead of the kinematograph, another method of photographic recording was tried, by continuously exposing the moving film while a slit was placed in front of the image perpendicular to the motion of the film. Two examples of the photograms\(^2\) are shown in Fig. 1; (A) is the case in which the flame is extinguished and (B) is that in which it was propagated further. It will be seen that the time interval during which the flame is held in standstill is of the order of 1/100 sec.

In our present case, therefore, the condition is essentially different from the ideal one taken as the basis of Morgan's theory, in which the effect of the heat of combustion as well as of the cooling by radiation is entirely put out of account. In the present case, the period of "indecision" is considerably long and of the order of 1/100 sec. during which the combustion is probably still going on. Moreover, our previous experiments with eudiometer\(^3\) has shown that the effect of cooling may have a profound influence on the propagation of flame, especially in the case of gases with low inflammability. In the present case, the decision whether the flame will extinguished or propagated will depend upon the balance between the heat evolved and that lost during that period. If such be the case, a prolonged supply of energy by a train of spark or a continuous glow following the first kindling spark will be of dominant influence upon the maintenance and propulsion of flame.\(^4\)

---

1) K. Yumoto, loc. cit.

2) Throughout our experiments, the "Schliven" method is used, since the laminosity of flame is too weak in our cases.


4) Recent investigation of G.I. Finch and L.G. Cowen, Proc. Royal Soc., A 111 (1926), 257; ibid, A 116 (1927), 529, with electrolytic gas in low pressure, has shown that the cathode "zone" is peculiarly effective in inducing combustion. Our experiment with the circuit (III) has shown that the spark effective in ignition reveals a long after-glow near the cathode end. The two facts may stand, we suppose, in some physical connection.
At any rate, a misapprehension of the statement that a dense capacity spark is *generally* more effective than a less bright inductance spark, might lead to a dangerous consequence especially in some practical case in which a combustible gas of low inflammability is concerned.

The authors express their best thanks to the Authorities of the Imperial Navy for the research fund granted, especially to Rear-Admiral Y. Ueda for his kind intervention.

--- Time.

(A) Primary 2.0 A.

(B) Primary 2.5 A.

Fig. 1. Circuit (I); interrupted by pendulum; gap 2. mm., vertical.