Fighting Fires and Preventing Dust Explosions with Flue Gas —U. S. Department of Agriculture, Press Service. The use of inert gas, or flue gas, piped from the furnaces of manufacturing plants for use in preventing fires and resultant dust explosions in grinding equipment should be seriously considered wherever the hazard exists, according to engineers of the Bureau of Chemistry and Soils.

Of 30 explosions occurring in feed-grinding plants during a 20-year period, 18 originated in the grinding equipment where it was impossible to prevent the formation of dust clouds or to eliminate sources of ignition. Experimental work by the department engineers has shown that it is practicable to use inert gas for flooding the inclosures of the grinding equipment and diluting the oxygen content to such a point that fires or explosions can not take place. The results of the investigation are described in Technical Bulletin 74-T, "The Value of Inert Gas as a Preventive of Dust Explosions in Grinding Equipment," recently issued by the department.

Although the investigations were conducted in feed-grinding equipment, the results suggest many other possible uses for inert gas as a fire preventive. A modern development of this fire-extinguishing principle is the storage of compressed inert gas in tanks with distributing pipes which lead to the most likely sources of fire and quick-acting valves to release the gas. Such equipment has been used on ships and also in factories. A portable extinguisher consisting of a small tank of carbon dioxide under pressure has recently been placed on the market.

Inert gas, especially carbon dioxide, has many advantages over other fire-fighting mediums since it will not injure metals, fabrics, food products, or other perishable materials. Neither does it freeze or deteriorate, and as it does not conduct electricity it can be used to extinguish fires in electrical equipment. Carbon dioxide leaves no residue, which is a distinct advantage, since frequently the residue or damage caused by the extinguishing medium constitutes a greater part of the total loss. These advantages indicate a promising field for inert gas as a fire-fighting medium as well as for explosion prevention.

THE TIME LAG OF THE SPARK GAP.

BY

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IT is well known [1] that under certain conditions a spark gap in air can be overvolted for a considerable time without a disruptive discharge taking place between its terminals, where by overvoltage is meant any voltage above the least voltage that will produce a disruptive discharge when applied for an indefinite period. If, however, ultraviolet light is allowed to fall upon the electrodes or if a sufficient number of ions are present in the gap, the discharge takes place immediately upon application of the overvoltage.[1,2] This time of overvoltage or, as it is usually called, the time lag of the spark gap is shortened by increasing the magnitude of the overvoltage and becomes extremely short when steep, high voltage wave-fronts strike the gap. Pedersen[2] has observed time lags of sphere gaps in air as short as 10^{-7} sec. and in needle gaps even 5.6×10^{-8} sec., while McEachron and Wade,[3] using the cathode ray oscillograph found the time lag of the needle gap to be of the order of magnitude of one micro second. A large number of observations with varying amounts of overvoltage have been made by various observers under a wide variety of experimental conditions but most of their results have not been beyond criticism [4] due to the unknown magnitude and distribution of the space charge formed as the result of the large difference in mobilities of positive and negative ions.

In the present work a new method of measuring the time lag is described and some of the lags for sparks in air at atmospheric pressure have been recorded. The field strength used ranged approximately from 60,000 volts per cm. to

[1] Sir J. J. Thomson, "Conduction of Electricity through Gases," Cambridge University Press, 2d Edition, p. 431.

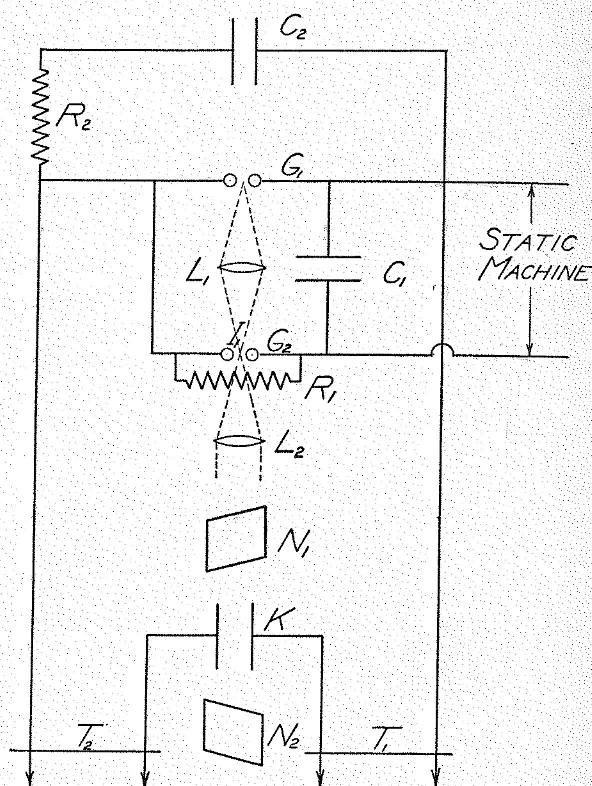
[2] P. O. Pedersen, *Ann. Der Physik*, 71, 317, 1923.

[3] McEachron and Wade, *General Electric Review*, 28, 622, 1925.

[4] Loeb, JOURNAL OF THE FRANKLIN INST., 205, 305, 1928.

400,000 volts per cm. with as steep wave-fronts as could be obtained.[5] The method here used not only enables one to measure very short time lags which occur with high field strengths but the measuring device itself does not affect the results. This latter feature, as will be shown later, is of extreme importance if the results are to be of any value.

FIG. 1



The measuring instrument is a modification of that previously used [6] to measure the order of appearance of spectrum lines in sparks and condensed discharges and can best be described by referring to Fig. 1. The condenser, C_1, of .0015 microfarad capacity is slowly charged by a static machine.

[5] Lawrence and Beams, *Phys. Rev.*, 32, 478, 1928.
[6] Beams, *Phys. Rev.*, 28, 475, 1926.

This impresses a voltage across G_1 and G_2, which are two spark gaps in series but, due to the electrolytic resistance, R_1, of 10^5 ohms and comparatively small charging current, practically all of the potential is impressed across G_1. As the voltage across G_1 is slowly raised, a point is reached where the spark discharge takes place. This overvolts G_2, provided G_2 is smaller than G_1, since the steep wave-front cannot pass R_1 and the voltage wave probably is doubled by reflection at G_2. After a certain time (which is to be measured in these experiments) the gap G_2 discharges, the voltage across C_1 falls to zero and the process is repeated. If the time lag in G_2 is fairly long, as in some of the experiments, the spark discharge in G_1 stops before G_2 discharges and sets up harmful oscillations. Therefore a condenser C_2 of .001 microfarad capacity with 150 ohms in its leads was attached in parallel with G_1 to keep it ionized until the spark at G_2 started. Light from G_1 was brought to focus by lens L_1 at the point I_1, made parallel by the lens L_2 and passed through a Kerr cell containing CS_2 which was placed between crossed Nicols. The point I_1 is not in the gap G_2 but above it. Light from G_2 was raised almost to the same horizontal plane of I_1 by means of a right angled prism (not shown in the figure), made parallel by L_2 and then passed through the Nicols and Kerr cell so that in the field of view as seen through N_2, G_1 appeared just above G_2. The leads to the Kerr cell K were attached by copper wires T_1T_2 to opposite sides of G_1, these wires were of variable length and free as possible from loops and other influences that tend to increase their inductance.

As the potential builds up relatively slowly across G_1 it is also applied across K which becomes doubly refracting and light can pass N_2. If then G_1 discharges it has been found that none of its visible light, at least, passes N_2 provided of course that T_1T_2 are as short as possible and the intensity of the field in K is not too great. It is only when the field producing the double refraction is of such a value that the amount of light passing N_2 varies approximately as the fourth power of the field strength that the quick cut-off can be attained. By increasing symmetrically the length of T_1T_2 the light from G_1 first appears and then as T_1T_2 are still further increased the light from G_2 appears. If the length of wire from G_1 to G_2 is equal to the difference in the light paths of G_1 to K and G_2 to K then the length of wire added to each lead from the first appearance of the light of G_1 until the first appearance of that of G_2 divided by the velocity of the electric impulse along the wire, is equal to the time lag of G_2. This assumes of course that the rate of increase of the light in G_2 is the same as in G_1, which is true to a very high degree of approximation since both gaps are in air and the amount of energy fed into G_1 by C_2 is very small during the initial stages of the discharge.

It should also be pointed out that it is necessary to observe the first appearance of the air lines in each spark because the fall of potential is almost coincident with the appearance of the air lines while the time between the appearance of the air lines and the metallic lines in single sparks depends somewhat upon the energy available for evaporation of the metal. The times between the appearance of the metal lines however are quite constant. The light from G_1 was carefully screened from G_2 and an air blast was directed between the terminals of G_2 so that the ions were removed between sparks. Care was taken to reduce the capacity of G_2 to a minimum by making the binding posts as small and as far apart as possible.

Since the time lags to be measured might be a function of such things as the steepness of the voltage wave which strikes it or the capacity of the gap these factors were investigated first. With, for example, 2 cm. brass balls in G_1 and G_2 and with those in G_1 3.5 mm. apart and those in G_2 2 mm. apart and the least inductance possible between G_1 and G_2, the time lag of G_2 was between 3 and 5×10^{-8} sec. Capacity was then added in parallel with G_2. A value of .00005 microfarad made the time lag greater than 10^{-7} sec. which with the particular arrangement used was the maximum lag that could be measured. This capacity was then removed and a few turns of wire added between G_1 and G_2 with another resultant increase in time lag. These observations serve to emphasize how important it is in this kind of work to reduce inductance and capacity to a minimum and suggests possible sources of error in other methods such as the capacity of the deflecting plates of the cathode ray oscillograph or large binding posts of the spark gap itself.

TABLE I.

For 2 cm. Brass Spheres in both G_1 and G_2.

Width of G_1 mm.	Width of G_2 mm.	Max. Time Lag 10^{-8} sec.	Minimum Time Lag 10^{-8} sec.
3.45	2.4	8.6	3.0
3.45	2.0	5.0	2.5
3.45	1.0	2.5	1.5

For Needle Gap, Radius of Curvature of .1 mm.

Width of G_1 mm.	Width of G_2 mm.	Max. Time Lag 10^{-8} sec.	Minimum Time Lag 10^{-8} sec.
3.45	7.5	10+	5.7
3.45	5.5	10	2.3
3.45	4.0	2.0	1.3
3.45	3.0	1.0	1.0−

Table I shows a typical set of observations for 2 cm. brass spheres in both G_1 and G_2 and when needles were substituted for the 2 cm. balls in G_2. It will be observed that as the gap G_2 is reduced and, therefore the voltage gradient raised, the time lag is decreased. It will also be noted that the time lag, especially at the lower field strengths, is not a definite magnitude but varies over a considerable range of values and in the needle gap the variation is greater than in the ball gap. When the field strength is increased the time lags become more definite and for the highest field strength used they become practically constant. This erratic behavior was at first thought to be due to factors in the circuit but a long series of tests and observations showed pretty definitely that the erratic behavior was not experimental error but the true nature of the spark lag itself.

It has long been known that in air at room temperature there is always a certain number of positive and negative ions continually formed by various natural agencies such as cosmic rays or radiations from radioactive materials. The electron when set free soon attaches itself to a molecule, or group of molecules, of oxygen or to the molecules of some electronegative vapor that is always present unless the air is purified with considerable care. The positive ion wanders around until it picks up an electron which may either be free or part of a negative ion. The number of ions usually present at any time is relatively small and distributed at random. The time lag of the gap here measured is then merely the time required for these ions under the impressed field to ionize the gap sufficiently for its resistance to drop to a small value.

In most of these experiments, since the voltage doubles at reflection and no special care was taken to insure clean smooth electrodes, the maximum field strength always reached the order of magnitude of 100,000 volts per cm. in some part of the gap. In these high fields an ion can reach a velocity several times the thermal velocity if allowance is made for the fact that a few of the free paths are longer than the mean. The negative ion therefore probably loses its electron in the first few collisions. This free electron is then in a position to readily ionize the gas and the discharge is started. The positive ion, with these high fields also contributes to the ionization and is especially effective in producing electrons near the cathode. The mobility of the positive ion is about 10^{-4} that of the electron. This effects a distribution of space charge which is very important in the fall of potential across the gap.

If we adopt the above rather crude picture of the phenomena taking place in the gap during the initial stages of the discharge, the erratic behavior of the lag is explained. In the case of both the sphere and the needle gap the field is not uniform over the whole volume between the electrodes and the ions are distributed at random. The rate of increase of ions is therefore not the same in different sparks which accounts for the fluctuations observed in the preceding experiments. In the needle gap although the field is very high near the point it drops very rapidly as the distance from the point is increased so that over the greater part of the gap the field strength is less than in the sphere gap. This should account for the greater fluctuations observed in the needle gap than in the ball gap. It would also explain in a qualitative way the observation that the fluctuations become less with increased voltage (decreasing width of gap). However it is difficult to see how the fluctuations can be reduced so much with the increase of voltage gradient and reduction of the size of gap alone.

It is now generally believed that there is a dense adsorbed

layer of molecules that covers the surface of electrodes in air. This idea was first proposed by Zeleny [7] to explain the discharge from pointed conductors and has since been used to interpret many phenomena in connection with the spark discharge. The molecular film may complicate the beginning of the discharge by offering a virtual resistance to positive ions that are formed near the cathode, thus rendering them less effective in ejecting electrons from the cathode until a critical velocity of the ion is reached. This may account, in part, for the short lags as well as the absence of fluctuations with high field strengths. However, from previous experiments on the nature of this film, one should expect the positeld ions to be able to puncture the molecular film at a lower fiive strength than that here used. On the other hand this film may make it easier for electrons to be "pulled out" of the cathode by the electric field than when the cathode is outgassed and in a vacuum. If this were true it could explain the very short lags and absence of fluctuations observed with high field strengths.

The writer is very much indebted to Professors L. G. Hoxton and C. M. Sparrow for many helpful discussions, to Mr. J. C. Street for taking some of the observations and to Mr. A. J. Weed, instrument maker, for constructing part of the apparatus.

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[7] J. Zeleny, *Phys. Rev.*, 3, 69, 1914. J. Zeleny, *Phys. Rev.*, 16, 102, 1920.

sodium, potassium, cæsium and rubidium were inspected for bands. No bands were attributable to lithium-sodium but each of these presents so many bands that the band of the compound may be hidden. All the other nine pairs showed bands, sodium-potassium having the most extensive. In general the bands lie close to the lines of the principal series of the two united atoms, but this is not true when lithium is one of the metals.

What fractional part of the total vapor is in the form of inter-metallic compounds? Carelli and Pringsheim found that at 727° there are 2 per cent. as many diatomic atoms of potassium vapor as monatomic ones. For the same quantity Ditchburn obtained .9 per cent. Mitchell, by Victor Meyer's vapor density method got 5 per cent. The authors hold that at the boiling point of the metals these molecules containing one atom of each of the two constituent atoms make up one or two per cent. of the total vapor.

G. F. S.

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PRESENT AND PROPOSED ACTIVITIES OF THE FRANKLIN INSTITUTE *

A REPORT TO THE MEMBERSHIP BY

HOWARD McCLENAHAN, E.E., M.S., LL.D.

Secretary of the Institute.

THE last few years have been years of vigorous life and activity in the Institute, and have witnessed growth and development which promise much for greater usefulness of the Institute to the city, and for enhanced reputation for this old society. Unfortunately, some of our members report that, to their regret, they have not been cognizant of these facts; they have expressed the wish that they might have an opportunity to learn in person of the plans and purposes about which now they read only in the papers. Apparently we are not good advertisers, and have been so much occupied with the plans themselves that we have had little time and energy to tell about them.

In preparing the programme of meetings and lectures for the year, the Secretary felt that the lecture season could not be inaugurated better than by a comprehensive report concerning the state of the Institute to the members of it. Thereby should come sympathetic understanding, warmer interest and more active support. So he has given himself the privilege, which is a pleasure, of addressing you tonight

* Presented at the Stated Meeting of the Institute held Wednesday, October 17, 1928.

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