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ITEM NO. 9

HIGH SPEED SCHLIEBEN CAMERA FOR OBSERVATION OF FLAME TRAVEL

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BRITISH INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

HIGH SPEED SCHLIEREN CAMERA FOR OBSERVATION OF FLAME TRAVEL

Reported by

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BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE
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HIGH SPEED SCHLIEBEN CAMERA

FOR OBSERVATION OF FLAME TRAVEL,

AT LUFTFAHRTFORSCHUNGSANSTALT, VOLKENRODE

by

G.B.R. FEILDEN (M.A.P.)

SUMMARY

The High Speed camera has operated at speeds up to 25,000 pictures per second, the duration of each exposure being about one microsecond. Intermittent spark illumination is used in conjunction with a simple rotating drum camera.

This apparatus has been used for fundamental research on flame propagation in gas-air mixtures, observations being made by the Schlieren method. At the time of the Allied occupation the research had not proceeded far enough to yield results of practical value, though satisfactory solutions had been found to the problems involved in the design of the camera itself.

1. SCOPE OF APPARATUS
2. OPTICAL ARRANGEMENTS
3. ELECTRIC CIRCUITS
4. CONSTRUCTION OF THE DISCHARGE TUBE
5. RESULTS
6. RECOMMENDATIONS

1. SCOPE OF APPARATUS

With the present electrical circuit, sparking speeds of up to 25,000 per second can be attained, a simultaneous spark occurring at four co-linear gaps. The duration of each spark is of the order of one microsecond and the intensity is sufficient to give an adequately exposed negative on a 27°Sch. film when using a f4.5 objective with the Schlieren apparatus. Thus, the apparatus may be expected to produce a sufficiently intense illumination for photographing solid objects, if a more sensitive film and a faster lens are used.

A single charge of the 3,uF power supply condenser will give a total of about 70 sparks. The rate of sparking varies during the discharge due to the reduction in the potential of the power supply condenser. Thus, where quantitative measurements are required, corrections must be applied to the observed results to allow for the variation in the rate of sparking, or a "time base" must be incorporated in the apparatus.

2. OPTICAL ARRANGEMENTS

The general arrangement of the Schlieren apparatus follows normal practice, and is shown in fig. 1, attached to this report. Light from the four spark gaps "L", after suitable collimation, is reflected from the concave mirror "S" through the windows of the combustion tube "B". That portion of the light which has been refracted in "B" due to temperature changes in the flame, is prevented from reaching the film "F" by the knife-edge "BL". The film rotates at a constant speed of about 6,000 R.P.M. and is carried on four separate drums "Tr". No special precautions are taken to ensure that an exposure is begun at the instant when the joint of the film is immediately opposite the lens "D", and in practice it is usually necessary to cut the developed film, and piece it together again, in order to present a consecutive picture of the combustion process.

As already mentioned, the objective of the camera has a maximum apperture of f4.5, and a focal length of 15 cm. was chosen to obtain a picture which covered the full width of a 35 mm. film.

3. ELECTRIC CIRCUITS

The circuit as finally developed is shown on fig. 2. A potential of up to 30,000 volts is produced by an X-ray transformer and rectifier connected to the terminals of the power condenser "C_2" of 3 microfarads capacity. The discharge condenser "C_1", which has a maximum capacity of 0.4 microfarad, is charged through the inductance "L", and reaches a potential equal to that of "C_2", so long as no sparking occurs at the gaps "F_1" to "F_4". The initial potential of "C_2" is kept just below the value necessary to ionise the combined length of the gaps "F_1" to "F_4" (which is about 1¼" in the present arrangement of the apparatus).

When a photograph is to be taken, the pendulum "P" is released. This first breaks the contacts "S_1" in the primary circuit of a large inductance coil "J". The high voltage simultaneously induced in the secondary of "J" causes a spark across the gap "F_4" and across the safety gap "HF". The occurrence of a spark at "F_4" reduces the break-down voltage of the gaps "F_1" to "F_4", and a spark is immediately produced at all four gaps by the potential of condenser "C_1".

After the first discharge of "C_1", the discharge tube is ionised, and hence has a reduced break-down potential. Further sparks occur each time the potential across "C_1" reaches the tubes break-down potential, the rate of sparking being controlled by the value of the inductance "L". For low speed work, iron cores are provided for "L", but for the highest speeds an air-cored inductance is used.

At a pre-determined interval after the breaking of the switch "S_1", which "triggered" the high frequency sparks, a second switch "S_2" is opened by the timing pendulum "P". "S_2" is in the primary circuit of an automobile ignition coil, and takes the place of the conventional contact breaker. The opening of switch "S_2" causes a spark at the gap "Zu" in the combustion tube "VB", so initiating combustion of the gas-air mixture under investigation. By careful timing, the complete cycle of events in the combustion tube can be observed by the sparks produced from a single charge of the power condenser "C_2".

A mathematical discussion of the requirements of this type of circuit has been published by Dr. Neubert who was responsible for the work at LFA, in "Zeitschrift für technische Physik" 1943, No. 8. Some details are also given in this publication of the early results obtained with the apparatus.

As far as can be ascertained, no other description of the apparatus or the results obtained with it has been published either in the German Technical Press or in LFA internal reports.

4. CONSTRUCTION OF THE DISCHARGE TUBE

This part of the apparatus is massively fabricated from mild steel, and is of circular section with bolted-on windows. The spark gaps are about ¼" long, tungstan wires of about 1 mm. diameter being used. Experiments have been carried out with a number of different gases in the discharge tube, but for high speed work, Dr. Neubert recommends the use of 80% H_2 plus 20% Freon "12", the mixture being at an absolute pressure of 2.6 atmospheres.

This recommendation is based on fairly extensive work which Dr. Neubert has carried out on the electrical characteristics of air-gas and hydrogen-gas mixtures. This work has not so far been reported, though a copy of a draft report on the subject was found in the laboratory containing the high speed camera. The results of the investigations are summarised in the curves reproduced in fig. 3. It will be seen that with either air or hydrogen the break-down voltage is increased in the most pronounced manner by the addition of Freon "12" (CCl_2F_2).

5. RESULTS

The apparatus has been used for the observation of flame propagation in propane-air mixtures in order to obtain information regarding the fundamental combustion processes. Various types of combustion have been observed by the Schlieren arrangement, including cases where detonation occurs. In all, some 400 film negatives are available in the Laboratory, showing the progress of combustion with various mixture strengths and pressures, and in the case where acoustic waves are present in the tube.

Recently an investigation was started on the mechanism of combustion in the V-1 flying bomb, with a view to improving the maximum altitude at which this type of prime-mover will operate. This work had, however, not proceeded far enough to yield any useful results.

The writer has come to the conclusion that Dr. Neubert's work consisted almost entirely of long term basic research - which, like so much of the work at LFA, had not yielded practical results by the time of the Allied Occupation.

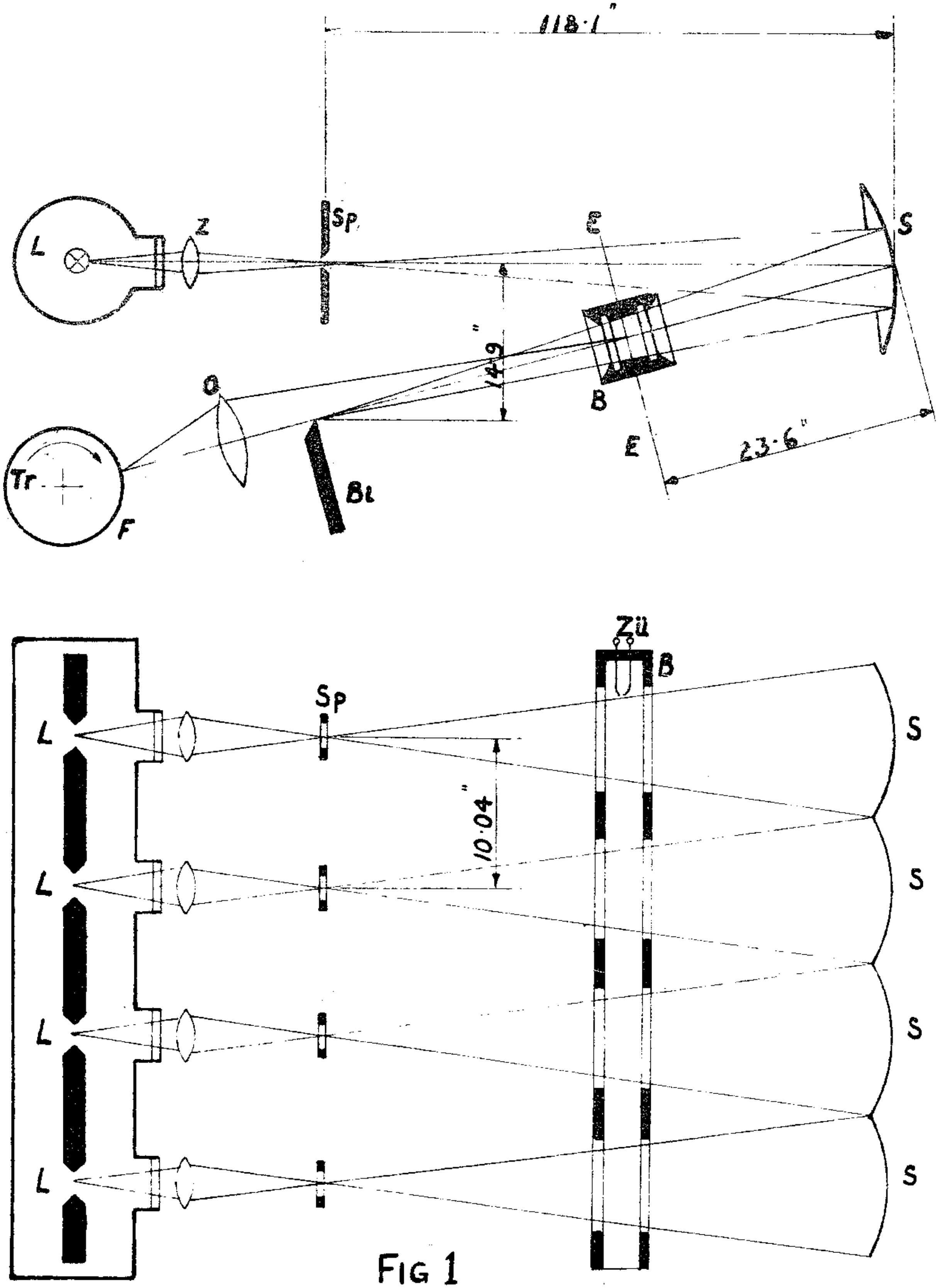

FIG 1

OPTICAL ARRANGEMENT OF HIGH SPEED SCHLIEREN CAMERA FOR OBSERVING FLAME PROPAGATION

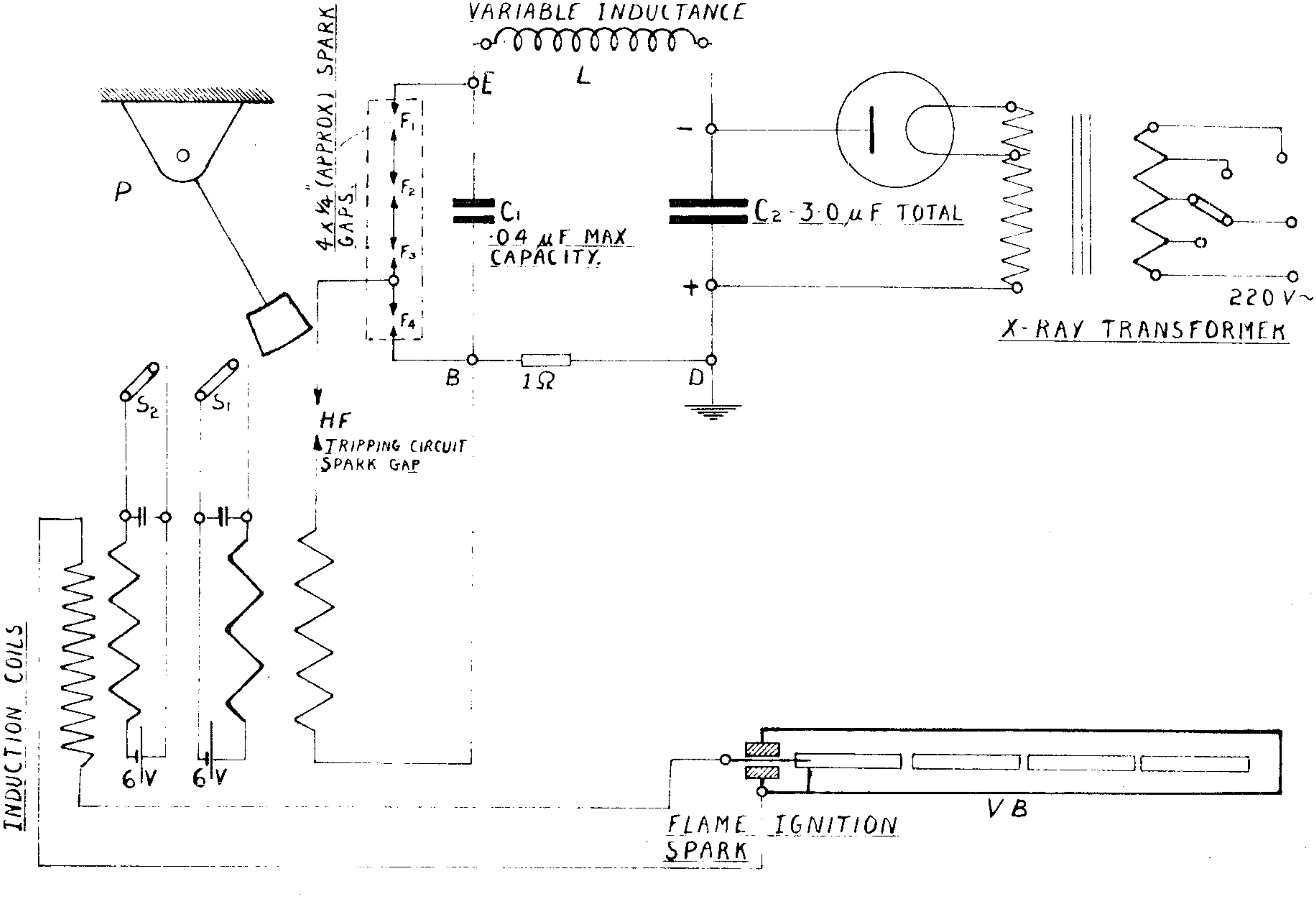

FIG2:- CIRCUIT DIAGRAM FOR HIGH-SPEED CAMERA ARRANGED FOR OBSERVATION OF FLAME TRAVEL

FIG.C:- CIRCUIT DIAGRAM FOR HIGH-SPEED CAMERA ARRANGED FOR OBSERVATION OF FLAME TRAVEL.

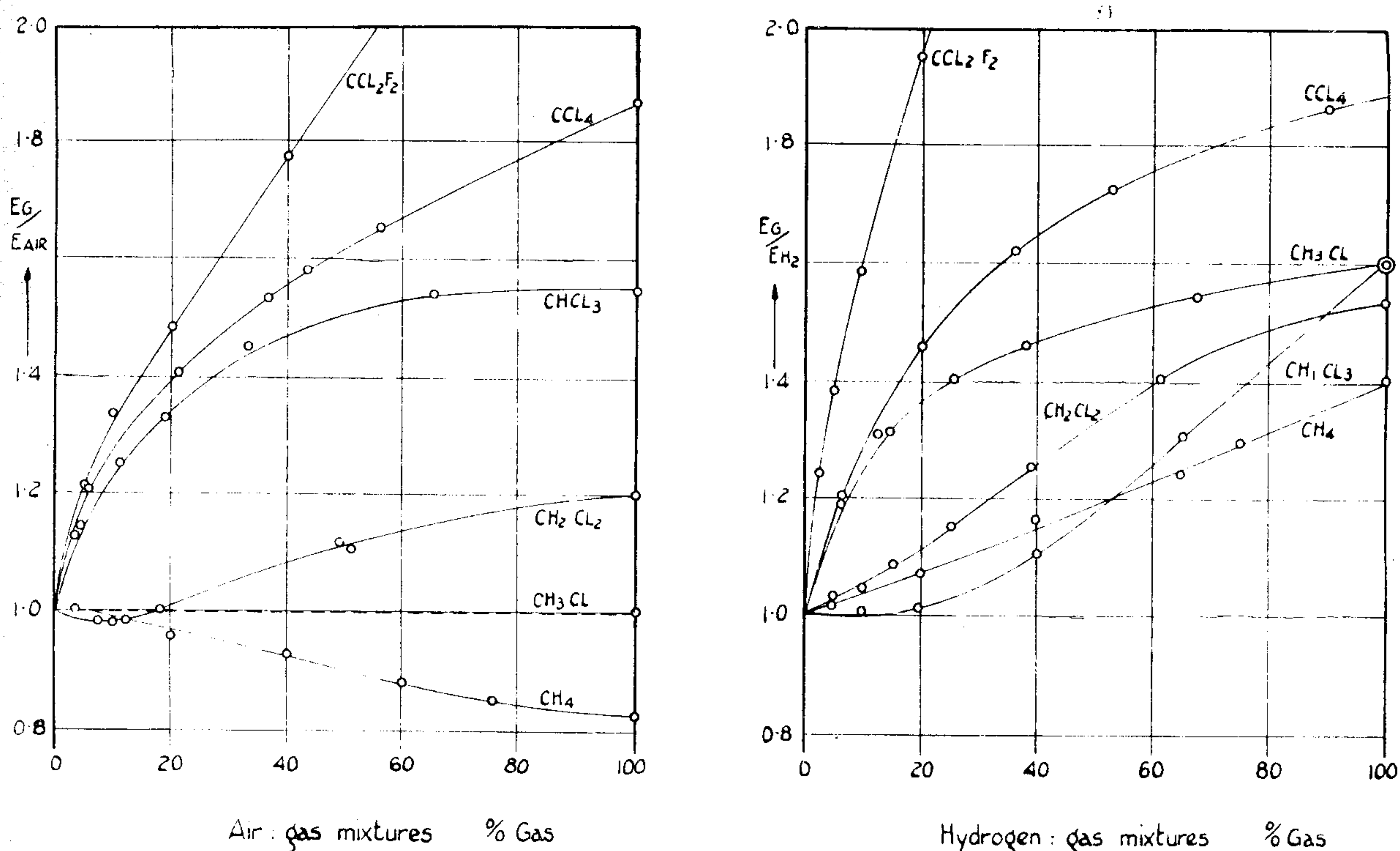

FIG. 3. BREAKDOWN POTENTIALS OF GAS MIXTURES