CXLVII.—*A Method for the Photographic Examination of Moving Flames.*

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The method generally used for investigating flame movements is that of photographing the flame on a sensitised plate or film moving at a known speed at right angles to the direction of motion of the flame. During an examination of flame movements in tubes 2·5 cm. in diameter, it was found that direct photography of the flame in certain mixtures gave poor results, even when the lens used and the tube containing the gas mixture were both of clear quartz.

The same mixtures gave satisfactory records by the use of a method depending on the fact that the progress of a flame causes an abrupt change in the optical properties of the medium through which it passes. Light passing through the seat of the disturbance is refracted, so that if a beam passes through the tube containing the gas mixture and falls on a photographic plate moving at right angles to the direction of motion of the flame, the progress of the latter is indicated on the plate by two lines of similar form, one light and one dark. These lines are close together, and once the velocity of the plate is known, the angle between the lines on the plate and the direction of its motion gives an accurate measure of the velocity of the flame at any selected portion of the tube.

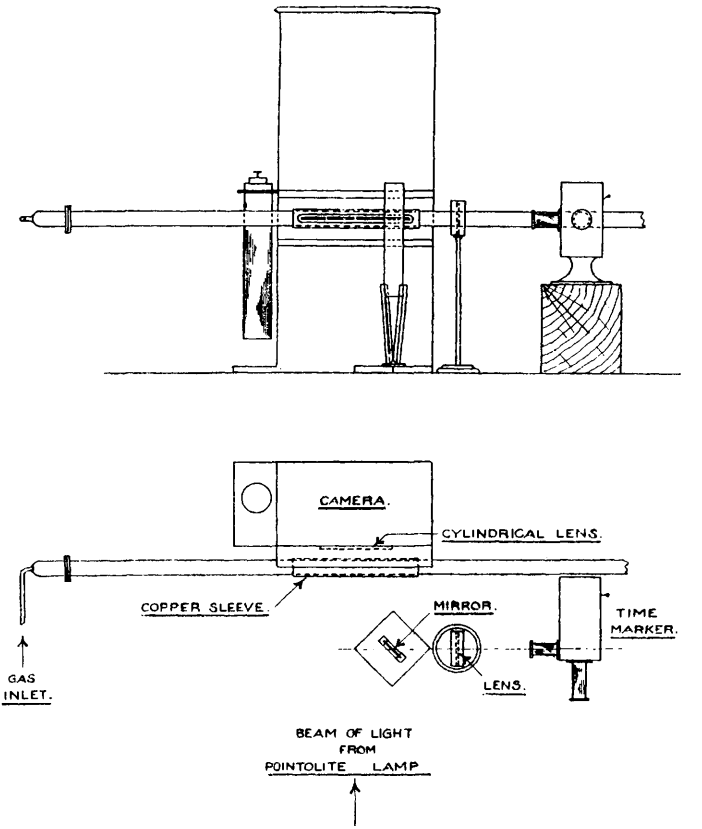
The apparatus actually used is shown in Fig. 1. The source of illumination was a 500-c.p. Pointolite lamp, and it was found best to use no lens between this lamp and the tube containing the gas mixture. Approximate parallelism of the light passing through the tube was ensured by keeping the lamp at a distance of 2 m. from it. Only the light passing through the central zone of the tube was utilised, as the portion of the latter opposite the camera was enclosed in a copper sleeve having cut in it two narrow longitudinal slits opposite one another. One of these slits was divided into 5 cm. lengths by spacing bars, which gave a length scale on the photographic plate. The time scale was supplied by an electromagnetic light interruptor controlled by a tuning fork and marking intervals of 1/100 sec. on the plate. The falling-plate camera utilised for most of the work was provided with a long cylindrical lens which focussed the light passing through the slits in the tube into a narrow band.

For the work with comparatively slowly moving flames, for which it was designed, this method has three advantages over the method of direct photography: (1) It gives better definition of the flame front, especially when it is remembered that the plates

taken show a magnification of about 1·05. (2) It gives better resolution. By its very nature the method shows up phenomena that would be almost, if not quite, hidden in an ordinary photograph. This is well brought out by Figs. 5, 6, and 7. (3) It is independent of the luminosity of the flame. It is thus possible to examine hydrogen–air mixtures near the limits for the propagation of

FIG. 1.

Apparatus for the examination of moving flames.



flame, whereas direct photography gives very poor results for mixtures containing less than 20% or more than 50% of hydrogen.

Against it there could be brought one minor objection. It was necessary to synchronise the fall of the plate and the passage of the flame past the camera window. For the flames examined by the author this was easily done by hand. For much faster flames it might be necessary to ignite the flame electrically by means of a contact closed by the falling-plate holder.

FIG. 2.

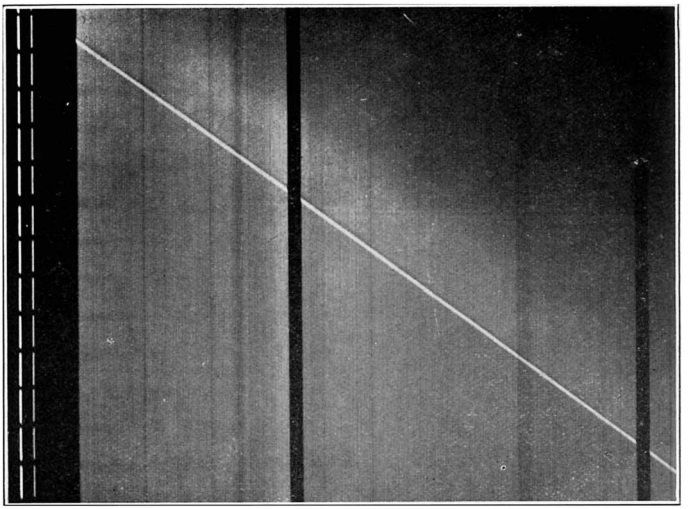


FIG. 3.

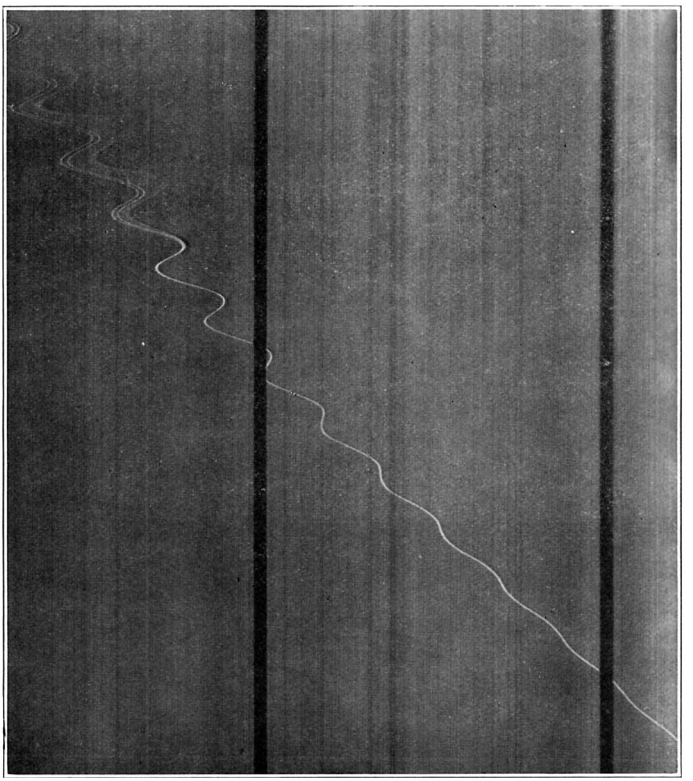


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FIG. 4.

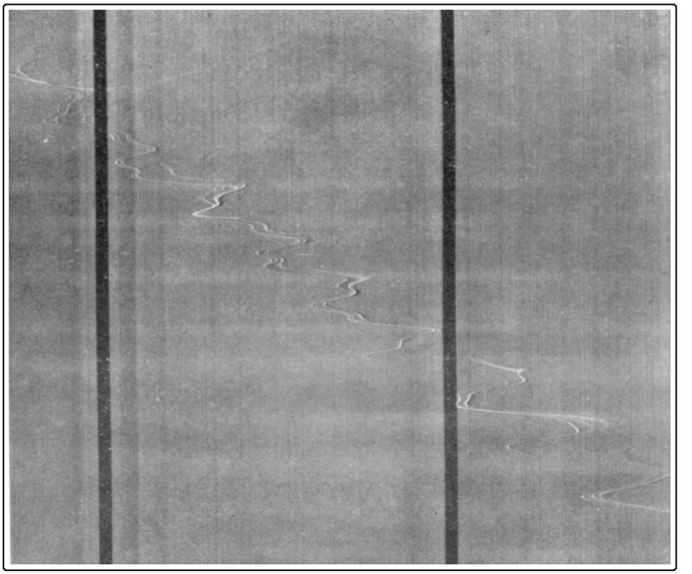


FIG. 5.

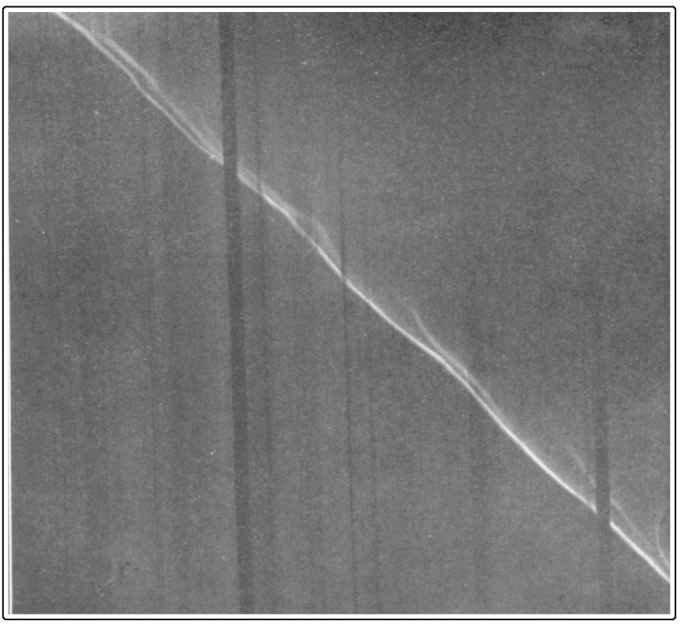


FIG. 6.

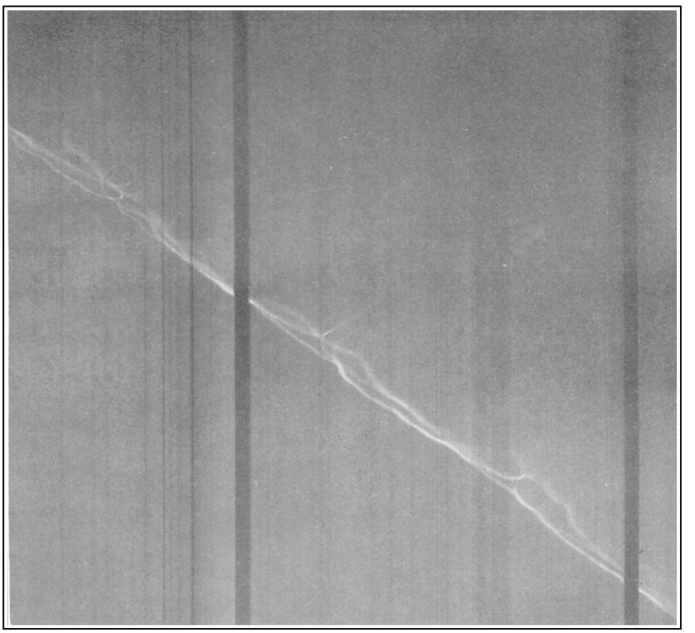
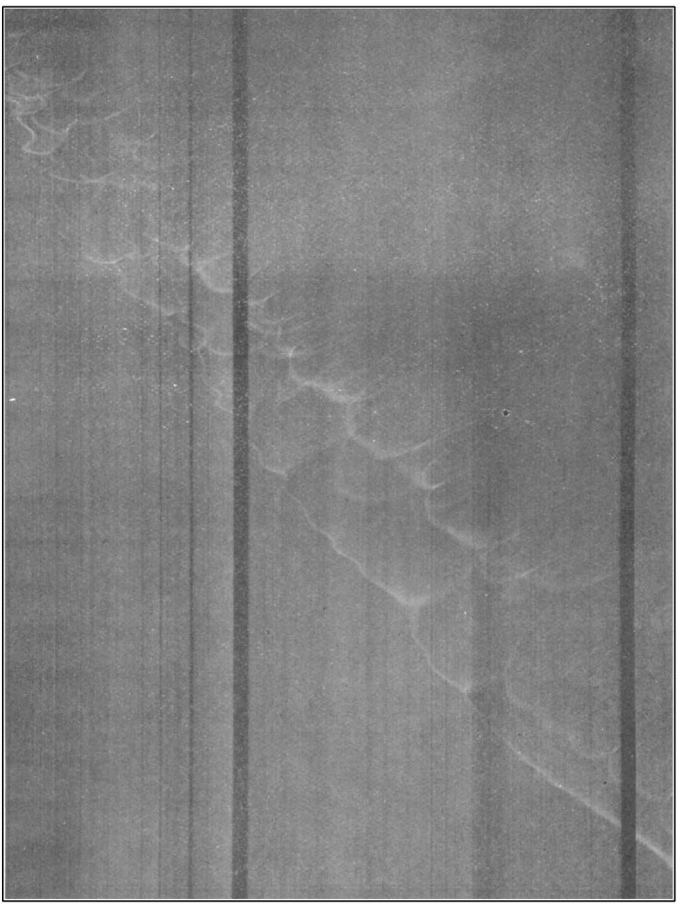


FIG. 7.



Figs. 2 to 7 show records obtained when a quiescent gas mixture was ignited by a gas flame at the open end of a horizontal, smooth, cylindrical glass tube 2·5 cm. in diameter, closed at the other end. Under these conditions, the flame generally moves at a substantially uniform speed for a certain distance, after which the motion becomes vibratory. Figs. 3 and 4 were given by mixtures in a tube 1·5 m. long; for the remainder a tube 2·98 m. long was used. All the flames are shown moving from the right to the left of the reader.

Fig. 2 shows a type of record frequently obtained for the first stage, the "uniform movement of flame." The mixture used contained 2·50% of light petroleum in air. Somewhat similar straight-line records were given by all methane– and ethane–air mixtures tested at the ordinary temperature.

Fig. 3 shows the transition from the uniform movement to the vibratory period very clearly. Vibrations at the frequency of the fundamental note of the tube increase in amplitude and suddenly give place to what may perhaps be termed the beginning of the vibratory movement proper, when the effective forward velocity of the flame is seen to decrease. This coincides with the first division of the flame trace into two parts—probably due to the production of a point of inflexion in the flame front. The mixture used contained 2·25% of light petroleum in air.

Fig. 4 shows the vibratory movement in a mixture containing 4·5% of acetylene in air, and Fig. 5 shows the uniform movement period for a mixture containing 18% of carbon disulphide in air. This record shows vibrations at the frequency of the fundamental note of the tube and illustrates the sub-division of the flame. Some of the flames left behind ultimately travel backwards. This record gave a normal value for the flame speed of this mixture. Fig. 6 shows a record given by a mixture containing 3·0% of light petroleum in air, and Fig. 7 shows that for a similar mixture containing 3·5% of light petroleum. Both records are for the "uniform movement" stage of burning. The first mixture occasionally gave flame speeds distinctly different from those normally found, and the second often did so at the ordinary temperature and gave quite erratic results when the original gas mixture was at 90°. The record shown in Fig. 6 is complex, and Fig. 7 shows that in this case we are dealing with more than one flame.

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