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Kinematographic Study on Aeronautics.

(*Provisional Report*).

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(with 4 plates).

Introduction.

It is well known that the stream lines in the steady motion of water can be observed by mixing it with some coloured matters as red ink. By using similar processes, there have been accomplished by others many trials of taking photographs of stream lines round aerofoil models or some other forms in running water and many interesting results have been obtained, giving a useful knowledge in the study on aeronautics. We can similarly observe the motion of air by mixing it with some fine dusts, smoke or coloured gases. For example, by looking smoke flowing out of a chimney we may judge the direction and speed etc. of the wind.

As it is desirous, if possible, to see the stream line pattern of air around the models used in wind channal experiments, we tried to photograph it by the method which will be described below. At first we took the instantaneous photographs of the stream line figures about various forms of models. However as this work was in progress we found that the momental photograph could not serve to satisfy us, we desired to take the figures kinematographically and after several trials we succeeded to take continuously about 1200 pictures in one second. We intended to study the state of rear current disturbed by the models used in the wind channel by taking as many potographs as correspond to different wind speeds. Thus we obtained a few sets of pictures for each model. But to our great regret, most of them together with the whole apparatus and our laboratory memo were destroyed by the great earthquake and fire of Sept. 1. 1923 before we examined the results. Among the scraps we found a few number of films which are reproduced in this report. These pictures may be perhaps of little value to give any knowledge upon the systematic study of aeronautics, and yet, as the recovering of the laboratory takes years and to repeat the experiment became impossible for the present, it has been too painful for us to throw these pictures away as rubbish. By the generocity of the Director of our Institute we were permitted to put these into print, as a provisional report, with the description of the method adopted to take them, for which we tender him our best thanks.

I. Momentary Photography.

Our first attempt was, as is stated above, to photograph the stream lines around the models used in wind channel experiments. For this purpose we constructed a special apparatus providing a wind channel and a camera. In photographing the objects we adopted two methods : the one was the striæ method of Töpler, the other was the directly projecting method of Dvořak. Both of them gave satisfactory results, though the former is more complicated in technique than the latter.

The wind channel attached to this apparatus was at first of Eiffel's type, specially designed for the present purpose. The diameter of the smallest cross section of the intake was 30 cm. and that of the diffuser was 44 cm. The difference of these two diameters was intended to avoid the confused motion of air in the experimental chamber. The maximum wind speed in this channel was nearly 45 m/sec., and the space distribution of the wind velocity was of deviation of one percent at most for the speed less than 40 m/sec.

As the wind channel of this type was not convenient in utilysing for the present purpose we constructed another wind channel which was of modified form of Göttingen type, of which the section was square form of 30 cm. in its one side. The back current which might exist in the channel of this type was avoided by a suitable arrangement. The maximum speed of the air current was about 40 m/sec., and the distribution and the fluctuation of the velocity were better than those in the wind channel described above, though the efficiency was far worse.

The concave mirror used in striæ method was of 7 meters in its radius and 15″ in its aperture. The light source was an electric spark between two alluminium ribbons, nearly 1 cm. apart, which were pressed between two pieces of hard stone.

The light source in the shadow method was an electric spark between two platinum wires of about 1 mm. thickness put in an ebonite rod. The one electrode was inserted in a side hole of the rod, and the other, provided with an adjusting screw at one end, was put in the central canal of the rod. By connecting these to an electric machine, we obtained, looking from other end of the canal, an approximate point source of light. Fig. 1. is the diagramatic view of it.

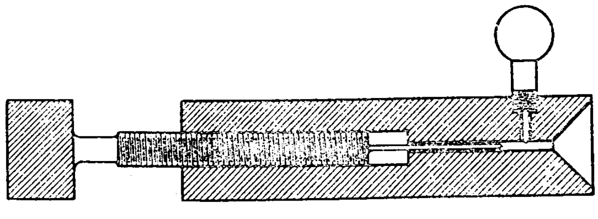


Fig 1.

Fig. 2. and Fig. 3. show the arrangements of the apparatuses of the striæ method and of the shadow method respectively.

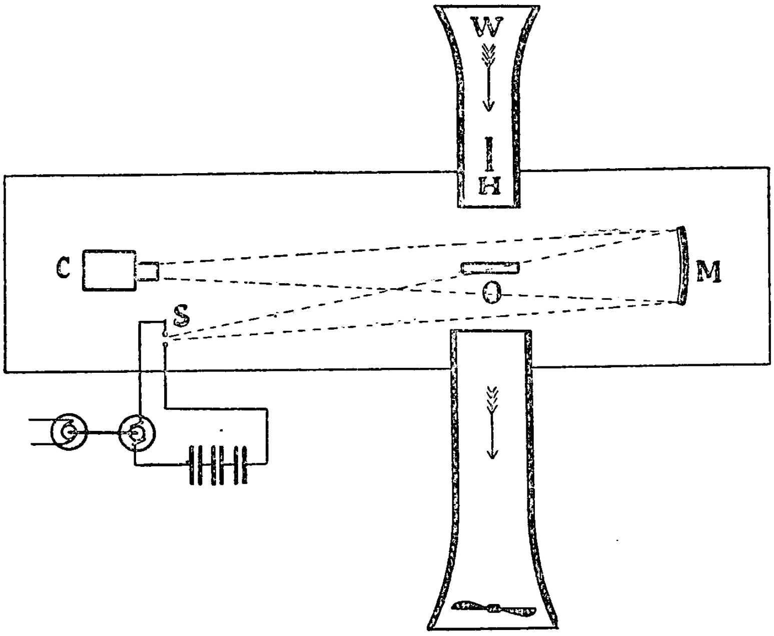


Fig. 2.

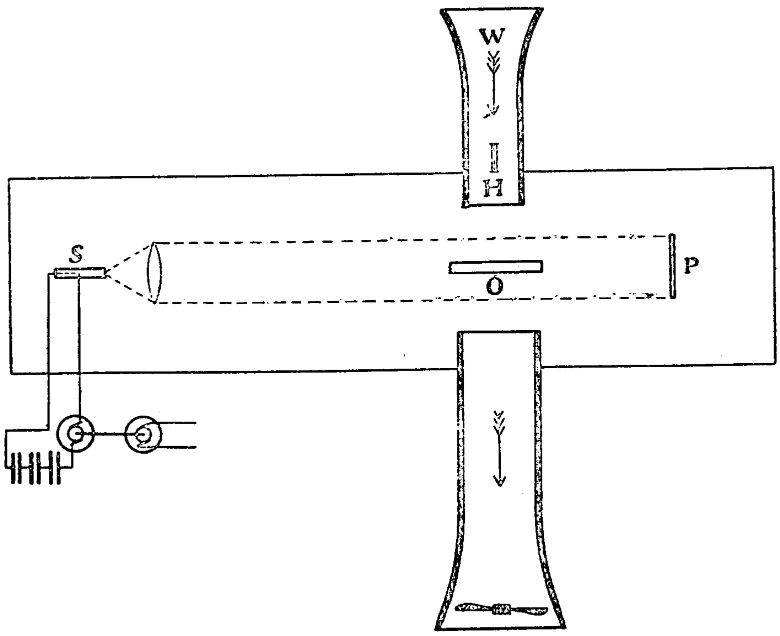


Fig. 3.

In these figures W is the wind channel, O the object through which the air current is disturbed, S the light source, M the concave mirror, C the photographic camera, P the photographic plate and H a heater, which is put to warm the streaming air so as to facilitate the photographing. The heater is made of thin manganin wire stretched on a mica plate and capable of conveying an electric current of about 10–30 amperes. By the presence of the heater, it was thought at first that the state of streaming might be much disturbed; but, in effect, by putting it at a certain position and adjusting the electric current we could scarecely recognize the intrusion of bad current produced by it.

The models we used were of various shapes. Plate 15 is a few examples left undestroyed by fire. They were all takan by the shadow method. Those which were taken by striæ method were all lost and could not be reproduced here.

(A) shows the stream lines against a plate of which the angle of attack was nearly 50 degrees, the velocity of the current being 16,6 m/sec. (B) represents those against a circular cylinder, the velocity of air being the same as that in (A). In (C) the triangular form is supposed to represent a mountain, against which a horizontal wind is blowing, the velocity of which being 19,1 m/sec.

We see from these figures that there is eddying motion of air behind an obstacle as is imagined to be. The eddying motion thus produced makes its effects upon the dynamic characters of obstacles in various aspects; e.g. the pressure distribution on their surfaces will be much influenced by the existence of eddies behind them. Moreover their existence may become the cause of the vibration of the obstacles. Thus it must be very interesting to study systematically the relation between the state of eddy formation and that of vibration, varying the wind speed, dimensions and forms of obstacles.

Plate 15 (D) represents an aerofoil model R. A. F. No. 19, the wind velocity being 7,8 m/sec., the angle of attack 12 degrees.

II. Kinematography.

It must be very interesting if we can see the state of streaming of air around the model through the kinematographic process. The usual apparatuses of kinematography in market, however, do not fulfil this requirement, as they can produce too few pictures e.g. 30 or so in one second; even the instrument so called super high speed machine in market gives only 200 or 300 pictures per second. There is however the instrument of Vickers & Co.'s make, which, so far as we are aware, is the best machine ever existed, and is said to take about 3000 pictures in one second, but its high price is almost prohibitive for our laboratory use. As our object is to take kinematographic pictures of air current of speed 10–40 m/sec., it is desirable to have at least 1000 pictures per second. And if we confine ourselves to take only the rear disturbances of the model in pictures, it is quite sufficient to expose the film for very short duration, e.g. for an interval 1/10, 1/5 or at most one second. To satisfy these requisites, we tried on several methods utilysing various instruments in our laboratory without success. The usual shatter method could not be adoptable as we had no powerful light source and the time of exposure in this method was too long so the pictures obtained were not clear enough to be analysed.

We considered that it is the best way to adopt the striæ method of Töpler by using periodic sparks of short duration as the light source. The periodic spark for this purpose must be of (*a*) regular intervals, and (*b*) constant intensity. Our first trial was to use a mechanical vibrator in connecting to the primary of a transformer. The second trial was to obtain sparks by using a rotary gap in the circuit of a high tension current rectified by means of Kenotoron tubes. Both these methods gave no satisfactory result. The third trial was to use a high frequency generator used in radio communication. Though there were several difficulties in technique, the last method was far better than those former ones.

The light source. The high frequency ganerator we used was of 500 cycles per second and was driven by means of a *D. C.* shunt motor. The frequency could be varied from about 480 to 610 by changing the speed of *D. C.* motor. The connection was as in Fig. 4.

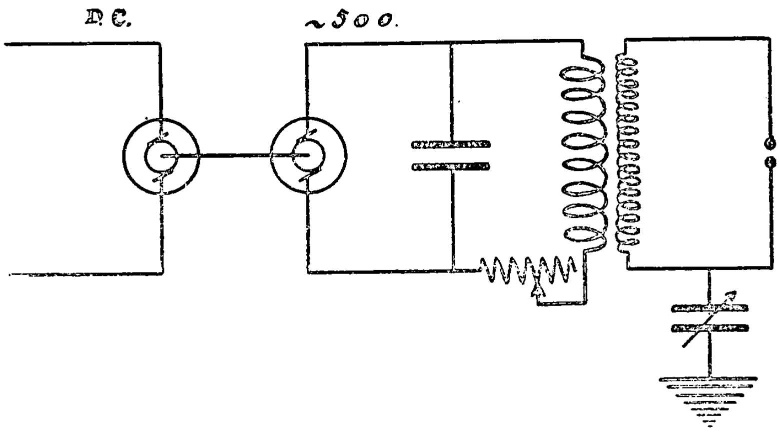


Fig. 4.

As stated above, the series of sparks as the light source must be of constant intervals: the ideal case baing two sparks in one cycle. To satisfy this condition we met with a great difficulty, for it was usual that the gap sparked at quite irregular intervals, perhaps two, three or more sparks in one peak.

After several trials we found that the ideal sets of sparks could be obtained by changing mainly the resistance of the primary circuit of the transformer and subsidiarily the capacities in the secondary circuit. They were of course inserted for this purpose afterwards. The regularity of the sparks was tested by means of a rotating mirror. The number of sparks in one second was measured by counting the number of rotation of the generator, and checked by the picture numbers photographed in a definite time. As this method did not give the exact number of sparks, we devised an apparatus consisting of a tuning fork of known frequency and necessary accesories to record time marks on the film side by side with the kinematographic records. But, unfortunately, we could not complete this apparatus before the fire and it was burned in half finished state. Thus the number of pictures per second in this provisional report must be recognized as an approximate one.

Method of Kinematography. As we obtained a light source of regular intervals of about 1/950-1/1200 second, it is easy to take kinematographic records of such numbers in one second. The arrangement of the equipments is sketched in Fig. 5.

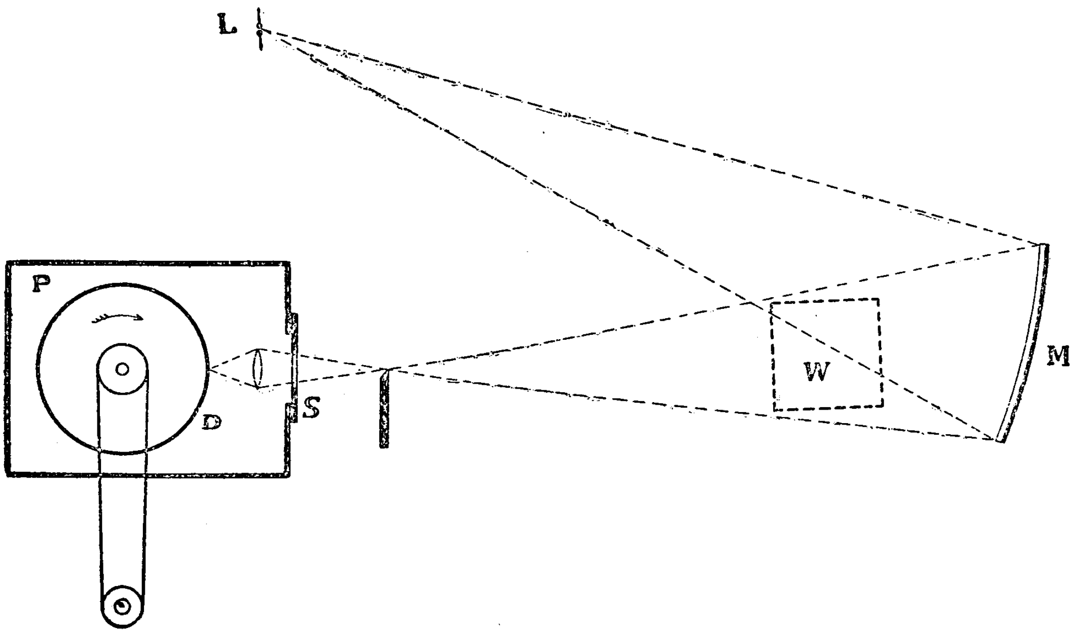


Fig. 5.

In this figure, *W* is the mouth of the wind channel where the object to be photographed was placed, *M* the concave mirror, *L* the light source, and *P* the photographic apparatus. The photographic apparatus was composed of mainly a shatter *S* and a wooden drum *D* round which film was wrapped. The drum was driven by a sinchronous motor. Just before the begining of the film came to a proper position, the shatter was opened by means of an electric devise, which is not shown in the figure, and it was closed after the exposure was ended; thus the economy of film was preserved.

In this way sevaral kinds of records were obtained and they were shown to public through a cinema projecting apparatus on a meeting of the Aeronautical Colloquium in our Institute.

Illustration of the Plates. Plates 16—18 are a few examples of the pictures gathered among the remains unburned by the conflagration. In these plates records of each film are only partly reproduced, and in order to grasp the state of air current with bare eyes the pictures are arranged in different manner from the records on films.

Plate 16 *A*. As will be seen from the annexed diagram, this is the set of pictures of the air current behind a plane which is placed crosswise the air stream of the wind channel making a certain angle of attack. The dotted circle in the diagram represents the position of the concave mirror used in striæ method and it is the whole field to be photographed. The velocity of the air current was 14 m/sec., and the number of pictures 1190 per second. From the series of pictures reproduced here it is difficult to observe the true motion, but when they were projected on a screen by an ordinary slow speed machine we could clearly trace out the motion; especially to observe the state of formation of eddies behined the plate is the most striking.

Plate 16 *B*. This is the set of pictures of air current against a rod of square section. The velocity of the wind was 15 m/sec., and the time interval between two pictures 1/1200 sec.

Plate 17 *A*. This is the pictures of the flow of air past a rod of circular section. The velocity of wind was 18 m/sec., and the time interval between two of them was 1/1010 sec.

Plate 17 *B*. This represents the flow of air past a rotating circular cylinder of 8 cm. diameter. The velocity of air was 3 m/sec. The number of rotations of the cylinder was 30 per second. This experiment was carried out on behalf of Prof. K. Wada, who was investigating the dynamical properties of a similar body in the Wind Channel Department of our Institute.

Plate 17 *C*. This represents the flow of air caused by the model of a revolving air screw. The speed of rotation of it was 18 per sec. and the time interval of the pictures was 1/1050 sec.

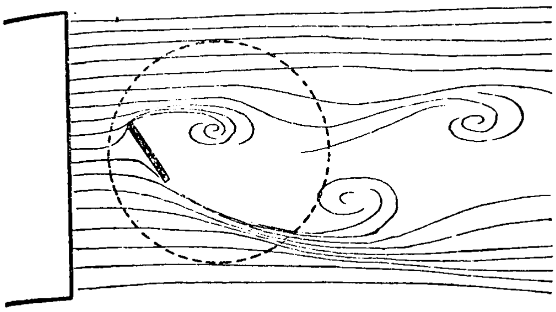
It is very interesting to observe the formation of eddies near the tip of the air screw. For the formation of such eddies a loss of energy must be accompanied, and it may appear in the test of an air screw as an eddy making resistance. If this resistance could be minimized by finding a proper shape of the blade, the efficiency of the screw must be considerablly raised.

Plate 18 *A.* This is the set of pictures showing the explosion of a gas bag. The bag was made of thin rubber membrane and contained a mixture of air and hydrogen in the percentages of 70% air and 30% H_2. The explosion was caused by an electric spark in the centre of the bag, the circuit of which was connected in series to the mechanism of opening the shatter of the photographic apparatus. Prof. A. Tanakadate found that, while he was working on the problem of the explosion of a gas bag, just before explosion took place a sudden, though very little, diminution of the pressure of gas in the bag was produced. But, as will be seen from the kinematographic records, when the gas ignited the bag is set in some oscillating motion, and thus the diminution of pressure might be concluded when it is estimated from the measure of the amount of swollen out of the bag at a point on it. Another set of photographs was obtained of the explosion of gas in a cylindrical metalic vessel, the one end of which was covered with a rubber membrane; but we could not see the vibrating motion of the membrane at all. Of course the photographic method alone does not settle the solution of this interesting problem.

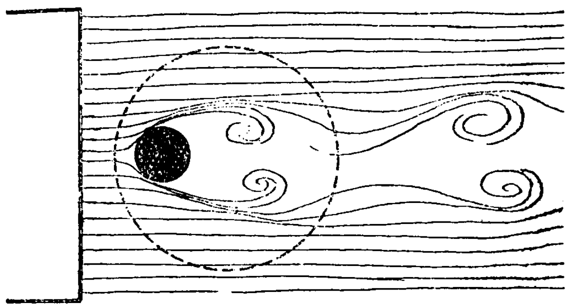
Plate 18 *B.* This is a part of a series of pictures showing the breakage of a vacuum glass globe struck very qnickly by one of us with a metalic hummer, the number of pictures being 1200 per second.

October 1923.

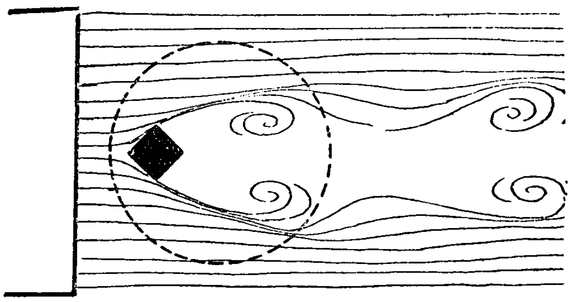
Diagramatic Illustrations for the Plates 16—18.
(the air streaming from left to right).



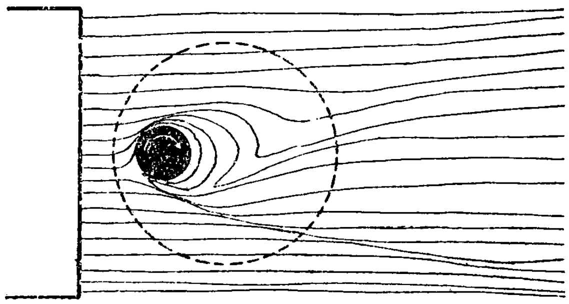
for Pl. 16, A.



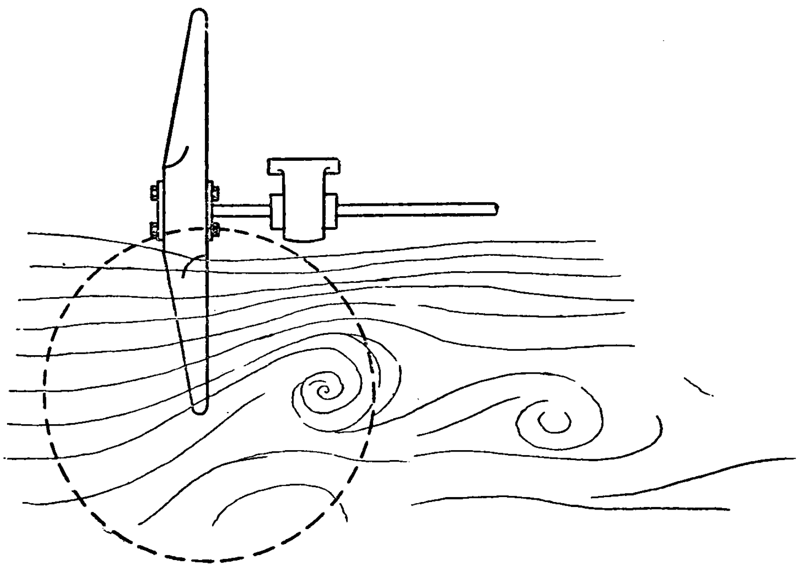
for Pl. 17, A.



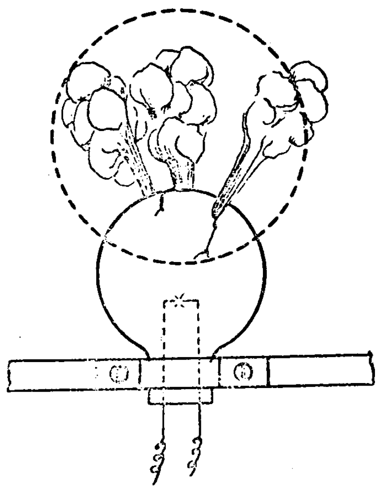
for Pl. 16, B.



for Pl. 17, B.



for Pl. 17, C.



for Pl. 18, A.

第　八　號

大正十三年九月發行

抄　　錄

高速活動寫眞による氣流の研究（序報）

所員　理學博士　寺澤寛一
技手　　　　　　山崎吉助
技手　　　　　　秋篠雄三

風洞試驗に用ふる種々の模型の附近に於ける氣流の有樣を「テプラー」の「シュリーレン」法又は「ドボラック」の直接投影法を使つて瞬間寫眞を撮つて氣流の研究に資せんとして實驗を進めて居る中に瞬間寫眞では目的を達するのに面白くないので是非活動寫眞に撮したいと思つて色々な寫眞機械を取調べたが賣品にはとても望みの品がないので有り合せの機械を使ふて漸く一秒に千二百枚位の繪を撮ることが出來る樣に成つた．然し殘念なことには九月一日の大震火災で折角撮した多くの寫眞の種板も裝置も實驗室記錄も悉く烏有に歸して仕舞つた．此報告には實驗の方法と燒け殘りの中から拾ひ集めた數枚の寫眞とを掲げた丈けなので本當の研究に資すべきものは一つもないかも知れない．

第十五圖は瞬間寫眞で撮つたもので(*A*)は平板に(*B*)は圓筒に氣流の當つた時の寫眞で氣流の速さは共に16.6 m/sec. である(*C*)は三角形であるが山の後ろでは氣流がどう變るかを大體見るのに役に立つかも知れない氣流の速さは19.1 m/sec. である(*D*)はR. A. F. 19と云ふ飛行機翼の模型で風速は7.8 m/sec. である．

第十六圖以下は高速活動寫眞で撮つたものである其Aは平板に風の當つた場合で風速14 m/sec. 繪の數は每秒1190枚の割である．

第十六圖, B. 正方形の棒に風が當つた場合．風速15 m/sec. 繪の數は每秒1200枚の割．

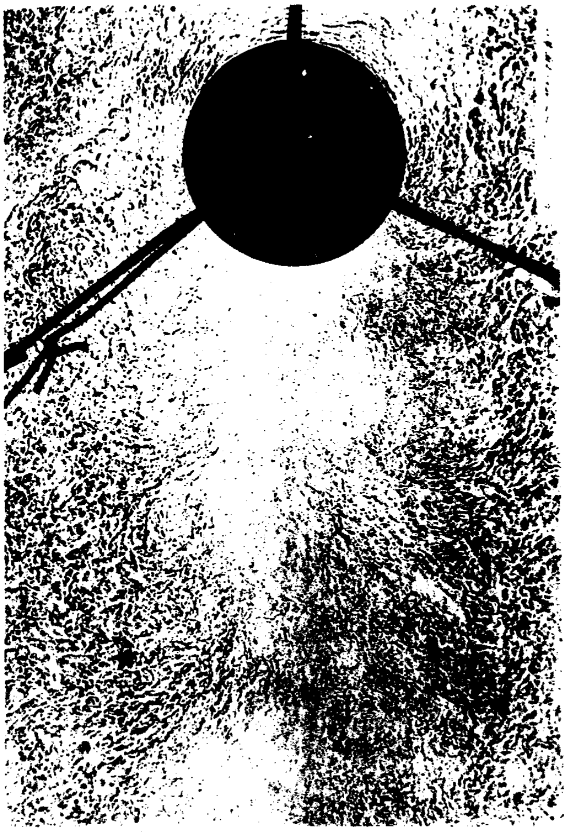
第十七圖, A. 圓筒に風の當つた場合, 風速18m/sec. 繪の數每秒1010枚の割．

第十七圖, B. 圓筒が風のある中で廻轉した場合, 風速は3 m/sec. で圓筒の廻轉速度は30 *r. p. s.* である．

第十七圖, C. 「プロペラ」の廻轉による氣流でその廻轉速度は18 *r. p. s.* 繪での數は每秒1050枚の割．

第十八圖, A. 空氣70% 水素30% の混合氣體をゴムの袋に入れて爆發させた場合の有樣である．Bは眞空ガラス球を鐵槌で破碎した有樣である．

此處に載せたものはほんの地震の殘り物丈けであるから研究所の復興と共に實驗が出來る樣になれば此方法で澤山繪を作つて研究の資料としたい考へである．



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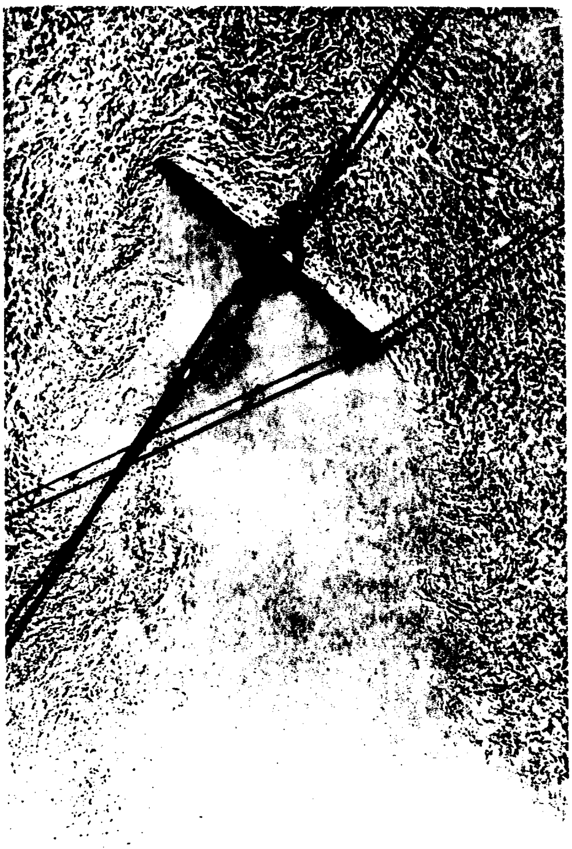
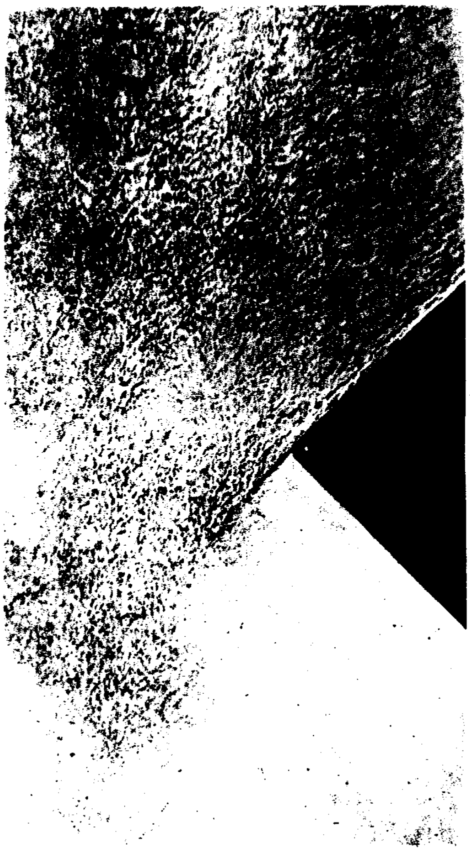
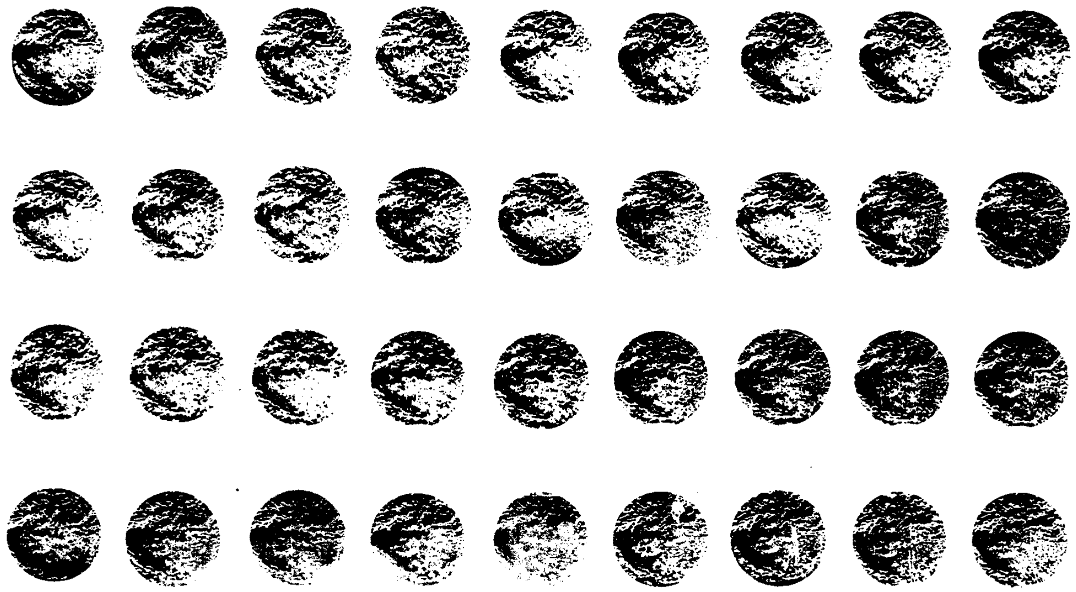




(A)



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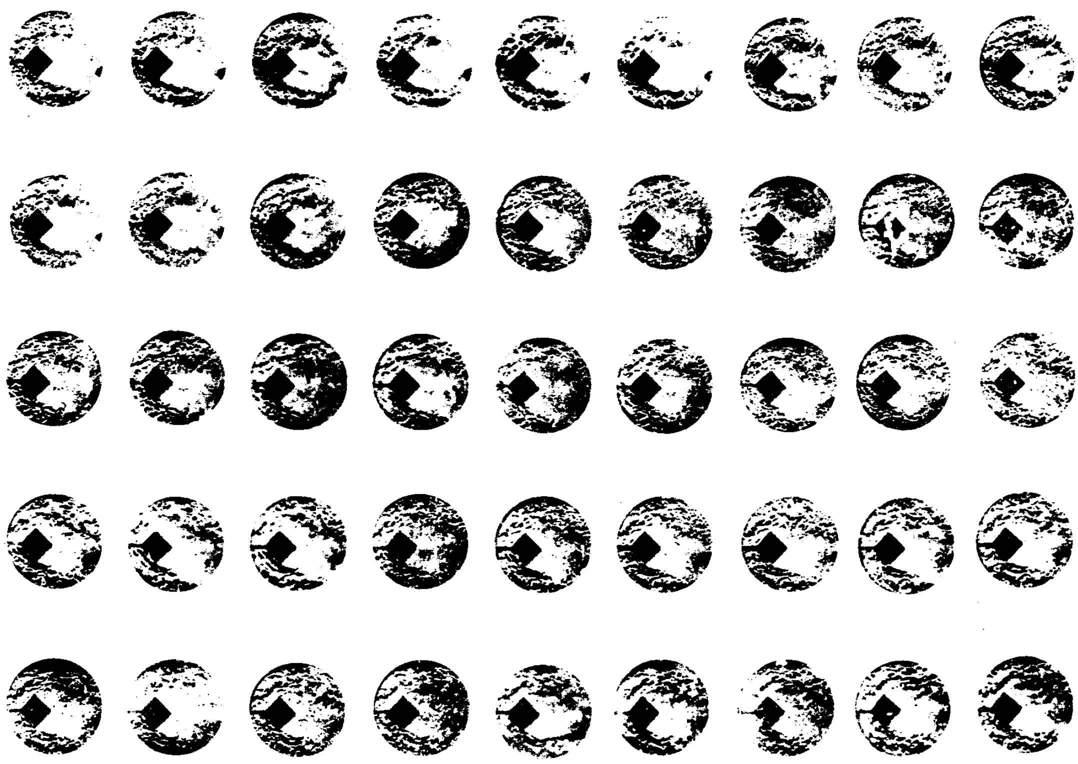

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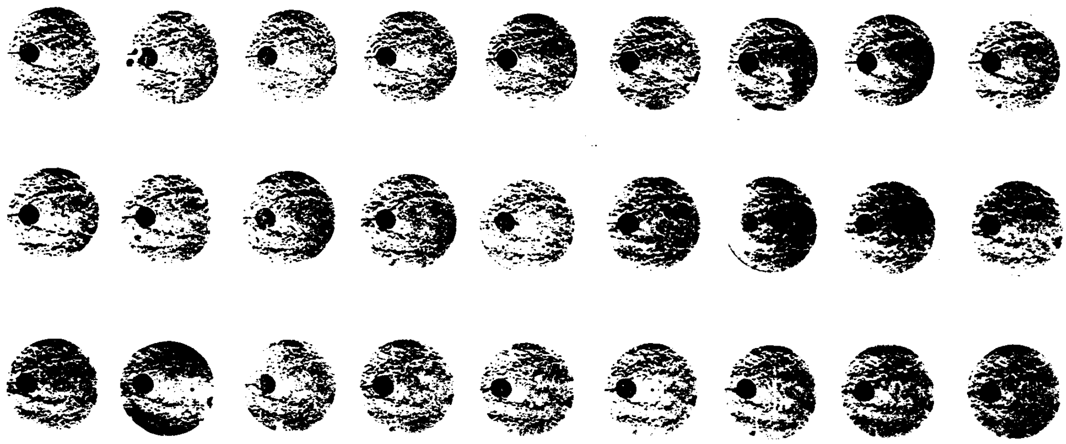

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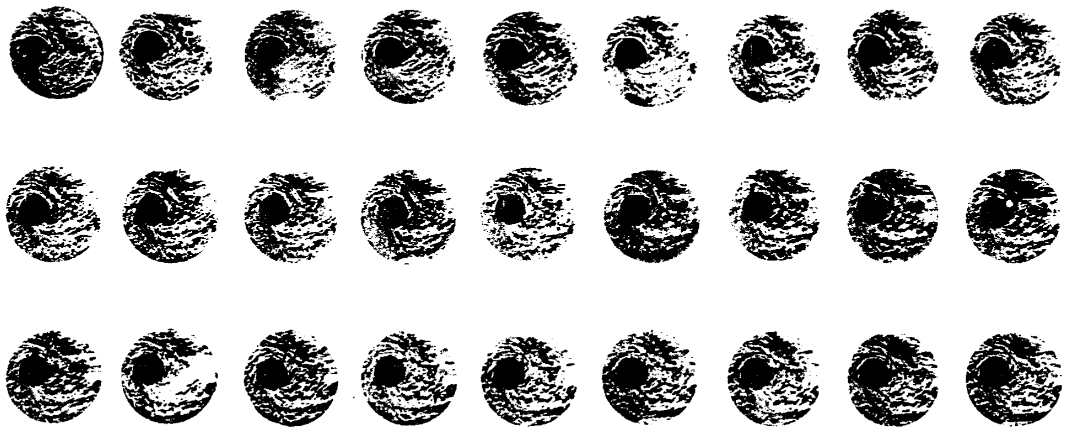

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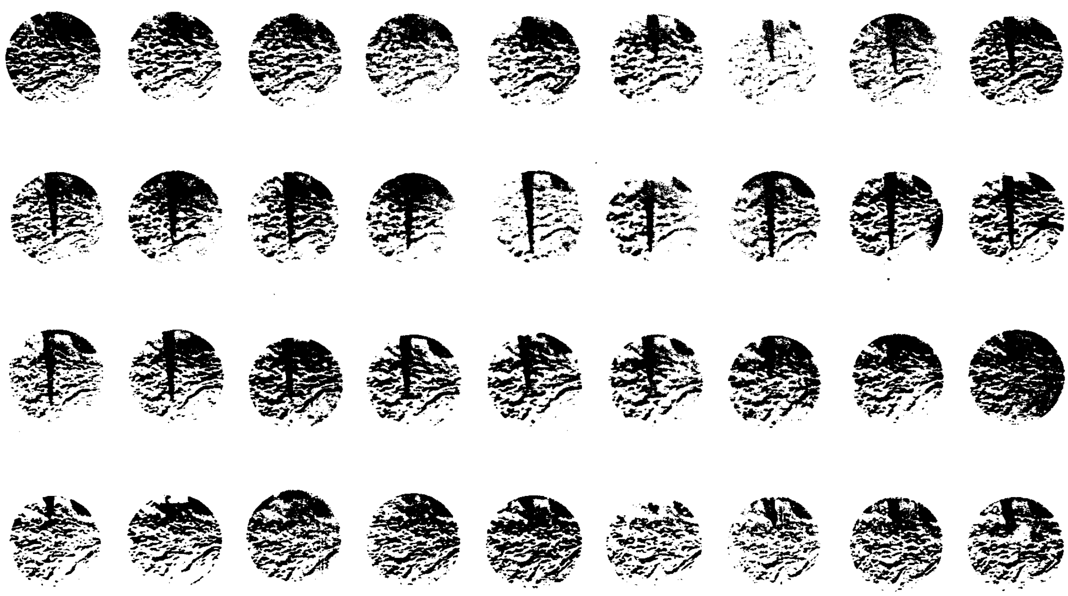

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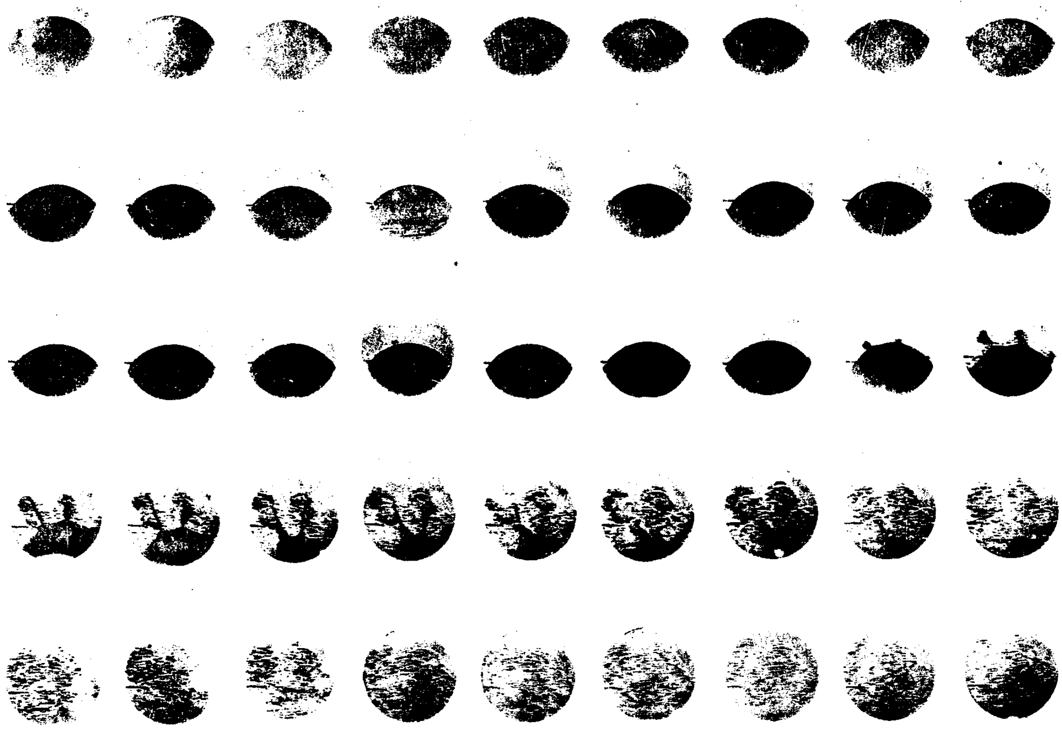
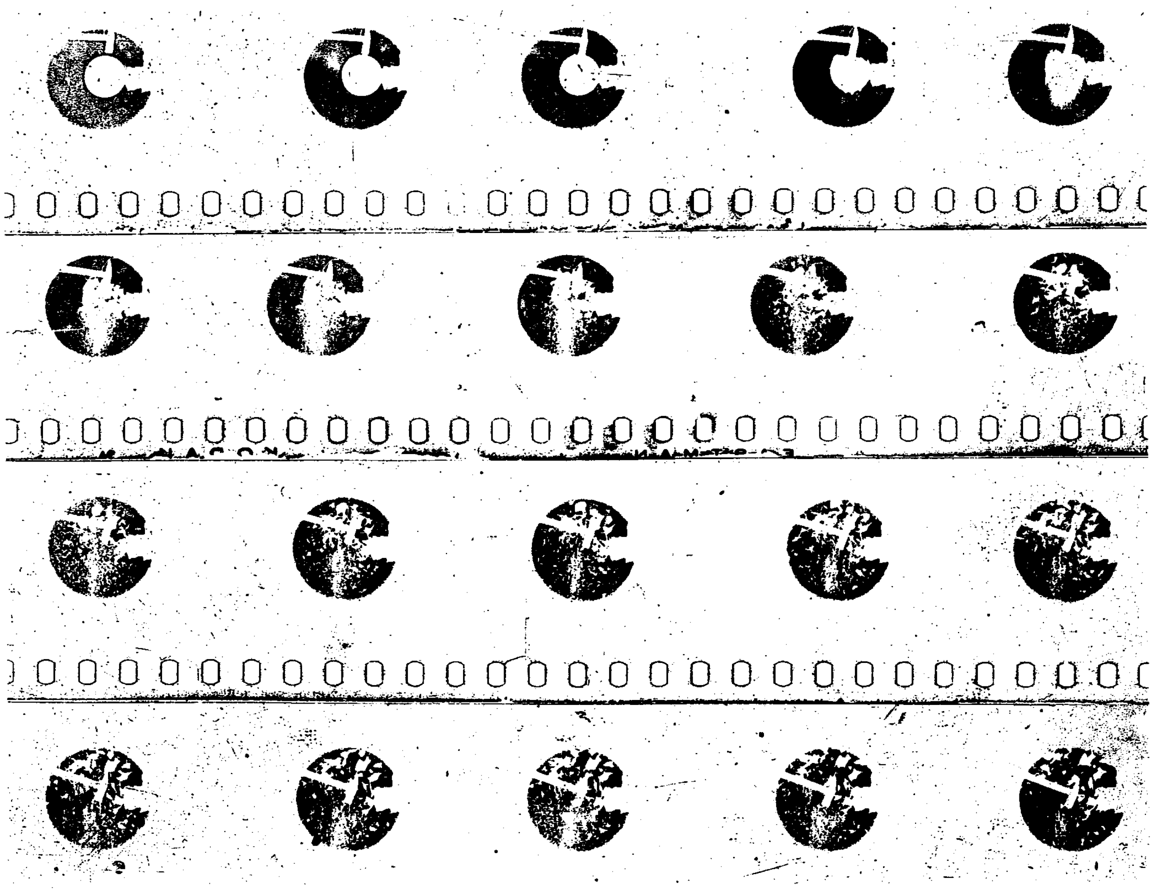


(A)



(B)