APPARATUS FOR THE VISUAL AND PHOTOGRAPHIC STUDY OF THE DISTRIBUTION OF THE FLOW ROUND PLATES AND MODELS IN A CURRENT OF WATER—By C. G. EDEN.

Reports and Memoranda, No. 31. *March*, 1911.

A small water channel has recently been constructed at the N.P.L. for the study of the flow round plates and models in a current of water.

It consists (Plate 1) of a trough 3 ins. wide, 4 ins. deep, and about 10 ft. in length, provided with glass windows 3 ft. long placed near the outlet end. At the other end of the channel a box provided with baffle plates acts as a "steadier" to the water which passes from it to the channel.

The supply of water is taken from a large tank fitted with a ball valve to maintain a nearly constant head of water. It has been found that a large reservoir of this kind is absolutely necessary owing to the changes of pressure in the water mains.

The water as it enters the channel flows over a triangular notch; by measuring the head of water at the notch it is possible to determine accurately the quantity of water supplied to the channel in a given time.

The mean velocity of the water flowing past a model placed in the channel has been taken as

$$V=\frac{Q}{(B\times H)-a},$$

where V = velocity in inches per minute.

Q = quantity of water supplied in cubic inches per minute.

B = width of channel, H = height of water in channel } in the neighbourhood of the model.

a = cross sectional area of model.

The water leaves the channel by a weir, over which it flows into a box fitted with an outlet pipe.

The maximum rate of flow obtainable is extremely low, and is about 2 ins. per second.

Method of experimenting.—In order to show the presence or absence of "eddies," "dead water," or "regions of sluggish flow" in the neighbourhood of balloon models, plates, &c., colouring matter can be introduced into the water either in the form of (i) a filament of coloured fluid (such as red ink), which may be seen to follow the path taken by the water in cases where true "stream-line" flow exists, or by means of (ii) a "cloud" of coloured fluid, which, after flowing past an object placed in the stream, leaves some of the colour in the regions of sluggish flow or dead water, where it can be observed for a length of time depending on the rate of flow in that region, or (iii) to show the existence of dead water in the case of balloon models with blunt tails and the formation of periodic eddies from inclined plates, the model is given a thin coating of either Chinese white (water-colour paint), or what has proved most useful for this purpose—condensed milk.

Observations of the nature of the flow of water in the tail region of balloon models.—Within the range of velocity obtainable in the water channel, the following observations on balloon models have been made. The three balloon models experimented with are shown in Plate 2—A, B and C.

Figs. 3, 4 and 5 (Plate 3) show that in the case of the fine-tailed model A there is a region of "sluggish flow" at the tail but no true "dead water."

The method of experimenting (ii) was that of allowing a cloud of coloured fluid to flow past the model. The photograph shown in Fig. 4 was taken 20 seconds after Fig. 3, and Fig. 5 was taken several minutes later, when nearly all the coloured fluid had washed away. Fig. 6 shows that in the case of the medium-tailed model B at the same velocity as before, there is a region in which

FIG. 1.

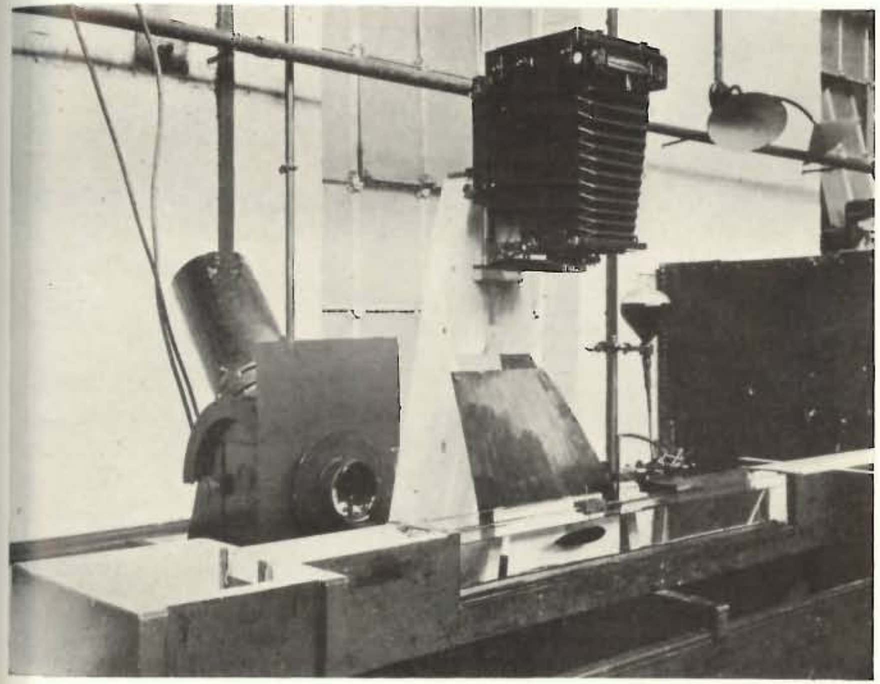
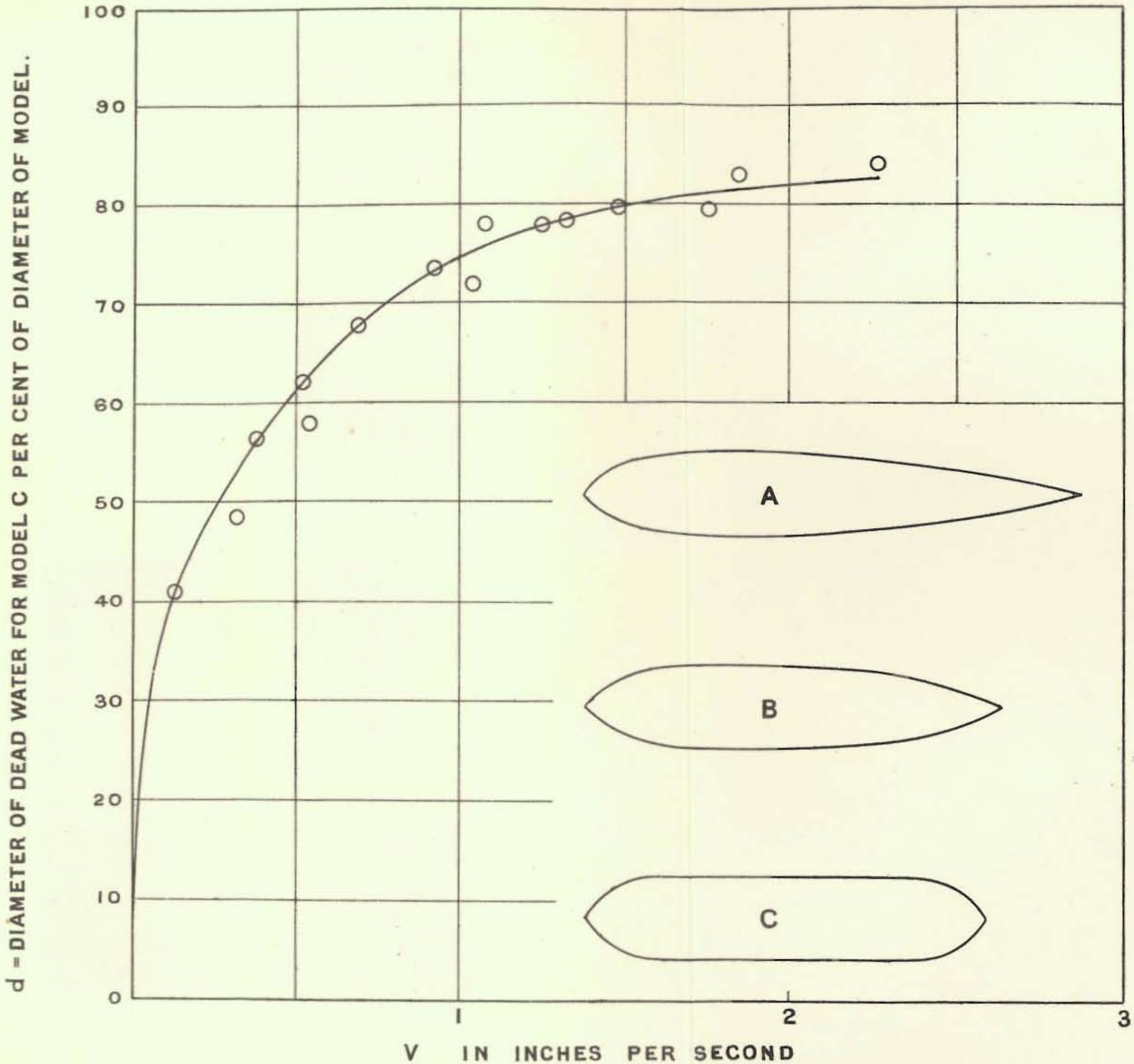


Fig. 2.



100
90
80
70
60
50
40
30
20
10
0
d = DIAMETER OF DEAD WATER FOR MODEL C PER CENT OF DIAMETER OF MODEL.
A
B
C
1
2
3
V IN INCHES PER SECOND

FIG. 6.

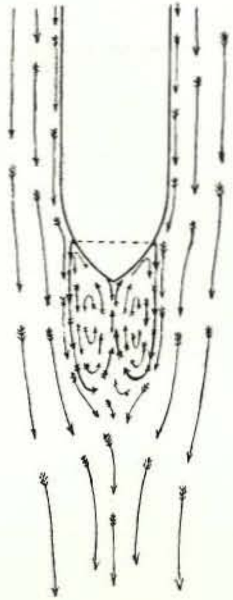


FIG. 7.

FIG. 8.

FIG. 3.

FIG. 4.

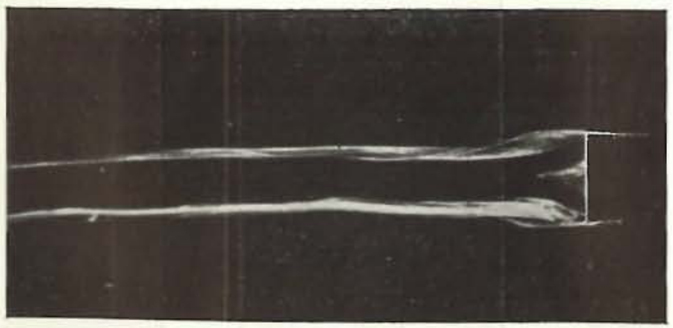
FIG. 5.

PLATE 4.

FIG. 9.

FIG. 10.

FIG. 11.



the colour remains for a considerable time, and it can be seen that within this region there is a very slow circulation of the water in the directions shown by the arrows in the diagram, Fig. 7.

Fig. 8 shows that there is a still larger dead-water region in the case of the blunt-tailed model C.

In the case of both models B and C the diameter of the "dead-water" region was found to increase with the velocity, and as the velocity at which the water flows past these small models probably corresponds to an exceedingly low velocity for the full-sized balloon, it is probable that the dead-water region will be large even in the case of a *fine-tailed* balloon of normal size at normal speed.

Fig. 2 (Plate 2) is a curve showing the relation between velocity and d (the diameter of the dead-water region expressed as a percentage of the maximum diameter of the model) for the blunt model C.

Observations on eddies from square plates.—The formation of periodic eddies at the back of small square plates inclined to the stream is shown in Plate 4, Figs. 9 and 10. The plate shown in Fig. 9 is $\frac{5}{8}$ in. by $\frac{5}{8}$ in. inclined 50 degrees to the stream, and that shown in Fig. 9 is $\frac{3}{4}$ in. by $\frac{3}{4}$ in. at 40 degrees angle.

The eddies are not unlike vortex rings, but as can be seen from the photographs the "rings" are not closed, and have the form of a loop, these loops being linked together to form a chain of eddies. If the velocity is very low, or if the angle of the plate to the stream is small, the production of periodic eddies ceases, and the type of flow is that shown in Fig. 11, where a true stream line flow exists.

It will be seen that two spirals are formed from the sides of the plate; these rotate in opposite directions, and are connected by an unbroken sheet of coloured fluid flowing from the trailing edge of the plate. The velocity at which the flow changes from a steady flow to a periodically eddying flow has been observed for two plates of different size, but of similar form, and set at the same angle to the stream. Their dimensions were $\frac{3}{4}$ in. by $\frac{3}{4}$ in., and $\frac{1}{4}$ in. by $\frac{1}{4}$ in. It was found that this velocity in the case of the small plate ($\frac{1}{4}$ in.) was almost exactly three times the velocity in the case of the large plate ($\frac{3}{4}$ in.); that is to say, the values of the product vl were practically the same in two cases, being 0·0019 and 0·0020, respectively, in foot second units*.

It is hoped that further examination of the conditions under which the change occurs, with variation of the velocity, and of the inclination of the plate, may give results of interest. The question as to the similarity between the flow in water and that in air, and the circumstances affecting this similarity, may perhaps also receive consideration. This question has been discussed by Dr. Ahlborn (Abstracts, No. 110, p. 122), who arrives at the conclusion that there can be no doubt as to the complete similarity of the flow in air and in water. This conclusion is reached from a comparison of his own experiments in water with those of Dr. Ludwig Mach in air, and he holds them to be confirmed by the known results as to relative pressures on plates in the two media.

* See note by Lord Rayleigh on the Principle of Dynamical Similarity, Report for 1909-10, p. 38.