

## DISCUSSION.

MR. PATRICK ALEXANDER.—Is there any way of reversing the model?

I was very pleased to hear that there is a difference in working against dead air and live air when meeting the surfaces of the model. Personally, I think it is more economical to have the air moving against the planes than to move these against the air, but at present we have no cheap and ready method of driving the air against the planes.

MAJOR HUME.—First of all, I think that in spite of the lecturer's modest remarks as to attributing the idea of these investigations to previous gentlemen, we should recognise that the credit of this sound and original work rests with himself, and it is most gratifying that this Institution should receive a paper on his work.

With regard to my own observations, they are couched entirely in the tone of an inquirer, and I am asking him perhaps one or two things which I feel sure he has already investigated but not felt them worthy of mention to-night.

Has he experienced any difficulty from whip in using a long, thin tube, seeing that he used its deflections for his lift measurements? He has explained how he dealt with the resistance of the tube, and I see he has to make separate observations.

The mass of the model has to be considered. Has he used entirely wooden models, as at the beginning of wind channel work, or has he found it necessary to devise a specially light structure of models? Is this important? Are all-metal models impracticable?

I note his method of measuring drag forces, and although this probably reads accurately, it takes a few swings to do it. It seems to me that these measurements might be properly read by means of a mirror recorder from the arm itself, the light beam lever of which weighs nothing, and a high degree of magnification can easily be obtained, and the results could perhaps be made photographic.

I was much interested in his observation with the smoke cloud on the vortices. Did he see any hint of the vortices ever changing sign? Does he consider that these vortices are in any way affected or damped by fore and aft slots of air in the wing?

Were his tapered wing sections invariably as his diagram shows, or, if the tapering is done in the reverse way, is there any improvement in the vortex?

I should like, in conclusion, to thank Major Gnosspelius most sincerely for an original paper on a subject which will leave us all thinking for some time.

MR. W. O. MANNING.—Re the amount of swing lost by the pendulum; he measures this by the assumption that resistance varies. Possibly, the resistance does not vary all the way up.

With regard to lift, he measures his lift by measuring the deflection of the rod. This might also cause error, as there is a certain amount of inertia in the rod. The rod will undoubtedly have a period, and this may have some effect.

There is another small cause of error. As the rod is slowly moving out while the model comes round, that will to some extent have the effect of washing out the angle.

I am rather interested in his remarks regarding whether VL is a new form. I should be very interested to hear whether he has made any experiments with the sphere. The resistance of spheres would be an extremely interesting point.

I congratulate Major Gnosspelius on showing us a method of experimenting with models which could be carried out at home.

MR. C. V. COATES.—I am purely a theorist, but am certainly of the opinion that at present hydrodynamics is founded on absolutely wrong assumptions. (By means of blackboard diagrams Mr. Coates explained his theories regarding turbulence, direction of vorticity, diffusion of vorticity, etc., and asked where the centre of vortex was considered to be.)

MR. CHARLES COOPER.—I have been much interested in Major Gnosspelius's descriptions.

How does he measure the lateral deflection of the pendulum due to the lift?

Is he able to detect any effect of interference due to the frame? The presence of that frame might easily account for the discrepancies between his experiments and those of the N.P.L.

MR. A. F. HOULBERG.—There is no doubt that in these days apparatus of this sort have advantages over other methods. I have always contended that to drive a column of air past a model is quite all right, but that far greater proportions are assumed when you have air that has no momentum. In the wind channel the momentum of the air damps out vortices far more than this method does.

I was extremely interested in his results regarding wing-tip vortices. These have been a subject of considerable interest to me for some years past, and I find that such vortices can be greatly modified or amplified by means of suitable shaping of the wing tips, and by certain conditions of wash-out. It would be most interesting to carry these experiments further, and this has been shown by certain experiments which Dr. Thurston and I have been carrying out. We find that wing-tip vortices have a considerable effect upon the burble point. Further investigation in that line is certainly desirable.

Has Mr. Gnosspelius made any experiments for the extension of the pendulum above the pivot point, which undergoes no deflection? It seems to me that by that means, and by having a suitable chart which is moved parallel with the axis of the pivot, you not only do that, but record the whole of the velocities of the pendulum.

MR. HOWARD-FLANDERS.—What is the position of the vortex when viewed in the plan? That is to say, does it start from the trailing edge, or further forward. Is it possible to know this under rather difficult conditions of observation? It looks as if the only method of knowing this would be by photography.

What happens to the vortex at the burble point?

Is there any difference noticeable between the inner wing and the outer?

Does the upper plane show different conditions from the lower? Or does the small size of the model render this unimportant?

Is there any trouble with torsion on the tube due to the c.p.? Does the model have to be re-positioned on its c.p. to avoid the whole tube twisting?

Does the very narrow base of the tube have any effect? I should have thought that the two bearings on which the pendulum swings ought to have been several feet apart.

Can he tell us anything about slotted planes? I suspect that he has been trying these.

Are wax models any use?

DISCUSSION NOTES BY CAPTAIN W. H. SAYERS, WHO WAS UNAVOIDABLY ABSENT.

Major Gnosspelius is to be congratulated on having made a serious effort to bring the testing of models within the reach of everyone who is interested in aerodynamics, and the Institution has reason to congratulate itself on having heard for the first time his account of the apparatus which he has developed.

The fact that with this very simple and cheap arrangement it has been found possible to reproduce with remarkable accuracy the results obtained on standard wing sections, etc., by the N.P.L. with their very expensive and very accurate equipment, seems to be good evidence of the usefulness of the method. But I am not altogether clear that this evidence is conclusive in all respects.

The drag readings are obtained in the form of the integral of the drag over the whole speed range from zero up to the maximum speed of the swing, and it is assumed in computing the drag coefficient that resistance varies strictly as the square of the speed. It is very generally admitted that the square law is far from true at very low speeds, and this must introduce a certain error.

Fortunately the resistance forces due to very low speeds are themselves very small, and the error due to this factor is probably negligible. In effect one is measuring the square root of the mean square of the drag over the speed range of the pendulum.

In the case of lift the force is measured at the maximum velocity of swing, speed at which drag is measured. If the square law were rigidly true this would and in effect this amounts to measuring lift at a speed roughly  $\sqrt{2}$  times the be immaterial, but in view of the evidence as to the scale corrections found in wind channels one would expect to find a ratio of lift to drag under these conditions very distinctly different to that obtained when both measurements are made at the same speed.

As in fact such a difference is not noticed on normal wing sections it seems desirable to consider very carefully whether this lack of discrepancy in this case is anything more than accidental. This seems particularly necessary in view of the divergence which is noted in regard to certain very thick sections.

If it can be shown that the square law is sufficiently close to the truth to make this form of test generally reliable and accurate, then it seems to follow that the "scale effects" observed in wind channels are the result of defects in the wind channel method of testing and are due to some such cause as a varying degree of turbulence with change of speed, etc.

## MAJOR GNOSSPELIUS'S REPLY TO THE DISCUSSION.

MR. ALEXANDER.—With regard to reversing the model, I do not think we have ever actually done this, but before running the apparatus it is necessary at times to calibrate the pendulum for the direction of line of swing. (The lecturer then drew a blackboard diagram showing that all the records of lift are on one piece of paper, first of all marking where the pendulum is vertical.) Although we have never reversed the model, I should expect the effects on the other side to be identical.

Re dead air and moving air, this is a point we do not know about, but we always noticed that our resistances were lowest when the air was very still. We took pains to close the room up and get rid of all draughts. Our drag measurements were variegated when the air was not still. The resistance certainly seems to be less in non-moving air.

MAJOR HUME.—Re length of tube; we did get a little whip at first, but this seems to be eliminated if you drop from the centre of percussion.

With regard to wooden models, we had to be ingenious. We found that if we made models of laminated mahogany one-quarter-inch-wide laminations, they did not cast, but kept their shape very well. They are very much cheaper than metal. Another advantage of wood is keeping down the weight of the model in order to keep up the velocity. There is, I think, no alternative to wood. Prandtl uses plaster of Paris over a steel plate, but that is too heavy for us.

Major Hume suggests a mirror recorder. We have thought of this, but are not quite ingenious enough to do it. It is one of the things we have often discussed.

Re vortices and the sense of rotation; at burble something strange happens, but we cannot quite tell what it is. The air is all mixed up. We have never tried any fore and aft air slots.

We have not tried tapered wings the other way, that is, with straight leading edges, but had tried a triangular wing, and the answer was—the same position for the centre of vortices.

MR. MANNING.—With regard to the assumption of error in the drag measurement readings, if you plot the speed of the pendulum it is a curve with a flat top, that is, the velocity does not vary much over the majority of the swing. The error is certainly there, but I do not think it is a very big quantity. We simply have to accept the fact that it is there, and do the best we can.

Re lift measurements; sideways whip may be there, but I do not know how to test for it except by altering the weight of the model and seeing whether the same readings occur.

With reference to VL for spheres, I think these results are not worth anything. Pannel of the N.P.L. collected spheres results, but those results were certainly far from satisfactory. The values of resistance vary for various experimenters by about 300 per cent. over the range of VL tested.

MR. COATES.—I am glad to hear that he thinks the hydro-dynamic theory is not very satisfactory. Professor Prandtl also did not understand my vortices. All we know is, that the air does not and cannot go down—it revolves. The air is dragged down from everywhere above, and simply has to go back again, thus starting circulation.

MR. COOPER.—The lateral deflection of the pendulum due to lift is measured as previously stated.

With regard to the frame, this is certainly bad, but it is the best we can do. One thing is interesting, however—it does not affect the end vortices; the general form of air flow continues.

MR. HOULBERG.—I am glad you do not like wall effect. I am not sure that the high lift attained on things like R.A.F. 19 are not wall effect.

I have not tried wash-out on vortices: this needs much time, and our experiments have been done in spare moments.

I have never found burble affected by wing tips.

With regard to extending the pendulum above the centre, I am not altogether in love with that idea, because you double the resistances on your pendulum. You could record these velocities if you had the apparatus (and, first of all, the money to do it with!).

MR. HOWARD-FLANDERS.—The position of the vortex in plan? Where does it start from? You cannot see anything in plan, and must therefore look end on. I have never been able to see anything by looking in any other way, owing to natural difficulties of observation.

What happens to the vortex at burble? It becomes much more confused.

The effect on the upper plane (due to the frame) is not quite so clear as with the lower one.

Re torsion on tube; decidedly there is none. When twisting the model round for varying angles you put a large torque on it, and you can feel that the tube does not move at all appreciably.

A longer axis at the top might be better, but this one seems quite satisfactory.

Re slotted planes, I have played with these, but I do not like them, because of the increased resistance. We want to reduce resistance. Wing-tip feathers make no difference at all; there is no added resistance.

With regard to wax models, the forces on these models are very considerable, and they therefore need to be as strong as possible. It is doubtful if wax would be strong enough, also it would be rather heavy—certainly heavier than mahogany.

CAPTAIN SAYERS.—Re drag measurements; he has not quite grasped the curve of pendulum velocity I tried to indicate.

I cannot get thick section results: the top lift seems non-existent.

I have grave doubts as to whether high-lift wings do high lift; in fact, I think they do not.

A very hearty vote of thanks to Major Gnosselius brought the meeting to a close.

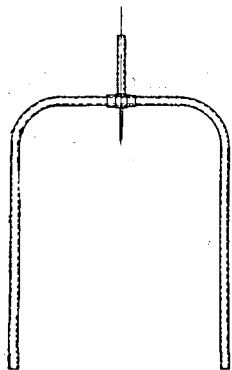


FIG. 1.

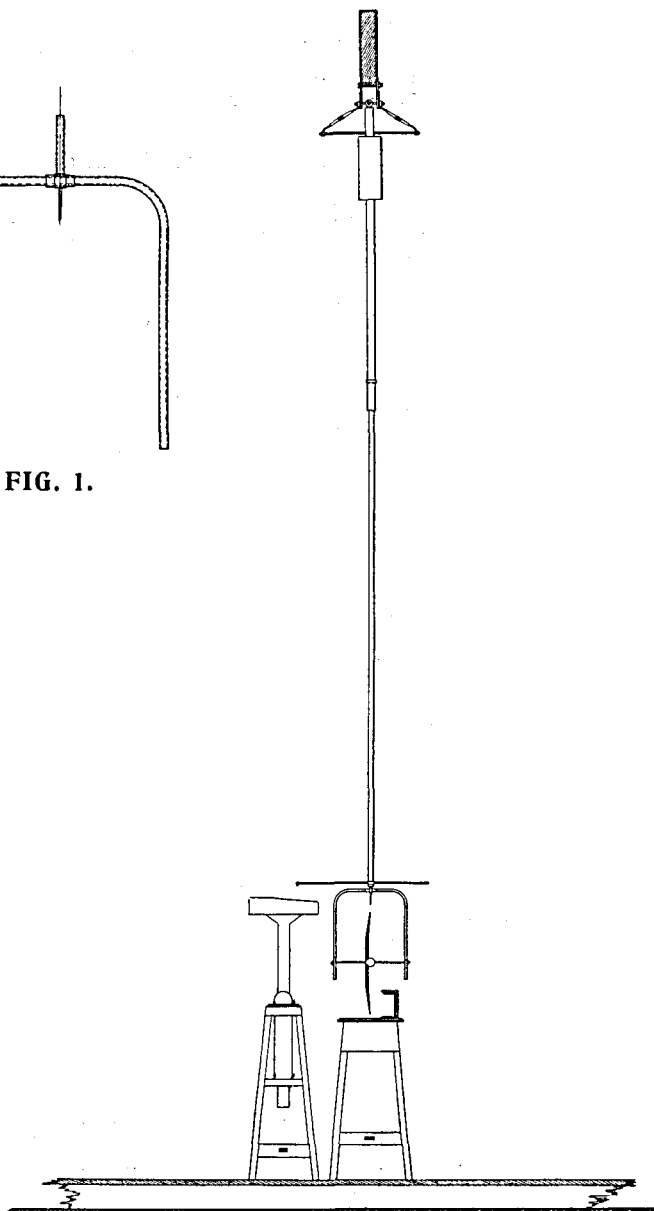


FIG. 2.

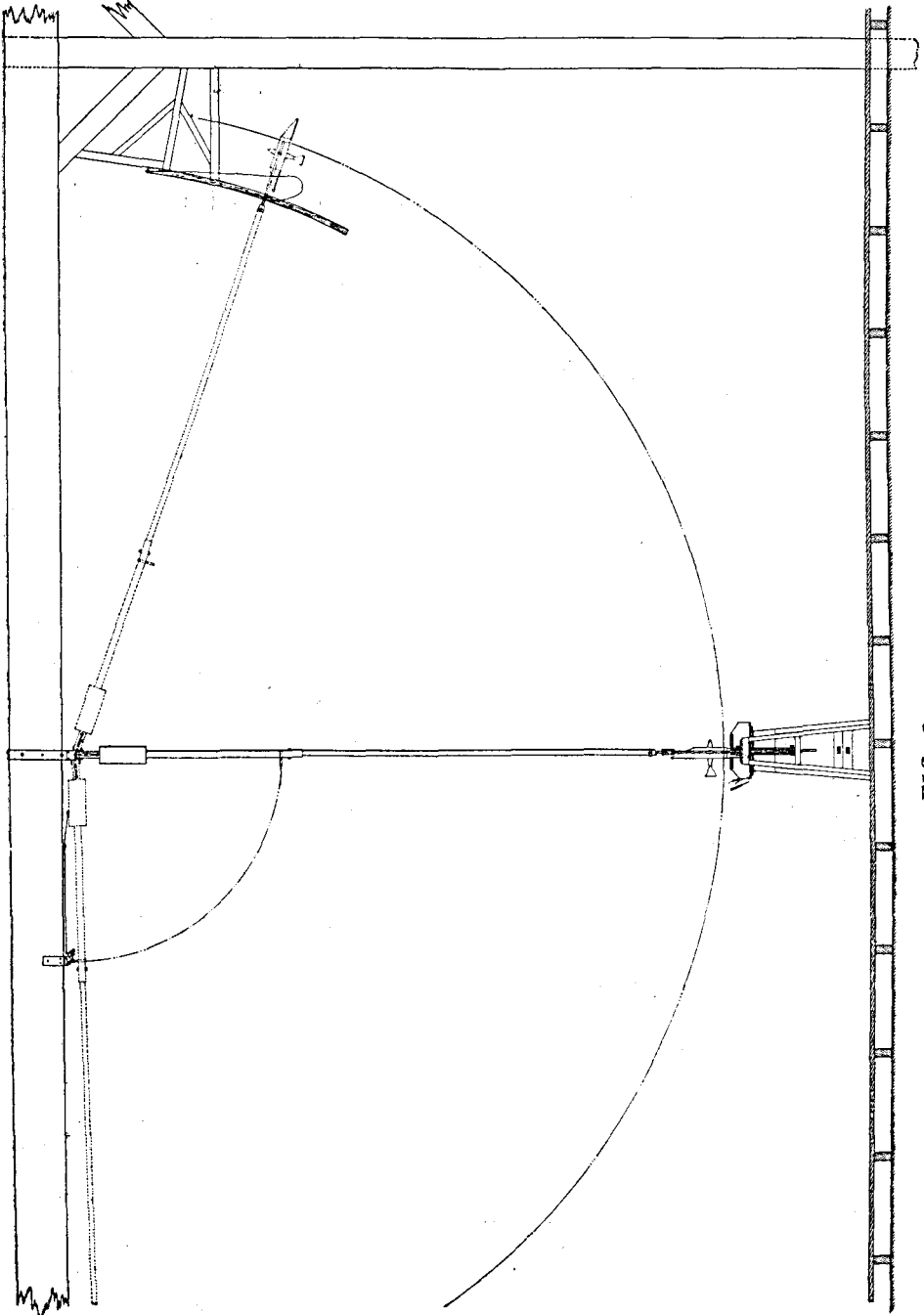


FIG. 3.