Further work upon this question may be forthcoming from experiments in a high-pressure tunnel. The force coefficients by the similarity law depend upon the ratio of the kinematic coefficient of viscosity to the product of speed times the linear dimensions. Now if we work out at the same value of this ratio for the model as we do for full scale the force coefficients will be the same. Usually the product speed times length is much smaller for the model than for the full scale and, since the same fluid is used in both cases so that the coefficient of viscosity will be the same, a direct comparison cannot be made. By using compressed air and a consequent increased coefficient of viscosity the effect of a change in the produce speed times length may be counterbalanced by the effect of change in that coefficient.

A wind tunnel 4 ft. square working in a compressed air chamber (10 atmospheres pressure) has already been constructed in America. There are very good reasons to believe, however, that the high-pressure tunnel is a most satisfactory method of studying the complex question of " Scale Effect " and considerable development might be expected in this direction in future.

DISCUSSION.

MAJOR GNOSSPELIUS.—I have listened to the lecturer with great interest, and fully agree with him as to the value of model work, for that is the only way to find anything out at a reasonable cost.

I am rather doubtful, however, as to whether you get a steady flow in the wind tunnels. It is uniform, I know, but is it also steady? I think that if one could check the wind tunnel results with those obtained by experiment in still air there would be quite a difference, and I do feel that this question of steady flow or otherwise is the weak point of the tunnels. It seems to me that it might account for some of the extraordinary effects which have been found by the N.P.L.

High-lift wings always suffer from this difficulty. I am not sure whether the top life curve which you get in a tunnel is not affected by the turbulence of the air.

I do not know whether you have studied holes in lift curves. It seems to me that if you could explain those holes it would go far to getting theories on rather a better basis. If we could only understand the differences in flow we should get much better success. I hope the N.P.L. will be able to solve this problem.

I thank Mr. Cowley very much for his interesting paper.

CAPTAIN SAYERS.—I thank Mr. Cowley very much for his interesting description of the apparatus and the type of work which has been done at the N.P.L. I

think perhaps I am one of those people who in the past have criticised them rather strongly, and should therefore like to emphasise that I am very glad to hear from Mr. Cowley that the N.P.L. are coming to realise that their experiments are not quite so useful to designers as they were thought to be. Personally I am inclined to think that the N.P.L. as a national institution ought to confine its work almost entirely to research into aerodynamic theory so as to provide a sound theory, and that aeronautical designers should conduct their own tests.

Regarding the possible effect of turbulence of flow in the wind tunnel, I have recently seen an American report of certain researches on wings, which were tested in a new wind tunnel having a non-turbulent flow. The results showed a lift coefficient of 80 per cent. less than when the same models were tested in another tunnel. The matter was referred to quite casually, as though it were an accepted fact that differences of turbulence would account for such a discrepancy. I should be interested to hear whether the N.P.L. have any evidence in confirmation of this American assumption.

MR. HOWARD-FLANDERS.—With regard to gliding and soaring flight, I should like to ask Mr. Cowley whether he is of opinion that turbulence of the air is a means of support in the flight of birds. Would it be possible to obtain ideas in this direction with a view to an increase of lift value?

MR. HOULBERG.—I should like to add my thanks to those of the other speakers for a very valuable lecture.

There was, however, one phrase used by the lecturer once or twice, namely, "ideal conditions," which I think is rather sweeping. The conditions in a wind tunnel may be ideal from the point of view of the operator, and ease of observation, but I doubt if the model is being tested under ideal conditions in view of the fact that it is tested in a stationary position, and therefore possesses no momentum, while air possessing momentum is driven past it, which is exactly the reverse of the conditions prevailing in actual flight. I have no doubt that this reversal of things causes a very grave discrepancy under certian conditions between wind tunnel and full-scale work, chiefly because the inertia of the moving air in the wind tunnel tends to rapidly damp out any disturbance or phenomena which occurs.

I am extremely pleased to notice that the N.P.L. has been considerably troubled by interference of the supporting spindle on the results obtained, which is a further indication of the difficulty of computing the total resistance of a machine by totalling the resistances of its various parts—a difficulty which designers have had to contend with for some time.

MR. MANNING.—I have found this lecture of very considerable interest. One thing I can say about the N.P.L. is that there is no doubt whatever that their general methods of testing are beyond all doubt accurate, and with their help the designer of certain types of aircraft can feel confident that the machines will behave more or less as they are expected to do.

With regard to turbulence, however, that is a question which the N.P.L. may probably have to tackle in the future. Constant pressure is an impossibility,

and it also occurs to me that there might be a variation of pressure due to the presence of the model in the tunnel. I do not know whether this is of importance. It is possible that any troubles which might arise from this cause would be of less importance, or probably non-existent, in the Eiffel, which is a type of tunnel that has always interested me. I hope that before long the N.P.L. will be able to continue their high-pressure tunnel. The information they have provided us with during the last few years has been very complete, but I think that the parts of an aeroplane about which we know least are probably the fin and rudder. There is a general tendency to run the weight up on these. The question of structure weight is of immense importance.

MR. COWLEY'S REPLY TO THE DISCUSSION.

I must congratulate the Institution on having members who can put so many interesting questions.

In reply to Major Gnosspelius I might say that I agree that the steadiness of flow presents a difficulty in wind-tunnel work. This subject has received considerable attention at the N.P.L. The tunnel disturbance in one instance was artificially increased by means of a net. It was found that a fairly large disturbance was required to give a measurable effect upon the aerodynamic forces on the model. Good streamline bodies were most sensitive, but aerofoils were very stable and I should say that the discrepancies between model and full scale on high-lift wings were not due to this cause. Everything points to the fact that the difference is due to the V.L. effect.

I agree with Capt. Sayers that the N.P.L. should devote its time almost entirely to research into aerodynamical theory and that test work should be left to the designers as far as possible. At present, however, this happy position seems very remote. The 80 per cent. errors mentioned by the American report I cannot explain as I do not know the report in question, but I can assure Capt. Sayers that we regard a tenth of that error as very serious at the N.P.L., unless, of course, it occurs near zero lift coefficient, where percentages mean nothing. The Americans are often guilty of giving incomplete facts in their reports, and sometimes do not record even the V.L. value for the test. Under these circumstances it is almost impossible to explain away discrepancies.

Mr. Howard Flanders' remark on gliding and soaring flights is very interesting, but all evidence seems to show that this phenomenon is due almost entirely to up-currents in the air.

With regard to Mr. Manning's remark on the effect of the presence of the model upon the general air pressures in the tunnel, I might say that this question has received full attention at the N.P.L. For ordinary tests the effect is small, and in wing tests can be allowed for by Prandtl's aerofoil theory with considerable accuracy. The corrections for an open type of tunnel, such as Eiffel's, are of the same order of magnitude as, but opposite in sign to, those for the closed type, at least as far as aerofoil corrections are concerned.

Written Reply to Mr. Houlberg.

At the time of the discussion I did not fully understand Mr. Houlberg's remarks. Evidently Mr. Houlberg considers that tests should be made with the air stationary and the model moving and not the converse as is done in wind-tunnel research. Apart from the question of turbulence and steady flow, which question was raised by Major Gnosspelius and Capt. Sayers at the meeting, there is no difference between the problems. It is merely a question of relative motion in the ordinary theory of mechanics. For example, if a body moving at 1,000 miles an hour strikes a body moving at 999 miles an hour in the same direction, the relative motion is the same as that obtained if the second body were reduced to rest and the first moved with a speed before impact of one mile per hour. I take it that Mr. Houlberg does not seriously contemplate the necessity of measuring the absolute velocities of the medium and of the body in space or relative to the Milky Way. This would be necessary if he wished to push his ideas.

A hearty vote of thanks to Mr. Cowley brought the meeting to a close.

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