AERONAUTICS.

TECHNICAL REPORT

OF THE

ADVISORY COMMITTEE FOR AERONAUTICS

FOR THE YEAR 1913-14.

(WITH APPENDICES.)

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REPORT FOR THE YEAR 1913–14.

To the Right Honourable H. H. ASQUITH, M.P., First Lord of the Treasury.

SIR,

THE work of the Advisory Committee for Aeronautics has continued during the past year on the lines followed in preceding years. A general account of the results achieved is given in the present Report. Full details of the experimental work will, as usual, be included in the Technical Report.

No change in the *personnel* of the Committee has occurred since the date of the previous Report. The names of the members of the Committee during the year 1913–14 are given on the opposite page.

The chief feature of the experimental work of the past year is the advance which has been made in the study of the conditions affecting the stability of an aeroplane, particularly as regards lateral stability. It is hoped that the more exact knowledge of the conditions necessary to secure stability which has been obtained from the experiments and investigations carried out at the National Physical Laboratory may be of direct value to designers and may lead to a definite improvement in the safety of the aeroplane.

The question of the strength of construction desirable on aeroplanes has also received special attention. This was one of the matters referred by the War Office to the Advisory Committee for further consideration and report, as recommended in the Report of the Committee on Accidents to Monoplanes. The Technical Report for 1912–13 contained a preliminary note on methods of calculation of the stresses in aeroplane wings ; further reports relating to strength of construction have been presented to the War Office during the past year and are referred to later.

Among other matters referred to the Committee by the War Office as arising out of the same report, the question of engine breakages has continued to receive attention. A number of fractured parts of engines have from time to time been submitted to the Committee for investigation and report, and these have been examined in the Engineering and Metallurgical Departments of the National Physical Laboratory. It is satisfactory to the Committee to know, from communications received from the War Office, that the reports made by them have received attention from the makers of engines, and have led to improvements in construction and design.

Equipment for experimental work at the National Physical Laboratory.—The 4-foot channel described in last year's Report, the design of which was the outcome of an extended research on model channels, has proved very convenient in use, and the various branches of research for which it is employed have all been satisfactorily advanced during the year. The erection of the 7-foot channel has made good progress ; the channel itself is nearly completed, and the construction in the

Laboratory workshops of the weighing mechanism for the determination of the air forces and moments on the models investigated is far advanced. The air current will be produced by a 10-foot propeller of ordinary type, driven by a 60-h.p. motor, and it is hoped that it may be possible to obtain satisfactory uniformity of flow up to speeds of 60 feet per second.

Owing to the urgent demands from both the naval and military departments for experimental data with regard to a large number of questions in connection with airships, aeroplanes and seaplanes, the Committee decided early in the year to provide a third air channel 3 feet square in section, with a somewhat simplified weighing mechanism, in which the simpler measurements, such as those of head resistance, lift, and moment about an axis transverse to the model, could be conveniently made, leaving the 4-foot channel somewhat more free for investigations of a more complex character involving the determination of all the forces and moments acting on the model. A small fund has been provided each year by the Treasury to enable demands for additional work, not foreseen at the time of framing the estimates, to be met, and it was found possible to provide the cost of this 3-foot channel from the balance available under this head.

A series of tests has been made on the same model in the 4-foot and 3-foot channels with a view to a comparison of the accuracy attainable in the two channels. The agreement obtained is regarded as very satisfactory. The 3-foot channel has now been in regular use for some months.

Some additions to and modifications in other existing apparatus have been made, which are referred to in later sections of this Report.

An important matter in connection with constructional work in Aeronautics, which has engaged the attention of the Committee from the time of their appointment, is the production of light alloys having the properties needed for various purposes in the manufacture of aircraft. Reports on light alloys, including a number of alloys specially investigated at the National Physical Laboratory, were included in the Technical Reports for 1909–10 and 1912–13. Certain of the special alloys produced were of a very promising character, but in some cases difficulties in rolling them occurred in practice. The Committee felt that further progress in the manufacture of light alloys in this country would be greatly facilitated by the provision at the Laboratory of means to carry out the rolling of alloys under circumstances which would permit of the variation and accurate observation of the attendant conditions—regulation of temperature, speed of rolling, &c. The matter was held by the naval and military authorities to be of great importance in relation to aeronautics, and application was accordingly made to the Treasury, in connection with the estimates for the year 1914–15, for the funds necessary for the provision of an experimental rolling mill at the National Physical Laboratory. Intimation has been received that the sum required will be included in the estimates, and this valuable addition to the equipment for the investigation of light alloys will be provided as early as possible. The building has already been commenced and orders have been placed for the machinery.

Experimental investigations in connection with airships.—Some further tests have been made of the resistance of airship models. These included the determination of the resistance of a model of an airship of the Astra-Torres type; and of a model of ordinary form, but with considerable curvature of the centre line. In both these cases the head resistance was found to be only slightly greater than that of the model of ordinary shape, undeformed, of equal length and volume; and the percentage increase in resistance was found to become less as the relative air speed was increased. Some experiments were also made on the second model with other deformations.

A series of tests was made to investigate the shielding effect of wind screens of different heights, placed in various positions and at different angles in front of the entrance to an airship shed. An airship model (Parseval) was placed behind the screen in the position it would normally occupy when about to enter the shed, and the components of the wind forces on it were measured for various directions of the wind. The investigation included the determination of the best position of the shed relative to the most prevalent wind.

Preliminary experiments showed that plane vertical screens were as efficient as screens with curved tops. The conclusions arrived at finally were that the centre line of the shed (drawn towards the entrance) should make an angle of 55° with the direction of the most prevalent wind; that the best dimensions for the screen were:—Length 6·6 D, height 1·07 D, "D" denoting the diameter of the airship; that the end nearest the shed should be in the plane of the entrance face of the shed, and at a distance 1·7 D from the centre line of the shed, with the other end of the screen at a distance 1·5 D from the centre line. The space between the shed and the near end of the screen should be blocked. The dimensions of the shed considered were:—Length 7 D, width 1·43 D, height 1·71 D. It was found that such a screen would afford efficient shelter for winds varying 55° on either side from the direction taken as that of the most prevalent wind.

A series of tests has also been made on a model of an airship car, with various modifications, to determine the head resistance, and the component forces when the car was inclined at various angles of pitch. The distribution of wind velocity above the cockpit under different conditions was also investigated to determine the best arrangements for shielding the crew from the wind.

Experiments on models of aeroplane wings.—Further experiments have been carried out during the year on a number of individual models of aeroplane wings of different section. The majority of these have differed only slightly in section from the form selected as the best from the results of the previous experiments described in the Report for 1912–13. The tests have been mainly directed to determining the effect of small modifications found desirable, from considerations of strength, in the design of wings for different types of machine. Details are given in an Appendix to this Report.

The effect was tried of a modification suggested by M. Constantin, which consisted in the hollowing out of the upper surface towards the leading edge. When the modification was made on a form of good efficiency the tests showed that the maximum lift and lift/drift were both reduced. In some less efficient forms of wing M. Eiffel found that an improvement was effected by the modification.

Particulars were given in the previous Report of tests of an aerofoil at different wind speeds, with a view to the determination of the effect of variation of speed and of dimensions on the aerodynamic properties of the aerofoil. It was pointed out that both theory and experiment showed that changes due to variation of velocity or of linear dimensions were so inter-related that any change in the product of velocity and linear dimension, whether due to alteration of the one or the other of these two quantities, would produce the same change, if any, in the aerodynamic properties of the aerofoil. Experiments were further described which showed that an increase in this product *vl*, beyond the value at present attainable in the laboratory experiments, would probably be accompanied with an increase in the efficiency of the aerofoil, but without appreciable change in the lift coefficient. An estimate of the increase in efficiency corresponding with the change from the model experiments to the conditions obtaining for an aeroplane wing in flight was also given.

The earlier experiments as to the effects of change of wind velocity have been confirmed by similar experiments on other aerofoils, while additional confirmation has been obtained from experiments on two exactly similar aerofoils of different linear dimensions. Further evidence as to the amount of the change in efficiency with increase of *vl* beyond the limits at present attainable will, it is hoped, be obtained when the 7-foot air channel is completed. The more recent experiments included an investigation of the movement of the centre of pressure with change of speed. It had previously been assumed, since such movement would depend mainly on variation of the lift coefficient, the change in which is small at the higher experimental speeds, that the change in the position of the centre of pressure with change of speed would be negligible in practice in full scale machines, or in passing from experimental results at the higher speeds to those for the full scale wing. This assumption was shown to be justified, so far as could be inferred from the general character of the results obtained.

Further experiments have been made on aerofoils with reversed curvature towards the trailing edge. These were in continuation and amplification of those previously described. The portion of the wing reflexed extended to a point distant 0·4 of the chord from the trailing edge. It was found possible to produce a wing section in which the centre of pressure was practically stationary over the ordinary range of flying angles, but this involved a loss in maximum lift of about 18 per cent., and of about 15 per cent. in maximum lift/drift.

Results which may be of considerable interest to designers have been obtained in experiments carried out at the request of the Superintendent of the Royal Aircraft Factory on wings of which the section can be varied during flight. The variation is obtained by rotation of the rear portion of the wing, of breadth 0·4 of the chord, about hinges in a line parallel with the leading and trailing edges.

This movable portion of the wing may, for convenience of reference, be called a "flap." Tests were made with the flap turned through various angles up to 90° on either side from its normal position. The results show :—(i) That with the flap turned down an increase in the maximum lift coefficient can be obtained, which would enable the landing speed to be reduced ; (ii) that with the flap turned a few degrees upwards the drift is diminished, which would be of assistance in getting up speed over the ground, and make it possible to rise after a shorter run ; (iii) that with the flap turned downwards through a large angle the drift is greatly increased, so that the flap would act as an air brake and reduce the run after alighting ; (iv) that the efficiency at speeds above that corresponding with the maximum ratio of lift to drift could be increased, enabling the upper limit of the speed range to be raised ; (v) that the climbing speed is improved. These experiments have only recently been completed and appear to show that the use of such flaps might be attended with appreciable advantages ; under certain conditions, however, there appears to be a region of instability in the air flow, and the question of their application in practice will receive further consideration. The effect of rotation of the flap on the movement of the centre of pressure has been examined. Determinations of the moment about the hinges of the air forces on the flap, necessary for the design of a controlling mechanism, are now in progress and the results will be given in an Appendix to this Report.

Experiments are proceeding at the request of the Director of the Air Department of the Admiralty on the effect of rear flaps when used as ailerons on the upper planes only of biplanes. This question is of importance for seaplanes. If ailerons are used on the lower planes they are liable to be damaged by the water.

Reference may also be made here to experiments which have been carried out as to the effect of a side wind on an aerofoil, and also on a similar aerofoil with a dihedral angle and having the angle of incidence reduced towards the wing tips. The measurements made included the determination of the longitudinal and lateral forces, and the rolling and yawing moments for various inclinations of the side wind, *i.e.*, for various angles of yaw.

Experiments on models of complete aeroplanes.—In the Technical Report for 1912–13 particulars are given of measurements of the forces and moments on a model of a monoplane of Blériot type, when placed in various positions oblique to the relative wind. With a view to a more complete discussion of the theory of stability in its application to this model, the "rotary coefficients" for the model were also determined. During the past year a similar series of experiments has been in progress on a model of a biplane. The model is generally similar to the B.E. type of machine, and is complete except for a few details, such as the bracing wires to the wings, and the propeller. The model lends itself to a greater range of experiments than the Blériot model, owing to the fact that it has a movable elevator and rudder, and it is proposed to investigate the stability of this model under a wide range of conditions, with the elevator and rudder in positions differing from those corresponding with normal horizontal flight.

Several series of experiments have been carried out on this model. Tests were first made to determine the effect of variation of wind speed. The general results were similar to those found for an aerofoil alone: there is a continuous increase in the value of the lift coefficient and of the ratio of lift to drift, and a continuous decrease in the value of the drift coefficient as the speed is increased. At the higher wind speeds the lift coefficient again approaches a limiting value.

The subsequent experiments have been concerned mainly with the determination of the forces and moments on the model when fitted with tail planes of different design, with the elevator set at various angles. The numerical data obtained are of great importance in dealing with the question of the stability, and of the effective control of the machine. It was found that the righting moment due to the tail was reduced by about 50 per cent. owing to the wash from the main planes. This effect was found to be practically independent of the type of tail plane adopted. It must be remembered in this connection that a large part of the righting moment due to the tail plane is required to overcome the negative moment due to the movement of the centre of pressure on the main planes. A careful examination is now being made into the character of the flow round the model to determine in what position it is desirable to place the tail so as to obtain the maximum effect.

To complete the observations on this model necessary to enable its longitudinal stability to be investigated, measurements have been made on it of the pitching moment due to pitching (rotary coefficient). The effect of the tail plane and elevator in damping out pitching oscillations is greatest in the neutral position of the elevator, and is appreciably reduced for settings of the elevator up to about 15° on either side of the neutral position. Different elevator settings are required to give the variations of speed obtainable within the speed range, and the data obtained in these measurements are of importance in the study of the stability of the machine under the various conditions of flight.

It is proposed to include in the Appendices to this Report a complete account of the determinations of forces and moments, and of the rotary coefficients, made on this model, with details as to the results for the various tail planes tested, and a full discussion of the conditions of longitudinal stability for various settings of the elevator.

Tests on aeroplane bodies.—A number of tests have been made on bodies, to determine the forces and moments acting on the body when oblique to the direction of the relative wind. Some of these tests relate to special forms of body designed at the Royal Aircraft Factory. In one case the body was fitted with fins and a rudder, and the effect of the addition of the fins and rudder was examined, as well as the action of the rudder when set over 10°. Another model tested was provided with a tail plane, elevator and rudder, and in addition was fitted with flaps at the sides and underneath, hinged to the body, to serve as air brakes. Tests on this model were made for various settings of the air brakes, and for different rudder angles. The measurements showed that with the rudder in its zero position the air flaps produced a considerable increase in the longitudinal force, with very little effect on the other forces and moments, which was exactly the result aimed at in their design. The brakes would thus be of value in reducing the velocity on alighting and in running over the ground. For rudder angles up to about 25°, the opening of the brake flaps was found to reduce the yawing moment due to the rudder, and the lateral force, by about 15 per cent. and by a smaller amount at greater rudder angles.

Tests have been made on two bodies of the same plan form, but of circular and square cross section, to obtain information as to the amount of difference in the values of the forces and moments due to this change in section. Details of the results obtained are given in an Appendix to this Report.

Continuous research has also been in progress with a view to determining the effect of various modifications of the body for shielding the flier and for other purposes. The tests have been made both on round and square bodies : the square form has manifest advantages as regards ease of construction, and it is possible that the fin effect of the square body may be utilized in design to assist in securing stability. The series of tests made for each form has included tests of the body alone ; of the body with various cockpit openings ; of the body with cockpit opening and flier in position, with and without shields. Two different forms of shield *behind* the flier have been tried, and each of these has also been tested in combination with three forms of shield in front. The velocity of the wind immediately over the flier's head was measured in each case, and the distribution of the air velocity in the neighbourhood of the body and shields has also been explored, with a view to determining the form of shield which while affording adequate protection to the flier would offer minimum head resistance to the wind.

Tests on rudders.—These have been made in connection with the tests on bodies and have been already referred to. They furnish information as to the yawing moments obtained, and as to the amount of interference of the body with the rudder for certain positions of the machine. The amount of the lateral force on the rudder is also given by the experiments.

Tests on tail planes and elevators.—The investigations on bodies and on the models of complete aeroplanes fitted with tail planes and elevators have now furnished a considerable amount of information with regard to the forces and moments on the machine due to their action. These are, of course, of primary importance for purposes of design, as indicating how the required degree of stability and of control is to be obtained. Reference has already been made above, in the section relating to tests of complete models, to the effect on the tail and elevator in a biplane of the wash from the main planes. The effect may be regarded as equivalent to a reduction in effective area of about 50 per cent. : to this point also it is desirable that attention should be specially directed. As previously stated, an investigation is proceeding with a view to determining the best disposition of tail plane and elevator, in view of the conditions of flow found to exist.

The moments acting on the elevator alone, about the hinges connecting it with the tail plane, have also been previously determined. These are needed in connection with the design of the controls.

The data obtained from these experiments on tail planes and elevators are of fundamental importance in the investigation of the stability of the machine. The final criteria necessary for the design of the tail plane and elevator of an aeroplane must, of course, be derived from the results of the stability investigation; and the data obtained from the experiments and calculations given in the Appendices to this Report will enable design to proceed on a satisfactory basis.

Stability.—In the Technical Report for 1912–13 a full account was given of the manner in which the experimental data obtained from wind channel experiments may be applied in the investigation of the stability of a given type of aeroplane. The data required include measurements of the forces and moments on a model of the machine when its attitude is varied in any manner from that corresponding with normal flight, so that it takes up different positions oblique to the relative wind; and also determinations of the "rotary coefficients," which indicate the effect of the air current in damping or accentuating any rotations which may be set up. The methods employed for obtaining all these data were described, and the manner in which they are employed in the examination into the stability of the machine explained. The various ways in which instability may arise were investigated, and a method of determining the degree of stability or instability in each case, by the calculation of a "stability factor," was indicated. The experiments and calculations were fully described and reproduced for one machine of the Blériot monoplane type, and it was pointed out to what extent the conclusions arrived at from the tests made on this model are of general application. Some special questions were also examined, including the effect of side wind on the propeller, the influence of the gyroscopic action of the propeller and rotating engine, which was found to be unimportant, and an effect of upward gusts. Both the lateral and longitudinal stability were investigated.

The continuation of the work on stability during the past year has followed two main lines. The calculations based on the experimental data already obtained for the Blériot model have been extended and applied to determine the effect of different types of initial disturbance on the subsequent motion of the machine. Further, the behaviour of the machine, so far as motion in the plane of symmetry is concerned, when moving through a gusty wind without alteration of the controls, has been completely analysed, the wind fluctuations being taken direct from the record of an anemograph. In the preparation of the charts which show the disturbed motion of the aeroplane a number of points of interest and importance have been investigated.

The experimental work has also been continued on a second model—of a biplane. This has already been referred to in the section relating to tests of complete models. The necessary data have been obtained for this model, with different settings of the elevator, to enable its longitudinal stability to be investigated over the whole of its range of flying speeds. The full discussion of these results is given in this volume.

The results arrived at from the stability calculations have been applied in the design of small models for experiments in free gliding flight. These experiments afforded very satisfactory confirmation of the conclusions arrived at from the calculations. It was found that all the different types of instability could be reproduced, in the manner anticipated, in the models, and that the model could be made both laterally and longitudinally stable by proper attention to the considerations brought out by the analysis.

In view of the importance of these investigations it may be useful to summarise briefly the matters which have been examined and the conclusions which have so far been reached.

As regards longitudinal stability no great difficulty is usually found in practice in securing the degree of stability desired. If instability occurs it is usually due to insufficient tail area. The insufficiency may be such that there is no restoring moment when the machine becomes inclined to the wind (static instability), or an increasing oscillation may be produced owing to the lack of sufficient damping of the motion (dynamic instability). The oscillation in the latter case is a slow oscillation, with a period of about 20 seconds, the machine following what has been termed by Mr. Lanchester a "phugoid" path, and consists in an up-and-down motion combined with a rotation about a transverse axis. In both cases the amount of tail area required is necessarily affected by the position of the centre of gravity of the aeroplane, while the dynamic stability is also dependent upon the moment of inertia about a transverse axis.

The investigations show that slight increase in the area of the tail plane beyond that corresponding with zero restoring moment (neutral static stability), is usually sufficient to ensure dynamic stability. It is probable that the increase necessary is so small that when determined for a few typical machines it will in future only be necessary to determine the static restoring moments, which will appreciably diminish the labour involved in the experimental work.

As regards the static restoring moment it is of great importance to note, as already pointed out, that in a biplane this may be considerably reduced by the wash from the main planes, and the amount remaining may be little more than sufficient to counteract the effect of movements of the centre of pressure on the wings. It may be found possible to diminish this effect by the adoption of a more favourable position for the tail plane, otherwise it would appear difficult to obtain any appreciable amount of restoring moment by the use of a neutral tail unless of excessive area. In such case the necessary compromise would be to use a large tail set at a slightly negative angle, thus reducing somewhat the efficiency of the whole machine. On account of this effect of the wash of the main planes and of the possible influence of the slip stream of the propeller it will probably be necessary to determine the static moment experimentally for any new type of machine.

Making use of the data obtained in the experiments described in the previous Report, an investigation has been made to determine the subsequent motion of a stable aeroplane after it has encountered an initial disturbance of one kind or another. The disturbances contemplated are such as would be experienced by an aeroplane suddenly entering air moving in any direction relative to the air in which it was previously travelling, or would be produced by sudden alteration of the engine speed, or of the position of the elevator. It is sometimes suggested that the results obtained from the theory of stability are of little practical value, since they are based on the assumption that flight takes place in air moving with uniform velocity, which is rarely the case in practice. It is, however, of course, possible to apply the methods employed in the stability theory, and to use the results obtained by it in examining the behaviour of an aeroplane flying through disturbed air, and the applications of such methods which have been made will, it is thought, be of great interest to all who are concerned with the theory or practice of flying.

Taking first the case of an increase in the relative wind, supposed horizontal and in the direction opposite to that in which the machine is moving, the subsequent motion for a stable machine may be briefly described as follows. The machine first begins to lose speed, to climb and to turn, taking an upward inclination. These motions all tend to reduce the speed further until after about 5 seconds the machine has reached its normal flying speed relative to the new air current, has ceased to climb and turn, but is flying tail down. The machine then begins to fall and the tail to lift. The oscillation is repeated three or four times with diminishing amplitude, until after about 40 seconds the aeroplane has taken up the horizontal velocity of the gust. These disturbed motions are slow and are easily controlled by the flier. Further calculations, in which account is taken of an appropriate motion of the elevator, show that the oscillation can be at once checked by its use.

If the aeroplane enters a vertical downward current it will immediately begin to take up the vertical motion of the air, and to acquire, in addition, a positive angular velocity in pitch which will make it turn into a tail-down position and finally lose speed. These preliminary changes take place very rapidly, and at the end of a second the aeroplane has ceased to move normally and has reached its maximum inclination to the horizon. Its forward speed continues to decrease for a few seconds more, and the subsequent history is the same as for the disturbance which follows a horizontal gust. The initial rapid movement in this case is of a type likely to cause some discomfort to the flier.

Analysis of the case in which an aeroplane enters a region in which the air is in rotation shows that the rotational motion of the air is very rapidly taken up, but the data necessary completely to determine the subsequent motion are not yet available.

When the elevator is put down the aeroplane rapidly reaches its maximum angular velocity and the machine turns so that it tends to dive and gain speed, the machine falling slightly to acquire the necessary energy.

A further illustration of the use and value of the methods employed in the calculations are also given in an Appendix to this Report, in the form of a complete analysis of the motion, in the plane of symmetry, of an aeroplane flying in a wind in which the horizontal velocity varies continuously in the manner shown by an actual anemograph record. The record was one specially taken at the Laboratory some time since, in connection with experiments relative to the wind pressures on engineering structures, with a very open time scale (2 inches to the minute); the ordinary record taken for meteorological purposes does not show the more rapid variations in sufficient detail for this purpose. The analysis shows that the machine accommodates itself very readily to the wind variations, and that no conditions ordinarily occurring in a gusty wind would cause any serious difficulty to a stable machine. The fluctuations of the speed of the aeroplane are nearly of the same order of magnitude as those of the wind. The changes in the angle of incidence are comparatively small; the variations in the inclination of the machine to the horizontal are greater, and the consequent climbing and diving tend to reduce the speed fluctuations, and help somewhat towards the maintenance of a correct mean speed.

The results that may be obtained by manipulation of the controls in passing through the same wind variations are also discussed in this volume, and the limitations attaching to the use of any control, even one of the automatic type which will act as if forewarned of the nature of the approaching gust.

The problem of lateral stability is of a more complicated character, and it is probably the conclusions arrived at in this connection that will have the greater interest for designers. The analysis, based on the experimental data obtained at the National Physical Laboratory, enables the influence of the various factors, *e.g.*, dihedral angle, fins or equivalent fin surface, fin action of the propeller in a side wind, &c., to be estimated, and shows the method to be followed to obtain the requisite degree of lateral stability. It becomes clear that somewhat careful adjustment is necessary to avoid on the one hand the type of instability characterized by the spiral dive, and on the other the condition which leads to an increasing oscillation in roll and yaw. It is seen that without the guidance afforded by theory and experiment lateral stability might be found by no means easy to secure, as is evidenced by the fact that nearly all the machines at present in use are spirally unstable, and depend on the use of the controls for maintenance of their correct attitude.

The three types of lateral or "asymmetric" instability which may occur, of which two have already been referred to, are—

(i) Spiral instability: after any initial turn the machine tends to side-slip inwards and to overbank, thus increasing the rate of turning, and tending to accentuate more and more the overbanking and side-slipping.

(ii) Tendency to an increasing oscillation in roll and yaw with accompanying lateral motion.

(iii) Tendency to turn tail foremost.

(ii) and (iii) differ from each other in the same way as the two types of longitudinal instability which have been spoken of as dynamic and static; (iii) is the case of static instability, when there is no restoring moment tending to bring the machine back if it yaws, and is due to lack of sufficient tail fin or rudder area. In the dynamic case the tail fin area is still insufficient to check an oscillation in yaw and roll; the occurrence of this type of instability is dependent on several factors, including the moments of inertia of the machine about the longitudinal and vertical axes. It is characterized by the fact that when the machine yaws it takes a bank which is not that appropriate to the turn: this is one feature which distinguishes it from spiral instability. It appears from the analysis that very little increase of rudder area above the minimum necessary to give a static restoring moment is usually sufficient to give dynamic stability.

Cases (i) and (ii) are in many respects opposed, the treatment necessary to correct the one type of instability tending to produce the other. Thus, too large a rudder leads to spiral instability, whilst too small a rudder may produce the increasing oscillation. If the rudder is so large as to give spiral instability, two remedies suggest themselves consistent with leaving the rudder area, and hence the flier's control, undiminished; the dihedral angle of the wings may be slightly increased, or the depth of the body forward of the centre of gravity may be made greater. Increase of the dihedral angle is the equivalent of the introduction of a relatively large fin above the centre of gravity, and care must be exercised in determining the amount necessary, or the unstable oscillation may again be produced.

It is clear from the foregoing that there must exist a condition of maximum lateral stability in which the machine is equally unlikely to become unstable either by a tendency to taking a spiral dive or to acquiring an increasing oscillation. It is usually, but not always, possible to produce this condition by adjustment of the rudder (tail fin) area alone; the adjustment may, however, depend on an extremely accurate knowledge of the resistance derivatives of the machine. In order to be able to obtain maximum lateral stability without too much difficulty it will in general be necessary to adjust both the rudder area and the dihedral angle.

It may be remarked that the motions involved are not rapid, and no additional discomfort to the flier is likely to arise from the use of such dihedral angles as will be necessary to produce sufficient lateral stability.

As in the case of the tail plane and elevator the slip stream of the propeller and the presence of the body may affect the efficiency of the rudder. Some experimental data relative to this are given in an Appendix to this Report, and the matter will be further investigated as early as possible.

Apart from the effect of the slip stream, the action due to the lateral force on the propeller when the machine is oblique to the relative wind is of considerable importance in connection with lateral stability. This action, which also occurs when the machine is turning quickly, can be represented as due to an equivalent fin held in the position of the propeller. It is thus evident that in considering the stability of an aeroplane the position of the propeller is of some importance, and if the propeller be in front of the centre of gravity, it should be compensated by an additional fin behind the centre of gravity. Again, the fin action of the propeller is liable to be removed by its stopping, and a margin of stability must exist to cover such variations.

In general, a margin will be necessary to allow for variation of the flight speed, which affects the lateral as well as the longitudinal stability, and also for turning, climbing, &c. The further work on the subject will be directed towards the provision of material which will enable a designer to choose any amount of stability which may be desirable for an aeroplane to cover all the ordinary fluctuations of speed and altitude during flight.

The behaviour of an aeroplane when subjected to various types of lateral disturbance will be dealt with in the Technical Report, as in the case of disturbances affecting the longitudinal stability. A full discussion of the question of maximum lateral stability will also be there given. The calculations to determine the effect of an initial disturbance were made for the Blériot model, which was found to exhibit spiral instability; the characteristics of this motion only develop slowly, however, and do not affect the conclusions arrived at with regard to the other effects of the disturbances. The motion in each case is compounded of an oscillation with a period of about six seconds somewhat heavily damped, a very heavily damped "subsidence" and a slowly increasing "divergence," or departure from steady motion, the last being the origin of the spiral instability. All disturbances are made up of combinations of these in varying proportions, together with a relative change of the phase of the oscillation. These variations correspond with the four arbitrary constants which occur in the solution of the differential equation of the motion, two of these constants determining the amplitude and phase of the oscillation. The oscillation is a complicated motion, the machine following a sinuous path about a mean straight line, accompanied with yawing and rolling, the bank being always opposite to that appropriate to the turn. The subsidence has its origin in the couple produced by an increase of the angle of incidence of the relative wind on the downward moving wing, and the accompanying reduction of angle of incidence on the upward moving wing; the effect is very rapid, and the amplitude of a disturbance of this kind is reduced to half its value in about a tenth of a second. In the case of the divergence, for the Blériot model, the time required for the amplitude to double itself was found to be about 44 seconds. This leaves ample time for the pilot to correct the tendency to unstable motion, provided he is able to exercise control.

The disturbances considered in the discussion given in the Appendices to this Report are those due to: (i) a side wind striking the aeroplane; (ii) an initial angular velocity in roll; (iii) an initial angular velocity about the vertical; (iv) sudden banking. In addition, the effects of warping, and of use of the rudder are discussed. For details of the particular combinations of the types of motion above considered which follow these several disturbances reference must be made to the Technical Report.

Catastrophic instability.—A brief account is also given by Mr. Lanchester in an Appendix of what he has termed "catastrophic" instability, which he has discussed in a paper read before the British Association at Birmingham. It is possible that an aeroplane may be so designed as to have two flight attitudes, in each of which the flight is stable in the more limited mathematical sense, in which the theory is restricted to *small* oscillations: one the normal attitude, the other with the machine upside down. If now the machine be struck, say by a downward gust, it may, if the strength of the gust be sufficient, change suddenly from the one condition of flight to the other; the machine is then catastrophically unstable. It is not suggested that this form of instability is very likely to occur, but it must not be ignored; features likely to tend to produce it are the use of a loaded tail, or of a tail having an aspect ratio which is low as compared with that of the main planes. If the tail be made as nearly as possible neutral, and if it be given an aspect ratio approximately equal to that of the wings, little danger from this cause is to be apprehended.

Strength of construction.—The question of the stresses which the wings of aeroplanes might have to bear, and the strength of construction necessary, arose in connection with the inquiry into accidents to monoplanes, and was referred by the War Office to the Advisory Committee for further investigation and report. The matter has received continuous attention, and reports on the tests to be applied to aeroplanes before acceptance, on the calculation of the stresses on aeroplane wings, and on the factor of safety desirable have been presented to the War Office and the Admiralty.

A preliminary note on methods of calculating the stresses in the spars of aeroplane wings, which deals especially with the determination of the added stresses due to deformation of the spar caused by disproportionate strains in the lift wires, is printed in the Technical Report for 1912–13. The more general question of the amount of load to be allowed for in stress calculations, and the factor of safety desirable, has since received very careful consideration. When flying horizontally in still air, the load borne by the wings is approximately equal to the weight of the machine.* When the machine is struck by a vertical gust, the stress in the wings may be increased from three to four times. Banking introduces a further increase in the "load factor"—that is, the factor by which the weight, or normal load, must be multiplied to give the load actually borne. Again, when a high velocity is reached during a steep dive and the machine is then "flattened out," it is possible that the total load on the wings may be six times as great as in normal horizontal flight, or even more than this. Such stresses would not arise under ordinary circumstances in a machine flown with reasonable care, but the conditions under which they would occur may at any time be brought about by temporary loss of control,

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* The weight of the wings should strictly be subtracted. Some load may also possibly be taken by other parts of the machine.

causing, say, a vertical dive, followed by an attempt at recovery. The possibility of a load factor as great as six has also been confirmed by careful calculations made both at the Royal Aircraft Factory and at the National Physical Laboratory, using information obtained from the experimental work on stability, in which due consideration is given to the time required for the operation of flattening out, and the muscular effort demanded from the flier.

In view of these facts the Committee have felt it necessary to recommend that an immediate effort should be made to obtain increased strength in the construction of machines. They have suggested that in determining the stresses in a wing for purposes of design, or acceptance, the calculations should be made for a load equal to three times the weight of the machine. The strength provided for in the design must include in addition allowance for a factor of safety in the usual engineering sense, to cover unforeseen defects of material or of construction. It would appear impossible at present to attain in aeroplane construction a factor of safety comparable with that usually allowed in the design of engineering structures, and reliance must be placed on careful inspection and test of all materials and parts. The Committee have recommended, therefore, that no machine shall be accepted in the future for service unless the factor of safety is at least two, and have expressed the hope that aeronautical constructors may find it possible, within a comparatively short period, to allow in design for an increase in the value of this factor up to four. A machine with a factor of safety of four, using the term in the sense here employed, would be designed to sustain a load equal to twelve times its own weight.

The Committee realise, however, that there are circumstances, especially in the case of Naval and Military aeroplanes, in which the advantages to be gained by the utmost saving of weight cannot be neglected and which may preclude, for a time at least, the attainment of values of this factor so high as have been suggested.

It is proposed to investigate further the questions involved in the realisation in design of the structural strength which is held, on general grounds, to be desirable.

Meanwhile, it may be remarked that attention is specially called in the Report to the fact that the exceptionally high stresses referred to do not occur under ordinary conditions of flight, provided a machine is carefully handled, and cannot arise to anything like the same degree in the less efficient types of machine.* In accordance with the recommendation of the Monoplane Accidents Committee, the Committee have expressed the opinion that steep dives should be avoided, whether the engine is on or off, and that so far as is possible care should be taken in descending that a speed exceeding by more than 15 or 20 per cent. the upper limit of the speed range is never reached.

The Committee regret that the importance of the considerations brought forward in their Report has since been emphasized by fatal

* By a "less efficient" machine is here meant one which flies normally under conditions corresponding with a high lift coefficient and which cannot attain the maximum speed now reached by some aeroplanes. Such "less efficient" machines have a relatively limited speed range.

accidents to members of the Royal Flying Corps. In one of these conditions appear to have arisen of the character contemplated in the Report, likely to cause stresses in the wings far exceeding those borne under ordinary conditions. In view of all the knowledge now available the factor of safety which the Committee have recommended as desirable cannot be regarded as too high, especially in the more efficient machines which have a wide range of flying speeds.

The suggestion has been made that the stresses would be appreciably diminished by the use of flexible wings, and some investigations have been commenced from this point of view with the object of ascertaining to what extent the employment of flexible wings might reduce the maximum load occurring under such conditions as have been already indicated. There are other problems, however, connected with the use of flexible wings, particularly their effect on the stability of the machine, which would need to be thoroughly investigated before their adoption could be recommended. Some of these problems present no small difficulties, and it does not appear probable that any immediate solution will be obtained.

Propeller tests.—The tests of propellers described in the Technical Report for 1912–13 provided a general confirmation of the theory which has been largely adopted in the design of aeroplane propellers, that the blade can be regarded as an aerofoil, and that the best form of blade section and the corresponding angle of attack can be derived from the known data for aerofoils. The fundamental law was also established that if the ratio of the forward speed to the revolutions be kept constant the thrust and torque will vary as the square of the forward speed: this result is usually known as the "square law." In view of the principles thus determined it has not been found necessary to devote so much attention to propeller research during the past year.

Some interesting results have been obtained in tests of a four-bladed propeller designed at the Royal Aircraft Factory. The blades were very narrow as compared with those of the usual two-bladed propeller, giving the equivalent of a high aspect ratio for an aerofoil; and the efficiency was found to be correspondingly high, the maximum efficiency being 81.2 per cent., while at a slip of 35 per cent., which was about the value at which the propeller would work in practice, the efficiency was 76.5 per cent. The results of these tests again confirmed the accuracy of the "square law." The feature of most interest, however, brought out by these experiments, was the behaviour of the propeller for negative slips, *i.e.*, when running as a windmill. As in similar experiments made at the aerodynamic laboratory at Koutchino, near Moscow, the negative thrust, or head resistance, of the propeller when not rotating was found to be considerable, amounting to nearly one-fifth of the amount of the positive thrust under normal conditions. The effect of this on the gliding angle of the machine will be appreciable.

Experiments are also in progress to determine the lateral force on this propeller in a side-wind: the theory developed by Mr. T. W. K. Clarke in the Technical Report for 1912–13 shows that the fin effect of the propeller under such conditions may be considerable, and it is of importance that accurate experimental data on this subject should be available.

Distribution of pressure on a cylinder.—Experiments have been made to determine the distribution of pressure round a cylinder with its axis at right angles to the air current. Results were obtained applicable to a cylinder of infinite length, and also for a cylinder of length equal to nine times its diameter. In the case of the infinite cylinder the portion of the front of the cylinder which is under positive pressure extends to about 35° from the wind direction on either side, while the maximum negative pressure occurs at about 70° from the wind direction. The negative pressure at the back of the cylinder is fairly uniformly distributed.

On passing from the results for an infinite cylinder to those for a median section of a cylinder nine diameters long, a marked diminution in the values of the negative pressures is found. The measurements show in a well-defined manner that the nature of the flow round a cylinder depends to a large extent on the ratio of its length to its diameter.

From a comparison of measurements of the total force on the cylinder with the values obtained by integration of the pressures it was concluded that the tangential forces due to friction over the surface of the cylinder are small in comparison with those due to normal pressure.

The above tests were made as a preliminary to a determination of the pressure distribution over an airship model when oblique to the wind. The latter experiments involve a considerable amount of experimental work, but will, it is hoped, be completed in time for inclusion in this volume.

Tests of wires.—A very complete series of tests of wires has now been carried out at the National Physical Laboratory. The more important results from the practical point of view were given in the Technical Report for 1912–13, but some additional tests, including those of wires of small diameter have since been made to complete the range of values of vl for which the results are applicable. The agreement with previous measurements is satisfactory.

Principle of dynamical similarity.—The value of the application of this principle in aeronautical work has been the subject of frequent reference in previous Reports of the Committee, and its use has been mentioned above in connection with the tests of aerofoils at different wind speeds. A number of special cases of interest have been noted in the course of the experimental work, and a discussion of some of these is given by Mr. Bairstow in an Appendix. They relate to the surface friction on pipes, the resistance of spheres, the resistance of cylinders, and the lift on inclined aerofoils. The discussion deals with general aerodynamic principles, and is of considerable importance in its bearing on the results of model tests.

Dr. Stanton has carried out during the past year a complete series of tests on the friction of fluids—air, water and oil—in pipes. Some points arising out of this work are discussed by him in a paper included in this volume.

Balloon fabrics.—Reference was made last year to some tests made to determine the amount of protection afforded by the use, for rubbered balloon fabrics, of a proofing containing finely-divided aluminium powder. Experiments carried out during the past year have confirmed the conclusion previously reached as to the value of this proofing. The aluminium-coated fabric was found to show little evidence of deterioration after an exposure of 157 "days," while fabric coated only with bichromate will completely lose its gas-holding properties in the same period. The added weight of the aluminium proofing amounted to about 4 per cent. only of the weight of the fabric. Tests were also made to determine the amount of heat transmitted by the aluminium-coated fabric: this was found to be about two-thirds of that transmitted by the same material not so coated: an appreciable saving of gas would thus be gained by its use.

A number of special tests of fabric have been made for the Air Department of the Admiralty. These included two investigations to determine possible causes of deterioration, and tests of seams.

Aeroplane fabrics.—A complete series of tests of aeroplane fabrics, including tearing and weathering tests, was described in the Report for 1912–13. The method of obtaining stress-strain diagrams for the fabric was there stated, and the way in which such diagrams can be employed to determine the tensile stress the fabric may have to bear under the conditions of air pressure that may occur in use was explained. These tests provide the most important information needed with regard to the characteristics of a given fabric and its value for use on an aeroplane.

The majority of these tests were made on doped fabrics. During the early part of the past year tests were made on a number of undoped linen fabrics. The strength of undoped fabrics is appreciably affected by the amount of moisture they contain, and it was found necessary to provide a means of making the tests under conditions which would admit of regulation of the temperature and moistness of the air. An investigation has since been in progress to decide upon standard conditions to be observed in tests of fabrics; the points requiring attention are the dimensions of the test specimen, the rate of application of the load, the temperature and the moisture of the air. A slow rate of loading has usually been employed at the Laboratory; a high rate of loading gives a higher figure for the tensile strength, which is to a certain degree illusory. It is useful, however, to be able to diminish the time required for making the tests, and experiments are in progress to attempt to correlate the results at the higher and lower rates of loading.

A number of tests have been made of fabrics taken from aeroplanes after being in use for a considerable period, and the results in some cases are of much interest. Very considerable loss of strength was evidenced in some instances, and the dope had become ineffective.

The result of redoping was examined, but was found to produce very little increase in strength. The ratio of the strength of wounded to unwounded fabric appeared to be little changed owing to exposure.

In view of the expense involved in the frequent renewal of the fabric on aeroplanes in service, it is of importance to obtain the type of fabric for the purpose most fitted to withstand exposure and tearing. The weight must be as small as is consistent with the other qualities desired; and the dope used should reduce the extensibility and protect the fabric from the weather. In collaboration with the naval and military authorities, it has been arranged that a more continuous series of tests shall be carried out on fabrics and dopes, special weaves being tried to determine the type giving the best results. The tests of the fabrics will be made at the Laboratory under similar conditions throughout, and the Treasury have undertaken to make provision for the additional assistance needed for this work.

Experiments on floats for hydro-aeroplanes.—Some preliminary tests of floats for hydro-aeroplanes were described in the Report for 1912–13. These were not specially provided for in the estimates for the year 1912–13, but were carried out with the funds allowed for additional investigations. Provision for the continuation of this work was included in the programme for 1913–14, and considerable progress has since been made. The apparatus for the tests has been redesigned and greatly improved, and the moment about a transverse axis can now be measured in addition to the lift and resistance.

In the first series of tests made in 1912–13 the experiments were chiefly directed to correcting the tendency of certain types of float to become submerged at low speeds, and to reducing the power required to overcome the wave-making resistance at certain speeds below the skimming velocity. The tests resulted in the design of a float which required a very much smaller h.p. than the more ordinary type. The best float of this series has since been appreciably improved upon; subsequent experiments showed that it was liable to run with the tip of its tail on the water, while the "mud-guards" should be higher at the forward end to give a greater restoring moment in case of an accidental landing at a low angle. It may be mentioned, however, that this form of float was tried on an experimental machine by the Royal Aircraft Factory, and behaved in most respects quite satisfactorily.

The second and third series of experiments were carried out during May and June, 1913. The floats tried in the second series were of similar type to the one previously found most satisfactory, but the tail now ended in a vertical stern post, and a series of such tails was tried having the flat lower surface set at different angles.

In addition to the ordinary tests with the float set at a constant angle of 6°, one model (which may be referred to as 60f.) was tried through a range of angles at different speeds, and a pair of floats to this design was also tried to determine the effect upon the performance of the floats of their distance apart. This effect was found to be practically negligible provided that the gap between the floats was at least equal to their breadth.

The most interesting conclusions drawn from this series of experiments were (i) that air holes to the step were of great assistance, even with "mud-guards" fitted; and (ii) that this type of float was not satisfactory from the point of longitudinal stability, the float tending to run at too great an angle at low speeds, with the possibility of a large increase in the tipping moment. The results obtained under this latter heading led to the design and test of a series of double step floats (described as Series 4).

The third series of tests were made on four floats derived from 60f., the best of the previous series, but of double the beam and displacement, representing a single main float in place of the twin floats. Three of these floats had a tunnel running along the underside of the forebody as far as the step. The power required to drive these was little in excess of that for the twin floats 60f., but they were not so clean in running as the narrower models, and still more unsatisfactory from the point of view of longitudinal stability.

Two more series of tests were run during the early part of 1914. In the fourth series (nine models) the floats were all modifications of 60f., but with two steps in place of one. The results obtained were very interesting, but the problem of designing a float which should give longitudinal stability on the water at all speeds proved more difficult than had been anticipated. The best float of the series, however, provided quite a satisfactory solution, at least for use in smooth water, and at the same time was as good as any previously tested from the propulsive point of view. Before further progress can be made it is necessary that the floats should be tried in use on rough water; without experience of the behaviour of the floats in both rough and smooth water it is difficult finally to determine which modification will give the best results as regards longitudinal stability under all conditions.

The fifth set of experiments was an entirely independent series, on floats of a special form, made at the request of the Superintendent of the Royal Aircraft Factory. Various modifications of the type originally designed at the Factory were tried, but it was found difficult to obtain satisfactory results without alterations which would be troublesome from a constructional point of view. The power required was also considerably greater than for the forms for ordinary use designed at the N.P.L. Twin floats of similar form were tried, but the results obtained were mainly of a negative character.

Other matters.—A number of special matters have been dealt with by the Committee during the past year. Some of these are of general interest and may be briefly referred to.

For various purposes the determination from an aeroplane of the vertical, and of the speed over the ground, are of importance. The two problems are very closely connected. It appears to be by no means easy to obtain a satisfactory solution, and various methods have been under consideration by the Committee. An experimental apparatus has been devised by Mr. Darwin, and will be tried in use on an aeroplane. This question will be further investigated.

A report was made to the Committee by the Superintendent of the Royal Aircraft Factory of instances in which compasses in use on aeroplanes had shown large variations from their correct readings. It was suggested by Mr. Mallock that a possible explanation was afforded by the combined effects of vibration and friction at the point of support. Experiments made have tended to confirm this view, and the matter is being further investigated with a view to modifications in design which will minimize the effect.

There has recently been some discussion in the technical press as to the relative merits of gravity-controlled and spring-controlled velocity meters for aeroplanes. The question is one of some interest, and certain points which arise in connection with it have an important bearing from other points of view, and at the request of the Committee the matter has been investigated at the National Physical Laboratory, making use of the data available from the analysis, already referred to, of the motion of an aeroplane in a gusty wind. The general conclusion arrived at was that either type of indicator could be used effectively to determine the forward speed of an aeroplane, and that each type has advantages and disadvantages peculiar to itself. Both types of instrument give the pilot an indication enabling him to set his machine at a suitable angle for the requisite manœuvre, and to check any tendency of the aeroplane to depart progressively from the desired condition.

Gyroscopic theory.—As mentioned in the previous report, a very complete account of the application of mathematical methods of analysis to the discussion of gyroscopic action is being prepared by Sir George Greenhill. This is now in the press, and will, it is hoped, shortly be ready for issue. It will be published as a separate volume.

Full scale work at the Royal Aircraft Factory.—The experimental work on aeroplanes in flight carried out at the Royal Aircraft Factory has been of great assistance to the Committee, both in indicating the lines of research likely to lead to the most useful results, and in furnishing comparisons between data for the full scale machine and for the model. The measurements made at the National Physical Laboratory of the air forces on the model have been employed in the Factory in the calculations made for the full-sized machine, and measurements on aeroplanes in flight have been made with a view to confirming and completing the model experiments.

The method of procedure followed has been to accumulate all the information possible with reference to one particular machine, and by constant examination and re-examination of all the available data to attempt to arrive at general principles applicable to other types. Thus, the head resistances of all parts have been determined in detail, using wherever possible the results of model experiments at the Laboratory; careful analysis of the figures has furnished general confirmation of the reduction in resistance with increase in *vl* predicted from the model experiments, and has shown in what directions further diminution of resistance can most usefully be sought.

The Royal Aircraft Factory graphs of resistance and power have been continued for all aeroplanes made, and are found to be increasingly instructive now that the experimental data and the corrections for scale and velocity are known with greater exactness. It is accordingly possible to prophesy with a fair degree of accuracy what the performance of an aeroplane will be when a known engine is employed upon it.

Again, the measurements of the moments on the model of the B.E. 2 machine when oblique to the wind, have been very carefully examined in comparison with the results obtained in flight, methods of measuring the amounts of the rolling and yawing movements of the aeroplane have been devised, and features of great importance in the study of lateral motions have been indicated and emphasized. Equally useful results have been obtained in the study of the controls. In this connection the Committee desire to recognize the valuable work accomplished by Mr. Busk, and his perseverance and skill in the testing in flight of the conclusions arrived at from the model experiments, and in the devising of methods of obtaining measurements on the full-scale machine in the air. Some details of this work have been given in the Technical Report for 1912–13, and it is hoped that further progress may be made in this direction.

In the account of the model experiments, reference has been made to the loss of effective tail area on a biplane. A number of different tails have been made and tested in flight on the experimental B.E. 2 machine, with a view to improvement in stability and control. As indicating the degree of stability attained, it may be mentioned that the machine has been flown for over 20 minutes without use of elevator control, and in a wind having gust speeds up to 33 m.p.h. With the use of Pitot tubes, the air flow over the tail region has been carefully explored, the slip stream of the propeller examined, and the effect of the wash from the main planes determined.

Tests have been made of fins of various sizes appropriately placed to secure lateral stability, with results confirming the conclusions arrived at by computation from the National Physical Laboratory model tests.

In connection with stability, it was thought necessary, in extension of the results obtained by the mathematical investigation and tests of models, to procure information as to the effect of larger departures from straight flight, and, therefore, experiments on large deviations have been made on aeroplanes at the Royal Aircraft Factory both as to lateral and longitudinal stability. For this purpose trials have been made with various sizes of tail, various positions of the centre of gravity, and various fin distributions and arrangements, and the effect of dihedral angle has been studied in various ways. Full instrumental records of these results are not yet available, but will, it is hoped, be possible later. As a first step, an instrument which will measure either the pitch or the rolling in straight directional flight is in process of construction.

The dual control of aeroplanes has not been pressed forward, in view of the rapid progress of the design of the aeroplane, which allows it to be flown without the use of any controls when once well clear of the ground. Such an aeroplane would allow of a couple of pilots relieving each other without the necessity for introducing dual control, which has hitherto been thought necessary to avoid any interruption of the control, as mentioned in the Report of 1912–13.

Experiments are in progress on air brakes, by which it is expected to provide the power of largely modifying the gliding angle of an aeroplane which is about to alight.

Strength of construction.—Special attention has been directed during the past year to equalizing the strength of construction throughout the aeroplane. A complete set of tests of every detail of an aeroplane has been carried out to obtain definite information as to its strength. The wing skeleton has been tested, to determine the strength of the compression members to resist drift without the help of the external wiring. The fuselage has been tested under torsion and in bending in both directions, and the deformations noted, the test being eventually carried to destruction. Fittings, such as sockets, wire joints, turnbuckles, wiring plates, &c., have been tested to destruction, while the fabric, ribs, spars, &c., have been tested both to six times the normal load, as well as eventually to destruction. The tail plane, elevator, elevator lever and control wires have been similarly tested under a high load, and eventually to destruction.

A test to destruction of an aeroplane of B.E. 2 type, as standardized for Army purposes, after 7 months use and 30 nights exposure, has shown this machine to be capable of bearing $5\frac{1}{4}$ tons—8·4 times the normal load of horizontal flight, the load being distributed so that the centre of pressure was distant 0·39 of the chord from the leading edge, and thus being divided equally between the two spars.

In connection with the calculation of stress diagrams, and of the factor of safety which should be allowed on an aeroplane, the effect on a known aeroplane of a dive, whether under power or not, lasting for any given amount of time, has been calculated and the maximum speed deduced. Calculations have been made at the Royal Aircraft Factory of the stress imposed by suddenly flattening out, after making allowance for the damping effect of the tail plane and the inertia of the machine. This practically involves calculating the path of the machine on flattening. As the outcome of these considerations, a method is in contemplation to render it impossible to expose an aeroplane to a stress in excess of that allowed for by its factor of safety. Experiments will be made as to the limit which this may introduce to the controllability of the machine, and thereafter it will be possible to determine whether such a scheme is suitable for adoption in general practice.

Measurements have been made, with the use of tautness meters, of the load grading along the span of the wings of the machine when in flight, to obtain a more accurate basis for the calculation of the stresses on the wing spars and for the determination of the factor of safety. The results corroborated those derived at the National Physical Laboratory from an investigation into the distribution of pressure over the surface of the wing, described in the Technical Report for 1912–13.

The wind pressure under the aluminium engine cowl has been measured, to provide information required for designing engine-cooling arrangements. The results also afforded assurance as to the sufficiency of the strength of the cowl.

The re-action on an aeroplane of firing a quickfirer gun has been successfully tried both with the aeroplane suspended, and later in flight. The actual instrumental measurement of such re-actions is being studied, and offers considerable difficulties owing to the rapidity of the effects.

Engines.—With a view to improvements in engine design extensive experiments have been made on the durability of cylinders, pistons, valves, &c., and an experimental engine has been constructed. The complete engine has given successful results under test.

Practical engine tests on a series of oils have been made with a view to detecting what it is that may be the cause of sooting of plugs and gumming of piston rings, &c., and generally, with a view to enabling the choice of a good oil to be made with certainty.

Air screws.—As is well known, the effect of gyroscopic action in the case of a two-bladed air screw leads to unpleasant vibration when turning. This is avoided by the use of a four-bladed air screw; but all wooden air screws have disadvantages from the military point of view, owing to the perishable character of varnished wood, and glues and cements. Moreover, four-bladed screws offer certain difficulties as regards transport of spares. Four-bladed screws have been made up in two halves for ease of transport, and a convenient form of six-bladed metal air screw has recently been constructed with the blades made of single pieces of thin steel, which promises certain advantages when constructional difficulties have been overcome.

Struts.—In view of the important aerodynamic effect of comparatively slight inaccuracies in the manufacture of struts, as shown by the wind-channel tests, a machine for the making of struts has been devised, in which any correct section desired is given by means of cast-iron templates.

Controls.—Many forms have been tried, including the use of pulleys, bell cranks, guide tubes, &c. The wheel warp and elevator pillar preferred by the Royal Flying Corps has been taken as standard. Mechanisms have been studied for obtaining the utmost convenience. The efforts with flap control have been found small enough to be well adapted to the standard type of control in machines of present size.

Instruments for various purposes.—In connection with the testing of engines a dial-reading petrol meter has been constructed to give the fuel flow, and a meter indicating the consumption of oil in gallons per hour. These will facilitate a quick and accurate determination of the performance of the aeronautical engines under test.

Improvements have been made in accelerometers of recording type with a view to the measurement of lateral forces on aeroplanes. Maximum indicating, and recording tautness meters have been devised for measurement of the pull on wires during flight; and with these measurements have been made of the load imposed on the main lift wire of an aeroplane when looping the loop.

A simple apparatus is being made for obtaining a record of angular movements of the aeroplane, especially in roll or pitch. The principle adopted is to throw an image of the sun on photographic recording paper.

Velometers, which accurately indicate the lift coefficient of an aeroplane at all altitudes of normal flight, and air-speed indicators of the spring-controlled type designed by Mr. F. Short, of the Royal Aircraft Factory, in February, 1913, have been designed and used with a view to deciding which of these two appliances is preferable for practical flying and navigation.

Certain methods of signalling are being tried, by which it is hoped that aeroplanes may be able to communicate with one another when in clouds, and with the ground, whether or not wireless apparatus is available. These experiments are progressing.

Engine tests.—A special installation of six wind tunnels, with appliances for starting, controlling and silencing aeronautical engines, and conducting complete tests, including instruments for the continuous measurement of oil, fuel, and water consumption and air flow, has been designed and made at the Royal Aircraft Factory. The whole is equipped with Heenan and Froude dynamometers suitable for measuring from 90 to 200 h.p. Further, special plant for applying a measured thrust to the engines under test, and tilting them to various angles of pitch and roll during their performance under power, has also been designed and installed.

Fabrics.—A considerable amount of work has been done on fabrics. With the assistance of Prof. Fox, of Manchester, a number of special weaves of aeroplane fabric were prepared with a view especially to finding the type most capable of resisting tearing. The tearing tests made indicated the classes of fabric most suitable for further experiment, and arrangements have been made to continue the work with the assistance of the National Physical Laboratory.

A system by which a panel of fabric is loaded so as to imitate the load distribution imposed on it by the air in flight has been devised, with a view to improving the method of weaving the fabric itself, while maintaining the minimum weight and the utmost resistance to tearing if wounded. Experiments on high local loading of the fabric are also being made.

The effect of damp on the results of tests of fabrics has been found to be important, and the matter is being investigated at the National Physical Laboratory. Difficulties with the slight irregular slipping of fabric in the jaws of well-made standard testing appliances have also been encountered, and, it is believed, entirely overcome.

Methods of treatment of airship fabrics—both plain cotton fabrics and cotton fabrics already proofed with vulcanized rubber—for the purpose of rendering them hydrogen proof, have been tried. A means of re-habilitating a rubbered envelope which has lost its gastightness is of great value, and two substances experimented with are at present in use on two of the airships, and have so far proved very satisfactory.

The study of dopes for aeroplane fabrics has also been continued, and a dope having considerable water-resisting properties has been made. A protective coating for the wood work of an aeroplane has also been prepared.

Hydro-aeroplane experiments have been continued on Southampton Water, and several new designs of float have been prepared. Some of these have been submitted to the William Froude National Tank for water tests and valuable information obtained.

Gust research.—Measurements of the dimensions of gusts have been made by means of an appliance devised at the Royal Aircraft Factory, called the Tetranemograph. From these it would appear that while, in accordance with the experiments of Dr. Stanton, described in the Technical Report for 1911–12, which were confirmed by the experiments of M. Maurain at St. Cyr, the lateral dimensions of gusts are not usually large, yet in a good exposure gusts not infrequently occur which exceed in lateral extent the dimensions of a modern aeroplane. It may be concluded that yet larger aeroplanes than we have at present would be in general less disturbed than are our existing machines, and though in some cases the disturbing causes might be, in proportion to the size of the machine, equally great, they would probably take effect more slowly. The design of larger aeroplanes is in hand.

Measurements of the movement of wind have been initiated by taking photographs of a vertical smoke column made by a rocket designed for the purpose. It is thought that with the evolution of the rocket and a more elaborate photography from points at right angles, such for example as by a couple of cinematographs, an instructive record of the exact movement of a section of the air may be obtained, provided the wind be not so great as to dissipate the smoke column too rapidly.

Airships.—During the early part of the year the work on airships was continued. "Eta," of calculated volume 100,000 cub. ft., with a speed of 44·5 miles per hour, was designed and made. One important characteristic of the design was a considerable increase in the length of the car over that of "Delta," with the object of relieving the envelope of bending moments. The car was, however, not so long as that of "Gamma," the length of which was liable to give rise to difficulties when landing on rough ground.

Naval work.—In addition to the various special questions which have been submitted to the Committee by the Director of the Air Department of the Admiralty as requiring experimental investigation, and which have been included in the programme of work at the National Physical Laboratory, reports have from time to time been presented to the Committee by Capt. Sueter as to matters of general interest arising in connection with the work in the field; and some particulars as to such matters, kindly furnished by Capt. Sueter, may be here included, to indicate the lines which are being followed in experimental work with actual aircraft, with a view to developing their capabilities for naval purposes.

Airships.—Arrangements having been made during the past year for the transfer to the Navy of the Army airships, the responsibility for the development of the airship has been undertaken by the Admiralty. Early in the year a Parseval airship and an airship of the Astra Torres type were acquired. Much experience has been gained in Germany in the use of the Parseval airships, of which evidence is afforded in many details of design. In its tests, the Parseval ship was found to give the satisfactory results expected. After the first trial the system of "ballonet steering" for control in the vertical plane was supplemented by horizontal elevators.

The Astra Torres airship (supplied by the Société Astra, Paris) was somewhat more of an experiment, but the ship has proved generally satisfactory, and has shown exceptional capability in the matter of speed, having established a record of 51.1 miles per hour on a short trial. As is well known, the Astra airship has a tri-lobe section, the form being maintained with the aid of an internal system of rope-girder construction, which also serves to give the necessary support for the suspension of the car. As a result of the tests this internal suspension system has been found satisfactory. The principal modifications introduced into the original design have been :—

(i.) The abandonment of the "moving car" device for trimming and for steering in the vertical plane. When first supplied, the car was capable of longitudinal travel. Owing to a breakdown of the air-blower in one of the early trials, and consequent loss of pressure, a great strain was thrown on the longitudinal wires, causing a fracture of the structural attachments. The car is now fixed, but is capable of slight adjustment fore and aft, when being rigged in the shed.

(ii.) The addition of horizontal elevators.

(iii.) The alteration of the horizontal fins and the addition of extra vertical fin surface.

The Willows Airship (acquired 1912) has performed useful training work. The envelope of oiled silk has been replaced by an experimental envelope made of Continental fabric by the Royal Aircraft Factory. A new car is under design for this ship.

The Military airships Eta, Gamma and Beta II., have also carried out useful training work. A good deal of envelope trouble was originally experienced with the Delta, but it has been remedied by the use of a dope devised at the Royal Aircraft Factory.

The construction of a rigid airship by Messrs. Vickers has been commenced. This firm has also acquired the rights of the German Parseval airships, and Messrs. Armstrong those of the Italian Forlanini airships, for construction in this country. Four and three airships respectively are under construction by these firms.

As regards the actual work of the craft already available the first essential has been to ensure the thorough training of the crews. Up to 31st December, 1913, the Naval airships had accomplished a total mileage of 14,600 miles without casualty, in addition to a total of

10,800 miles of free balloon work, also carried out for training purposes.

Seaplanes.—On March 31, 1914, the number of aeroplanes and seaplanes in the possession of the Navy was 103. Much progress has been made in actual work in this field. War exercises have been carried out in conjunction with the patrol flotillas, and naval aircraft participated in both the naval and military manœuvres. A total mileage of over 131,000 miles was accomplished during the year ended December 31, 1913.

During the summer months H.M.S. "Hermes" was fitted with a launching platform and special derricks, and as a result of the experiments carried out it was decided to provide a special seaplane-carrying ship.

Good progress has been made in connection with the use of wireless telegraphy. Practically all war aircraft are now fitted with transmitting apparatus, and successful experiments have been made in the receipt of messages in aeroplanes.

Flights by night have been made both in aeroplanes and in seaplanes. No searchlights were carried in the former, but in the case of seaplanes two searchlights were used to facilitate alighting on the water. No difficulty was experienced in the air in preserving the balance of the machine whilst flying without lights.

Systematic experiments have been carried out in connection with armament, and in bomb dropping.

As regards progress in *matériel,* machines have been successfully constructed with folding wings. On the seaplanes spring floats are being generally adopted. Advantage is being taken of the results obtained in the float experiments at the National Physical Laboratory, and the general tendency in float design is towards the boat-shaped type with flared bows, in preference to the toboggan shape. The twin-float craft have proved the most seaworthy. A type with single centre float and two large wing floats has been found satisfactory, and experiments are proceeding in the development of the boat type on these lines.

Meteorological work.—The Branch Meteorological Office at South Farnborough, established at the request of the Army Council, commenced operations there in November, 1913, in the quarters provided for the purpose at the Royal Aircraft Factory. The equipment necessary for a meteorological station, with self-recording instruments and other appliances for meteorological work in connection with the requirements of aviation, has been provided mainly out of Army funds. The apparatus got together for the observation of pilot-balloons and for experimental work at the Aerological Station of the Meteorological Office at Pyrton Hill has been brought over to South Farnborough and will be used there in future.

In connection with the Branch Office the preparation of a daily chart based on observations transmitted by telegraph each morning from the Central Office has been arranged in order to enable the Meteorologist in Charge to issue information as to the prospects of weather for the following days for the use of the Factory and the Flying Schools at Farnborough.

Out of the funds assigned to the Advisory Committee provision has been made for a special assistant for experimental work on the detailed examination of wind structure. Mr. H. Billett, B.Sc., Assistant Demonstrator at the Imperial College of Science and Technology, was appointed by the Meteorological Committee for this purpose, and attended at the Meteorological Office for preliminary training. He was detailed by the Director of the Office to inquire into and report upon the local details of a remarkable tornado which was experienced in South Wales on the evening of October 27, 1913.

A report has been prepared upon Vertical Motion in the atmosphere, as deduced from the observations of pilot balloons at Pyrton Hill, using for the purpose a formula for the ascent of a balloon in still air by Mr. J. S. Dines, from observations made in one of the balloon sheds at South Farnborough.

Experimental work has now been begun at South Farnborough with an apparatus designed at the Factory for recording simultaneously the wind velocity at four separate points.

Dr. Shaw has been specially engaged upon the theoretical study of the relation between the variations of horizontal wind velocity with height and the corresponding horizontal distributions of pressure and temperature. An abstract of the results of the investigation has been communicated to the Committee in the form of a pamphlet on the *Calculus of the Upper Air.* Details of the investigation are given in three papers :—

(1) Upper Air Calculus and the British Soundings during the International Week (May 5 to 10), 1913, communicated to the Scottish Meteorological Society.

(2) Principia Atmospherica. A Study of the Circulation of the Atmosphere. An address delivered at the request of the Council before the Royal Society of Edinburgh on December 1, 1913.

(3) The Interpretation of the Results of Soundings with Pilot Balloons, read before the Royal Meteorological Society on February 18, 1914.

Reports and memoranda.—The Appendices to this Report give as usual detailed particulars of the experimental work which has been carried out. Some other papers of a more general character are included. The following is a list of the Appendices, grouped as in previous Reports : –

General questions in aerodynamics.—The law of dynamical similarity :—

(i) Variation with speed of the forces due to viscosity. By L. Bairstow, A.R.C.Sc.

(ii) Note on the persistence of stream-line flow in water flowing in pipes of small diameter. By T. E. Stanton, F.R.S., M.Inst.C.E.

(iii) Discussion of the results of measurements of the resistance of wires, with some additional tests on the resistance of wires of small diameter. By E. F. Relf, A.R.C.Sc.

Wind channels.

A description of the 3-foot air-channel at the National Physical Laboratory, and a comparison of the results obtained in it with those of the 4-ft. channel. By the Aeronautics Staff in the Engineering Department of the National Physical Laboratory.

Experiments on airship models.

Determination of the resistance of model airship envelopes, together with experiments to find the effect on the resistance of various deformations. By F. H. Bramwell. B.Sc.

Experiments on the shielding effect of wind screens at the entrance to airship sheds. By A. Fage, A.R.C.Sc.

Determination of the pressure distribution round a cylinder. By A. Fage, A.R.C.Sc.

Determination of the pressure distribution over the surface of a dirigible of Parseval form when oblique to the wind, and comparison of the results with those obtained from total force measurements. Variation of head resistance of a dirigible of Parseval form with change of speed. By A. Fage, A.R.C.Sc., and W. J. Stern, B.Sc., A.R.C.Sc.

Determination of the head resistance and pitching moments on a model of an airship car with various modifications. By E. F. Relf, A.R.C.Sc.

Experiments on models of aeroplane wings, bodies, &c., and on models of complete aeroplanes.

Aerofoils of high aspect ratio. By F. W. Lanchester, M.Inst.C.E.

Experiments on models of aeroplane wings :—

(i) Experiments on a number of aerofoils of various sections. By F. H. Bramwell, B.Sc.

(ii) Change in the position of the centre of pressure of an aerofoil, and a re-determination of the variation of lift and drift with variation of wind speed. By F. H. Bramwell. B.Sc.

(iii) Further experiments with aerofoils having reversed curvature towards the trailing edge. By F. H. Bramwell, B.Sc.

(iv) Experiments on an aerofoil having a hinged rear portion. By J. L. Nayler, B.A., E. W. Stedman, A.R.C.Sc., A.M.I.C.E., and W. J. Stern, B.Sc., A.R.C.Sc.

(v) Experiments on an aerofoil having a hinged rear portion when forming the upper member of a biplane combination. By J. L. Nayler, B.A., E. W. Stedman, A.R.C.Sc., A.M.I.C.E., and L. W. Bryant, A.R.C.Sc.

Experiments on models of complete aeroplanes :—

(i) Experiments to determine the lift, drift and pitching moment on a model biplane, and their variations with change of wind speed. By F. H. Bramwell, B.Sc.

(ii) Effect on the forces and moments on a biplane of varying the form of the tail plane and elevator. By F. H. Bramwell, B.Sc., and E. W. Stedman, A.R.C.Sc., A.M.I.C.E.
(iii) Investigation of the flow of air, as affected by the main planes, in the neighbourhood of the tail plane of a biplane. By F. H. Bramwell, B.Sc.
(iv) Determination of the pitching moment due to pitching for a model biplane at various inclinations to the wind. By F. H. Bramwell, B.Sc., and E. F. Relf, A.R.C.Sc.
(v) Calculation from the experimental results of the performance of an aeroplane similar to the above model. By F. H. Bramwell, B.Sc., and E. F. Relf, A.R.C.Sc.

Tests on aeroplane bodies:—

(i) Experiments to determine the forces and moments acting on various aeroplane bodies, when inclined to the wind. Tests of an aeroplane body fitted with air brakes. By E. F. Relf, A.R.C.Sc.
(ii) General investigation to determine the effect of various modifications of form on the forces and moments on an aeroplane body, and of different methods of shielding the flier from the wind. By E. F. Relf, A.R.C.Sc.

Stability.

Catastrophic instability. By F. W. Lanchester, M.Inst.C.E.

Note on the stability of the flying machine as affected by considerations relating to propulsion. By F. W. Lanchester, M.Inst.C.E.

Investigation of lateral stability, indicating the conditions applicable in design for securing maximum lateral stability. By L. Bairstow, A.R.C.Sc., and J. L. Nayler, B.A.

Experiments on models in free flight, in illustration of the conclusions arrived at from the mathematical investigation of stability. By L. Bairstow, A.R.C.Sc., and J. L. Nayler, B.A.

The longitudinal motion of an aeroplane consequent on various simple types of disturbance from the conditions of steady flight. By L. Bairstow, A.R.C.Sc., and J. L. Nayler, B.A.

The lateral motion of an aeroplane consequent on various simple types of disturbance from the conditions of steady flight. By L. Bairstow, A.R.C.Sc., and J. L. Nayler, B.A.

The longitudinal motion of an aeroplane in a natural wind. By L. Bairstow, A.R.C.Sc., and J. L. Nayler, B.A.

The longitudinal motion of an aeroplane in a natural wind, when use is made of the elevator. By L. Bairstow, A.R.C.Sc., and J. L. Nayler, B.A.

Calculation of the longitudinal stability factors of a biplane over the whole range of its flying speeds. By F. H. Bramwell, B.Sc., and E. F. Relf, A.R.C.Sc.

Propellors.

Tests on a four-bladed propeller for thrust and efficiency, the experiments being extended to negative values of the thrust to determine the resistance during gliding flights. By F. H. Bramwell, B.Sc., and A. Fage, A.R.C.Sc.

Experiments to determine the lateral force on a propeller in a side wind. By F. H. Bramwell, B.Sc., E. F. Relf, A.R.C.Sc., and L. W. Bryant, A.R.C.Sc.

Strength of construction.

Note on a method of obtaining flexibility in a monoplane wing by the insertion of spring controls in the lift wires. By T. E. Stanton, F.R.S., M.Inst.C.E.

The longitudinal motion of an aeroplane provided with flexible wings. By L. Bairstow, A.R.C.Sc., and F. H. Bramwell, B.Sc.

Report on the precautions taken as to the strength of details on the B.E. class of aeroplanes, with appendices. By Mervyn O'Gorman, C.B., Superintendent of the Royal Aircraft Factory.

The maximum loading attainable on the wings of an aeroplane owing to flattening-out after a prolonged dive. By T. W. K. Clarke. Presented by Mervyn O'Gorman, C.B., Superintendent of the Royal Aircraft Factory.

A basis of aeroplane design to secure a uniform margin of strength. By the Superintendent of the Royal Aircraft Factory, and F. M. Green, A.M.Inst.C.E.

Hydro-aeroplanes.

Furthe experiments in connection with the design of floats for hydro-aeroplanes. Second, third and fourth series. By G. S. Baker, late R.C.N.C., M.Inst.N.A., and G. H. Millar, B.A., A.Inst.N.A.

Full scale work.

Report on trials of Naval Airship, Parseval type, carried out at Bitterfeld, Germany, during April, 1913. By Capt. Murray F. Sueter, C.B., R.N., Director of the Air Department of the Admiralty.

Report on the Astra-Torres Naval Airship. By Capt. Murray F. Sueter, C.B., R.N., Director of the Air Department of the Admiralty.

The velocity of the air in the neighbourhood of the tail plane of the tractor biplane B.E. 2. By Mervyn O'Gorman, C.B., Superintendent of the Royal Aircraft Factory, and E. T. Busk.

Lateral stability. By Mervyn O'Gorman, C.B., Superintendent of the Royal Aircraft Factory, with experiments by E. T. Busk, of the Staff of the Royal Aircraft Factory.

Longitudinal stability. By Mervyn O'Gorman, C.B., Superintendent of the Royal Aircraft Factory, and R. H. Mayo, with experiments by E. T. Busk, of the Staff of the Royal Aircraft Factory.

Fabrics, &c.

The use of finely-divided aluminium as a protective covering for the exterior of balloon fabrics. By Guy Barr, B.A., B.Sc., and A. Blackie. B.A.

The influence of atmospheric humidity on the results of tensile tests on fabrics. By Guy Barr, B.A., B.Sc.

Tests on doped fabric taken from the wings of aeroplanes after prolonged use. By Guy Barr, B.A., B.Sc.

Report on tearing tests of fabrics. By Mervyn O'Gorman, C.B., Superintendent of the Royal Aircraft Factory, and J. Smeaton, of the Staff of the Royal Aircraft Factory.

Notes on aeroplane dopes. By J. E. Ramsbottom, Ph.D., D.Sc. Presented by the Superintendent of the Royal Aircraft Factory.

Meteorology.

Fifth report on wind structure. Vertical motion in the free air above Pyrton Hill. By J. S. Dines, M.A. Presented by the Director of the Meteorological Office.

Formulae and tables of constants for use in the discussion of the results of soundings with registering balloons and pilot balloons. By W. N. Shaw, Sc.D., F.R.S., Director of the Meteorological Office.

Photographing the smoke trail of rockets. By the Superintendent of the Royal Aircraft Factory.

Gust research with the Royal Aircraft Factory's Tetranemograph. Presented by the Superintendent of the Royal Aircraft Factory. With experiments by F. Short, of the Staff of the Royal Aircraft Factory, and J. S. Dines, M.A., of the Meteorological Office, South Farnborough.

Special matters.

Discussion of the action of different types of air-speed indicator. By L. Bairstow, A.R.C.Sc.

The abstracts of Technical Papers have been continued, and are printed at the end of this volume.

Signed on behalf of the Committee,

RAYLEIGH,

President.
