AERONAUTICS.

TECHNICAL REPORT

OF THE

ADVISORY COMMITTEE FOR AERONAUTICS

FOR THE YEAR 1912–13

(WITH APPENDICES).

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* *See* footnote on page 2.

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MEMBERS OF THE COMMITTEE.

REPORT FOR THE YEAR 1912-13.

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

SIR,

IN accordance with the procedure followed in previous years it is proposed in the present Report to give a general account of the work of the Advisory Committee for Aeronautics during the year 1912-13. Detailed particulars of the various researches referred to in this Report will be included later in the Technical Report of the Committee.*

At the date of the last Report Major-General Sir C. F. Hadden, K.C.B., was a member of the Committee. On his retirement in July, 1912, Brigadier-General D. Henderson, C.B., D.S.O., Director of Military Training, was appointed by the Army Council to be their representative. In the same month the membership of Captain Murray F. Sueter, R.N., now Director of the Air Department of the Admiralty, was resumed. The names of the present members of the Committee are given on the opposite page.

The Committee believe that their Report of last year has been found of great assistance in deciding questions of design, and it is hoped that this Report will prove no less valuable. In many respects, notably as regards the investigation of stability, great advance has been made. In addition to questions previously examined, the problem of the construction of floats for hydro-aeroplanes has this year been the subject of systematic experiment.

The special Committee appointed by the War Office to enquire into the causes of accidents which occurred last year to monoplanes of the Royal Flying Corps, and upon the steps, if any, that should be taken to minimise the risk of flying this class of aeroplane made their report to the Secretary of State at the end of 1912. The Committee recommended that a number of special questions should be referred to the Advisory Committee for further investigation, and a communication has been received from the War Office asking that these matters should receive early attention. The demands from the Constructive Departments for experimental data also continue to increase, and the Committee have consequently found it necessary to ask for provision to be made for additions both to the equipment and the staff for experimental work during the coming year.

Equipment for experimental work at the National Physical Laboratory.—It was stated in the last Report that arrangements were being made for the construction of a larger air channel. As a necessary preliminary a large number of experiments were carried out on model air channels of different types, with various modifications of design. A general account of this research, which has afforded information of great value, is given in an Appendix to this Report, though it is impossible to reproduce all the

* Herewith included as Appendices to this Report.

particulars as to many designs which have been tried and rejected in the course of the research.

As the outcome of this investigation the four-foot channel previously employed in the experimental work has been replaced by a new four-foot channel in which great improvement in the conditions of experiment has been obtained. The pulsations in the flow, which are the chief cause of difficulty in air channel experiments, have now been so reduced that the accuracy of individual measurements can be relied on in general to within one-half per cent. The ease and rapidity of working have thereby been very greatly increased, and since the completion of the new channel a large amount of important work has been accomplished.

The new channel has been provided with a specially designed weighing mechanism by means of which the forces and moments acting on a model, whether of an aeroplane wing, or of an entire aeroplane, in any presentation to the wind, can be completely determined. This complete determination gives all the aerodynamic data necessary for considering the steady motion of an aeroplane in flight. For an examination into the qualities of a given machine in relation to stability, certain other quantities must be known, called by Professor G. H. Bryan "rotary derivatives." These can also be determined with the aid of auxiliary apparatus which has been fitted, and measurements of these rotary derivatives, on models of complete aeroplanes, are now in progress. It is hoped that, before the date of publication of the Technical Report, the work may be sufficiently far advanced to enable a complete examination into the conditions of both longitudinal and lateral (asymmetric) stability for at least one type of aeroplane to be included in that Report.* The measurements made of forces and moments will, it is thought, prove of great interest and value to constructors.

The application of the principles developed in the course of the above investigation to the design of the proposed seven-foot channel necessarily led to some modifications in the plan originally projected for the channel, and the building to contain it, and it was necessary to make application to the Treasury for the further funds required. In doing so the Committee urged very strongly the national importance of making provision to enable tests to be carried out on a sufficiently large scale to approximate as closely as possible to the conditions obtaining in practice. Intimation was received from the Treasury that the sum necessary would be included in the estimates for the year 1913-14, and the larger channel will be completed as early as practicable. Two channels will then be available, in both of which, it is hoped, it will be possible to carry on model experiments under very satisfactory conditions. The larger channel will be the more appropriate for measurements on fully rigged models of complete aeroplanes, while the smaller channel will be convenient for the investigation of the wind forces on the different parts of the machine, information which is essential to the designer.

* This examination is given in Reports Nos. 77 and 79, pp. 135 and 180 of this volume.

Improvements have also been made during the year in the other apparatus available for research. A number of minor alterations have been carried out on the whirling table with a view to increasing still further the accuracy attainable. High accuracy in these measurements is essential, as the improvements in efficiency to be expected by modifications in blade form and section do not amount to more than a few per cent. The photographic methods developed last year for studying the flow of fluids past obstacles have been improved, and the apparatus available has been supplemented by a kinematograph camera.

Special equipment has been designed and constructed for use in the tests of models of floats for hydro-aeroplanes which have been carried out in the William Froude National Tank.

Experiments on airship models.—The investigations into the forces acting on airship models, to which much attention was given in the earlier stages of the experimental work, were fully described in the Technical Report for 1911-12, and it has not been found necessary to undertake additional research in this direction during the past year. Some tests have been made on the resistance of airship models in the William Froude National Tank, and when opportunity offers it is hoped to extend these experiments, especially in relation to the determination of the conversion factor for passing from model to full scale results. More immediately pressing questions have, however, demanded attention during the year now ended.

It may be mentioned that a valuable account of experiments on balloon models, conducted under the direction of Professor Prandtl at the Göttingen Laboratory has recently been published in the report on the work of that laboratory issued in the year book for 1911-12 of the German Society for the Study of Airships.* Attention has already been drawn to an earlier but less complete description of these experiments (Technical Report of the Advisory Committee for 1911-12, Abstract 127).

Experiments on models of aeroplane wings.—A number of further experiments have been made, in continuation of those described in the previous report, to determine the effect of various modifications in the form of an aeroplane wing. The earlier experiments had shown that the efficiency of the wing is mainly determined by the camber of the upper surface, and that the best result is obtained with a camber of about 1 in 20. The under surface is much less important and may be flat, or very slightly concave.

The next step in examining the effect of variation of the upper surface was to determine the result of changing the position of the maximum ordinate, keeping the camber constant. With many forms of wing, as the angle of attack is increased, a point is reached at which there is a sudden drop in the lift obtained. It is desirable both that this drop should be as much as possible reduced, and that the angle at which it occurs should be as large as possible. It was found that great improvement in both these respects could be obtained by change in the position of the maximum ordinate. The result arrived at as the conclusion from this

* Jahrbuch der Motorluftschiff-Studiengesellschaft, Fünfter Band, 1911–12.

research was that the best position for the maximum ordinate was at a distance equal to about three-eighths of the chord from the leading edge. A slightly higher value of the ratio of lift to drift could be obtained by moving the position of the maximum ordinate a little nearer to the leading edge—to about one-third of the chord from the edge—but at some risk of re-introducing the uncertainty of flow causing the sudden drop in lift. In this respect the flow is very sensitive to small changes in the position of the maximum ordinate. With the maximum in the best position above stated this sudden drop is eliminated, and the lift maximum extends, with little diminution, over a considerable angular range.

The above experiments were made on aerofoils of upper surface camber somewhat greater than 1 in 20, as so small a camber is scarcely practicable in the construction of an aeroplane wing, the resulting thickness being insufficient for strength. In continuing the work with a view to determining the best form of wing, some experiments were carried out on the effect of thickening the leading edge of an aerofoil, a modification promising some advantages from the point of view of strength. The observations, however, showed that loss of efficiency resulted.

Other modifications were also tried, especially that of thickening the wing toward the trailing edge. The result of all these experiments, which were carried out in consultation with the Royal Aircraft Factory, was to lead to the selection of a particular form of wing (hereinafter referred to as R.A.F. 6) as the most satisfactory from the point of view of construction and aerodynamic efficiency. This gave a lift coefficient (absolute) of 0·32 at 5°, with a maximum ratio of lift to drift of 14·3; the maximum lift coefficient was 0·6 at 15°. Full particulars as to the lift and drift and the position of the centre of pressure are given in an Appendix to this Report. The aspect ratio was 6 : 1; some increase in the efficiency could of course be obtained by increasing the aspect ratio, with counterbalancing disadvantages as regards construction.

In addition to considerations of strength and aerodynamic efficiency there are other properties of an aeroplane wing which are of great practical importance. Among these may be mentioned the movement of the centre of pressure, which, apart from its influence on stability, may produce disadvantageous effects through excessive self-warping of the wing. At the request of the Superintendent of the Royal Aircraft Factory some experiments have accordingly been made on aerofoils with the surfaces reflexed towards the trailing edge, to determine whether a reduction in the movement of the centre of pressure could be secured by this means. The experiments are not yet completed, but it appears probable that it will be possible to confine the movement of the centre of pressure within very small limits. As is to be expected there is some loss of efficiency, but this is not of very serious amount, the ratio of lift to drift still remaining fairly high.

Effect of warping.—A complete series of measurements has been made to determine the forces and moments acting on a warped aeroplane wing. The experiments were made on an aerofoil of the form R.A.F. 6. The results of these experiments will no doubt be of great interest to all constructors. It may be explained that the front spar in an aeroplane wing is fixed, while the back spar is loosely jointed at its point of attachment to the body*: the effect of warping is to rotate the wing about the front spar through an angle which varies from zero at the junction with the body to a maximum at the wing tips. In the experiments made this maximum was 6°.

The observations showed that no loss of lift resulted from warping at ordinary flight angles, but, as was to be expected, there was some increase in drift, reducing the maximum lift to drift ratio to about 12·2. The effect on the movement of the centre of pressure, for variation in the angle of incidence, was negligible. The lateral force—tending to produce side-slip—was also negligibly small. As regards the rolling and yawing moments at small angles of incidence the result of warping is to give a maximum rolling moment with practically no yawing effect, which is exactly what is required in practice. As the speed of the machine decreases and the angle of incidence increases, the effectiveness of the warp control gradually diminishes, while the yawing, or interference with the steering, increases.

From the data for the lift and drift and centre of pressure of the unwarped wing at different angles of incidence, it is possible, on the assumption that successive "elements" of the wing (cut off by planes parallel to the plane of symmetry) can be treated as independent, to calculate the forces and couples on the warped wing. The calculation, however, does not allow for the fact that the forces on similar sections at the wing tips, and nearer the median plane, are necessarily different, *i.e.*, there is no allowance for end effect. The results showed good agreement between calculated and experimental values, over the range of angles of incidence of practical importance, except in the value of the rolling moment. This exception is probably mainly dependent on the omission of the end effect, since the forces on the portions of the wings towards the tips produce the maximum contribution towards the total rolling moment. It is hoped that when the experiments on pressure distribution have been completed this point will be cleared up.

Pressure distribution over the surface of an aeroplane wing.—The possibility of obtaining such data as the values of the forces and moments on a warped wing by this process of "integration" is of great importance in view of the resulting reduction in the labour of measurement and the simplification of methods, and with a view to the further elucidation of this and analogous questions the pressure distribution over the whole surface area of the aerofoil model of R.A.F. 6, at different angles of incidence, has now been examined. The results have been carefully analysed, and an account of this work is given in an Appendix to

* This statement needs some modification in the case of a biplane with rigidly braced central section.

this Report. Among other important matters on which this investigation may throw light is the question of the possibility of determining the "rotary coefficients"† with sufficient accuracy by calculation. The work will also be applied to aspect ratio problems, and to the examination of the movement of the centre of pressure for the end portions of the wing, which is important in relation to automatic warping.

The application of the results obtained for model aerofoils to full scale aeroplane wings.—The question of the possible variation of the force coefficients with alteration of dimensions and of velocity has been further investigated. Much evidence has now been accumulated in favour of the truth of the law of dynamical similarity to which attention was drawn by Lord Rayleigh and Mr. Lanchester in the first Report of this Committee; and it may be regarded as established that if there is any change in the force coefficients with variation of dimensions, there must be a change also with variation of velocity; the change will, in fact, depend on the variation of the product of velocity and linear magnitude.

It is thus possible to examine the effect of a change of dimensions by investigating the result of a change in the wind velocity. A series of experiments was accordingly conducted in the new four-foot channel to determine the variation of the lift and drift coefficients of a model aerofoil when the air speed changes. The accuracy of measurement in the new channel is such as to render the determination of any such variation a relatively simple matter. The measurements were made at wind velocities of 10, 15, 20, 30, 40 and 50 feet per second. At the lower velocities appreciable change is found to occur in both lift and drift coefficients as the velocity increases; but the difference between the values corresponding to velocities of 40 and 50 feet per second is small. Speaking generally the change is towards increased lift coefficients at the higher velocities, and it appears that at 50 feet per second the limit of such increase has practically been attained. On the other hand the drift coefficient decreases as the velocity increases, and it does not appear that the limit of the decrease has been reached for the model at 50 feet per second. The full scale aeroplane wing may thus be expected to be somewhat more 'efficient' than the model aerofoil; it will give a greater ratio of lift to drift, and the aeroplane will be able to glide at a less steep angle than would be inferred by calculation from the model results, without the special allowance necessary for scale.

To determine this allowance for scale or "conversion factor" further experiments are still needed, though perhaps a tolerably good estimate might now be made. To this end the larger air channel to be constructed will be of value, and the results so obtained will be supplemented by experiments on models in water in the William Froude National Tank, as well as by comparison with measurements made on full scale aeroplane wings. In the latter connection a comparison made between the N.P.L. model results at high wind velocities and observations carried out on

† See the section relating to stability, p. 14.

full scale wings at the Aerotechnical Institute of the University of Paris, at St. Cyr, is of interest. This shows good agreement as regards the lift coefficients, which is in accordance with the conclusions derived from the N.P.L. experiments above described; but the measurement of the much smaller drift coefficients on the full scale presents great difficulties, and as regards these no satisfactory conclusion can yet be drawn.

Measurements of forces and moments on models oblique to the wind.—As stated earlier the balance provided for use in the new 4-foot air channel has been designed for the convenient measurement of the three component forces and the three component couples acting on a model inclined in any attitude oblique to the relative wind. The three forces may be called the longitudinal force, along the axis of the aeroplane; the lateral force, perpendicular to the plane of symmetry; and the normal force, normal to the plane containing the two preceding forces. The normal force becomes the lift when the machine is in the attitude of steady horizontal flight. The three couples or moments are those tending to produce rolling, pitching and yawing respectively.

Complete measurements of these component forces and couples have been made on models of complete aeroplanes, and the results obtained will no doubt engage the attention of designers. They have been employed in the discussion of the stability of the types tested, referred to later.

Tests of aeroplane bodies.—Some determinations have been made of the forces and moments acting on models of aeroplane bodies, and also on a model body with tail plane, and both with and without the rudder and elevator planes. The results of these measurements, which are given in an Appendix to this Report, will, it is hoped, be of immediate value. The tests on bodies are to be regarded as preliminary to a systematic research with a view to investigating the best forms of aeroplane body, which has now been commenced.

Tests on struts and wires.—The results of an investigation into the wind resistance of some aeroplane struts were described and discussed in the Technical Report for 1911-12. Further experiments have now been made to determine the forces acting on inclined struts, including a systematic examination of a series of struts with sections of different 'fineness ratio,' this term being used to denote the ratio of the maximum breadth of the section to its length. These are of great theoretical and practical interest, and throw light on various points which arise on the one hand in connection with the design of airship envelopes—the section of a fair-shaped strut corresponds with the longitudinal section of an airship body—and on the other in relation to the tests of aerofoils. The strut tests confirm the view expressed at an earlier date that the upper surface of an aerofoil is of paramount importance, the effect of modifications of the under surface being relatively small.

Some experiments have also been made to extend the results obtained previously (Report for 1910-11) for the resistance of wires and ropes, in order to determine the resistance under conditions equivalent to those occurring in practice on machines travelling at high velocities. Under the law of dynamical similarity to which reference has already been made, this equivalence can be secured by increasing the diameter of the wires tested, since it is not possible in the channel to attain so high a velocity as is reached in flight. Doubling the diameter of the wire is, however, exactly equivalent to doubling the wind velocity, as has been conclusively shown in the earlier report on wires (*loc. cit.*), and the recent measurements thus give accurate results for the resistances of wires at ordinary flight velocities.

Other tests on models of parts of machines.—Other tests of interest which are described in the Appendices are those on a model of a fixed tail, with elevator, and on a model of a landing chassis wheel. All such tests have been made as complete as possible, and the numerical values obtained in the individual observations at different angles of incidence are tabulated in the report on the work.

Stability.—In the reports for previous years it has not been possible to devote very much attention to the theory of stability, which had perforce to yield precedence to the collection of the more fundamental data without which no useful examination into the conditions of stability of the actual, as distinguished from the theoretically simplified machine, could be attempted. At the time of publication of the last Report, however, the preliminary work had reached a stage at which there was some hope of attacking successfully the question of stability, and during the past year a great amount of attention has been devoted to the subject, both in its theoretical and practical aspects. Assuming that the character of the air flow is not appreciably altered by small variations in the forward velocity of the machine—and all the information available seems to indicate that this assumption can be made without sensible error—it is necessary for the full discussion of the stability, longitudinal and lateral or 'asymmetric,' of a given machine, not only that the values of the component forces and moments acting on it when inclined at various angles to the relative wind should be known, but also that the values of a number of coefficients, called by Bryan the 'rotary derivatives,' should be determined. As already stated, the forces and moments have been determined, for one or two models completely rigged, apart from the propeller and cables; and methods have been devised for the determination of the rotary derivatives. Measurements of the more important of these derivatives have already been made and the results are recorded in an Appendix to this Report. In addition, the possibility of calculating the values of the rotary derivatives by integration methods, from a knowledge of lift and drift and pressure distribution data, has been investigated. The Committee desire to congratulate the members of the Aeronautics Staff of the National Physical Laboratory on the great advance which has thus been made in the study of this important subject.

The methods developed by Bryan have been applied to the results obtained from the tests of the model of a complete machine, and it has been shown that the criterion of longitudinal stability, given by Bryan and Lanchester for an ideally simplified machine, can be readily expressed, with the aid of model tests, in a simple form for the actual aeroplane, using the diagrams furnished by the model tests in the channel. The conditions for lateral stability have been similarly discussed, using the results of the model experiments made, and conclusions are drawn as to the means by which lateral stability may most readily be secured. The work must still be regarded as in the preliminary stage, but results of undoubted value have been reached, and there seems every prospect that great progress will be possible during the coming year.

In addition to the investigation of stability in the more limited mathematical sense, in which it applies only to relatively small departures from the attitude of normal flight, the necessary data are being accumulated to enable the behaviour of the machine under more exceptional conditions to be thoroughly examined. Some progress in this direction has already been made, and special attention will be devoted to this work during the coming year. In response to the request from the War Office arising out of the report of the Departmental Committee appointed to enquire into the causes of accidents to monoplanes, the question of vol piqué, in particular, will be specially considered.

It was pointed out some years since by Mr. Lanchester, and has been urged by many other writers, notably recently by M. Alexandre Sée in a paper which has attracted much attention, that too high a degree of stability in relation to small disturbances is not a desirable quality in an aeroplane, and that the condition to be aimed at is one of nearly neutral equilibrium. This view is entirely in accord with previous experience in other problems of locomotion, among which may be mentioned the classical examples of the stage-coach and the ship. In the former too low a position of the centre of gravity, in the latter too great a metacentric height, were found to lead to unpleasant rolling motions. It will be evident that if, as is to be expected, the well-known theory which explains the cases cited is equally applicable to the aeroplane, it will be necessary for the conditions affecting stability to be determined with the highest possible exactitude and with the utmost completeness, as somewhat nice adjustment will be necessary to attain the desired balance of opposing conditions. Whether as regards longitudinal or lateral stability, it would, from analogy, appear necessary that an aeroplane should be stable, but that its 'stability factor' should not be too great. At the same time, for larger departures from normal conditions, it is probably desirable that the restoring moment should become greater. The whole question therefore calls for the most careful and close investigation, and in this connection the large air-channel to be constructed will no doubt prove especially valuable.

The tests so far undertaken to determine the essential factors on which stability depends have been made, for the most part, on models of complete machines. For the designer, data are necessary as to the effect of all the component parts of which the machine is built up, and as to their mutual interference. This provides a somewhat extensive programme of further work, which however is absolutely essential to future progress in design.

Photographic methods for the investigation of the flow of fluids past obstacles.—Progress with this work has been somewhat delayed owing to pressure in other directions, but the interesting new procedure described last year has been further improved by careful attention to certain matters of detail, and the photographs reproduced in this Report show a decided advance on previous results. Kinematograph methods are now being employed, and will be further developed during the coming year; by this means it is anticipated that it will be possible to trace completely the growth and subsequent progress of eddies, and thus to throw light on the many peculiarities observed in connection with the action of the air on models of aeroplane wings.

'Absolute' determination of the wind velocity.—For comparative tests of the efficiency of different forms of aeroplane wings and for much valuable experimental work, exact knowledge of the wind velocity at which the test is made is not of fundamental importance. For 'absolute' determinations of lift coefficients and other similar constants, however, accurate knowledge of the wind velocity is essential. As is evident from the experience of all aerotechnical laboratories this measurement is one of the most difficult of all those met with in the early stages of aerodynamic experiment to make with accuracy. It is difficult to obtain a steady air current of uniform velocity; it is probably more difficult to measure this uniform velocity when obtained.

In view of the high accuracy which can be reached in the measurements of forces in the new air channel it was necessary to re-investigate more closely the methods of measuring the air velocity in the channel. Wind velocities have usually been measured by the combination of velocity head and static pressure tubes known as a 'Pitot' tube, and an investigation was undertaken on the whirling arm to compare the readings given by the Laboratory standard form of Pitot tube with the velocity at which the arm was being driven through the air. The determination of the arm velocity relative to the air is complicated by the fact that the rotation of the arm sets up a 'swirling' motion in the air of the room, which must be measured and for which due allowance must be made. The experiments were conducted with great care, and the result arrived at was that within the limits of accuracy of the experiments, which could be relied on to one-tenth of one per cent., the static pressure tube of the Pitot registers correctly the static pressure, and the Pitot tube proper correctly measures the velocity head. This result differs slightly from that obtained some years since by Dr. Stanton in his well-known experiments to determine the wind pressures on engineering structures, at a time when the whirling table was not available, and is a valuable supplement to the data furnished by that research.

For the determination of the air velocity in the channel a new method has recently been employed, which consists in measuring the difference between the pressure just inside the channel wall and the static pressure in the room outside. An opening in the channel wall communicates with one limb of the usual form of sensitive tilting gauge used at the Laboratory for measuring differences of pressure, while the other limb is exposed to the static pressure in the room. To determine from this measurement the velocity along the axis of the channel it is necessary to calibrate this arrangement against a standard Pitot tube placed in the centre of the channel. The new method has the advantages that the reading is more easily made, and that it is unnecessary to introduce any obstruction into the channel, even so small as a Pitot tube, at the same time as the model under test. The accuracy thus obtainable in the measurement of wind channel velocities is of a sufficiently high order to enable full advantage to be taken of the increased accuracy in the measurement of the wind forces on the model.

Propeller tests.—The fundamental wind velocity measurements above described required the use of the whirling arm for a considerable period. During this time attention was devoted to the construction of a model propeller of which the blades could be rotated, so as to obtain a continuous variation in pitch. A systematic series of tests on this model to determine the effect of pitch variation has now been carried out. Complete tests at various translational speeds were made with the blades set at four different angles, and the results are analysed in the report on the work. Tests have also been made in the air channel of aerofoils having sections of the same form as the different propeller sections, and a comparison will be made between the measured results for the propeller, and those which can be derived by calculation from the aerofoil tests. In this way the possibility of applying 'integration' methods to the propeller will be investigated.

Some tests have also been made to determine the change in the thrust and efficiency of a propeller due to a change in the blade section, the plan form and pitch remaining unaltered. The experiments were made on two Ratmanoff propellers, of section similar to a typical aerofoil, in one of which the pressure face was very much more hollowed out than in the other. The values of the thrust for the propeller with hollowed blades were only slightly greater than those given by the other at the same values of the slip ratio, while the former showed a maximum efficiency exceeding that of the latter by about 3 per cent. It is interesting to note, in relation to the fact established that it is the upper surface of an aerofoil which chiefly affects its lift and efficiency, while variations in the under surface are comparatively unimportant, that the influence of a considerable alteration of the pressure face of a propeller blade—corresponding to the under surface of the aerofoil—is so small.

Factors of safety in aeroplane construction.—In connection with some investigations undertaken at the request of the Departmental Committee on the accidents to monoplanes, and with a view to the carrying out of the recommendations made by that Committee as to matters needing further examination, calculations have been made at the National Physical Laboratory of the stresses at different points of the main spars of some types of aeroplane wings, under both normal and abnormal conditions. Strength tests on sample spars, and on specimens of different varieties of wood as employed in aeroplane construction, have been made, and the factors of safety for spars and cables have been calculated. The method employed in these calculations is explained in an Appendix, and the investigation will be extended later to an examination of the best methods of calculation of the stresses which may occur in the various members of the wing structure, and to the determination of the factors of safety which should be allowed. It is necessary that constructors should clearly realize that the stresses obtaining under conditions of frequent occurrence in ordinary flight may be as great as three times those produced in steady horizontal flight; while under the abnormal conditions which arise in the case of a vol piqué, still greater loads may be thrown locally on parts of the wing. The structural strength required in the wing skeleton calls for much closer and more detailed examination than it would appear yet to have received, and the question is engaging the careful attention of the Committee. It is hoped that it may be possible to indicate methods of calculation, and to set out in a simple manner, the procedure to be followed in the determination of the factors of safety for the various members of the wing, with a view to establishing a uniform system under which constructors may be able readily to draw up a satisfactory specification for the various parts of the structure which shall ensure an ample margin of safety.

Closely related to this matter is the question of the tests to be applied to the completed aeroplane in order to secure that no machine is accepted for service unless structurally of sufficient strength. The tests generally to be satisfied by the completed machine before acceptance are receiving immediate consideration by the Committee.

Stresses in the fabric, and on the attachments of the fabric to the ribs, of an aeroplane wing.—Following the examination into the strength of the wing skeleton, the local stresses to be borne by the fabric, and the methods of securing the fabric to the ribs have also been investigated. It is thought that the simple methods indicated in this Report for determining the stresses on the fabric and its attachments, with the aid of the stress-strain diagrams for the fabric referred to elsewhere (p. 20), will be of value in manufacturing practice. The curves of pressure distribution over an aeroplane wing obtained both by Eiffel and at the National Physical Laboratory show that the local pressure on the fabric may under normal conditions be three or four times as great as the average pressure over the whole wing surface; under abnormal conditions it may be very much greater. It is shown, however, that with a good fabric, undamaged, the stress necessary to rupture the fabric is never likely to be reached.

With regard to the methods of attachment of the fabric to the ribs of the wing an important memorandum has been presented to the Committee by the Superintendent of the Royal Aircraft

Factory, communicating the results of tests made by his direction to investigate the strength obtained by the use of different fastenings. Ultimately it was decided to connect the top and bottom layers of fabric by a knotted sewing at intervals of about $2\frac{1}{2}$ inches along each rib, the exposed part of the sewing being covered with the usual tape stuck on and tacked. The result proved highly satisfactory: the portion of the wing loaded withstood an average load of 130 lbs., with a maximum of 250 lbs., per square foot. The ribs were very badly bent and the central spar cracked, but no failure occurred of the fabric fixing, which was the question under investigation.

Gyroscopic action of rotating engine and propeller.—A memorandum by the Superintendent of the Royal Aircraft Factory included as an Appendix to this Report gives particulars of measurements and calculations made to determine the amount of the effect due to the gyroscopic action of a 100 H.P. rotating Gnome engine. The calculations are made for extreme conditions as regards the radius of the turning circle of the machine, whether for evolutions in the vertical or horizontal plane, and the amount of the couple on the engine framework due to the gyroscopic action is found to be no more than can be readily taken up so far as strength is concerned. From the point of view of handling, also, the effect comes well within the aeroplane controls, and produces much the same result as a small gust, with the difference that its magnitude and direction are known and expected.

At the request of the Committee and by the special desire of the representatives of the Constructive Departments, Sir George Greenhill has undertaken to compile as complete as possible an account of the mathematical methods of analysis applied to the discussion of gyroscopic action, which will be of great interest both to mathematicians, and to technicians in other branches of engineering as well as in aeronautics. This will be issued by the Stationery Office as a separate publication, apart from the Technical Report of the Committee; its preparation will occupy some months and it will be published during the coming year.

Balloon and aeroplane fabrics.—The work on fabrics during the past year has been directed more especially to the examination of aeroplane fabrics, and of the methods of treatment employed to render them weather-proof. The further work which has been carried out in relation to balloon fabrics may, however, first be referred to.

Balloon fabrics.—The standard method now employed for the determination of the rate of leakage of hydrogen through fabrics was described in the Report for the year 1909-10. The tests are made on large samples some 16 inches in diameter, and a test of two or three such samples affords a reliable criterion of the average quality of the material as regards permeability. With a view, however, to determining the rate of leakage of impure hydrogen—mixtures of air and hydrogen—another method has been devised, in which smaller samples can be used. In general principle the apparatus is similar to the well-known Renard-Sürcouf balance, but modifications have been made to ensure greater accuracy in the results. The measurements made with this apparatus have shown that the rate of diffusion of the hydrogen through the fabric is proportional to its concentration: this is in accordance with the generally accepted theory of diffusion of hydrogen through fabrics, that the process consists in the solution of the hydrogen in the proofing material on the one side and its evolution on the other.

An apparatus has also been devised for the determination, by a rapid and convenient method, of the lifting power of samples of hydrogen. The apparatus determines the lifting power directly, *i.e.*, the difference in weight of equal volumes of air and hydrogen.

An extensive series of experiments has also been made on the use of gelatine as a proofing for balloon fabrics. A percentage of glycerine was mixed with the gelatine to reduce the stiffness of the fabrics so proofed. Promising results were obtained as regards strength and hydrogen-retaining capacity, and the composition was also found satisfactory for the making of seams. The even application of the proofing was difficult under laboratory conditions, and further improvement would no doubt be effected in the preparation of the proofed material on a larger scale.

Tests have also been made on the use of finely divided aluminium as a proofing for balloon fabrics, a firm making the material having presented samples for examination. The samples were submitted to the usual exposure tests, as described in last year's Report, for upwards of 100 " days," and comparison of the results obtained with those for fabric provided with the usual protective colouring appears to show that a great advantage is obtained by the aluminium process. The matter will be further investigated.

Aeroplane fabrics.—An extensive series of tests has been for some time in progress on the properties of aeroplane fabrics. In giving a brief description of the work the tests may be divided under three heads: (i) initial tests of unused fabrics; (ii) exposure tests, and tests of fabric which has been for some time in use on aeroplanes; (iii) tests of " dopes," and investigations into methods of treatment to preserve the fabric and to prevent it from becoming slack in use, whether from alternations of damp and dryness or from other atmospheric conditions. Some additional tests of aeroplane fabrics were described in last year's Report.

The initial tests applied to unused fabric consist in the determination of the weight per unit area; the tensile strength in warp and weft; the resistance to tearing; and the extension of the fabric corresponding to any given tension. In the last case the results are exhibited in the form of a stress-strain diagram. The variation in behaviour from one specimen to another of the same material is of course considerable in fabrics, and a special procedure has to be adopted in preparing a stress-strain diagram to obtain an average result which shall be truly typical of the fabric. These diagrams have been of great value, in connection with enquiries into recent accidents, in calculating the stresses to which the fabric may be subjected when in actual use on an aeroplane. The experiments on the resistance to tearing have furnished approximate figures for the loss of strength locally owing to small wounds: thus it has been shewn that in the neighbourhood of a small cut one half-inch long the strength to resist the spreading of the cut is only one-half to one-third of the strength of the unwounded fabric.

In the exposure tests the method of procedure is to cut sets of rectangular pieces for exposure from a sheet of fabric, the distribution of the specimens being such that each set should give a fair average of the whole sheet. The several sets are exposed for periods differing by about 15 days, so that comparisons are effected between the qualities of the fabric after 0, 15, 30, 45, 60 . . . days. By a " day " is here denoted a consistently measured period of exposure to "radiation," approximately equivalent to that of an equinoctial day of bright sunshine. For the purposes of the comparison the stress-strain diagrams are determined at the end of each period, and from these can be readily observed the extent to which deterioration has proceeded. To accelerate the effects the samples are watered on days when no rain falls, and from comparison with tests on similar samples after exposure on aeroplanes it would appear that 21 " days " test at the laboratory is appreciably more severe than seven months in actual use. Samples after seven months' use showed relatively small loss of strength.

To examine the effect of dopes, samples treated with various preparations have been compared with untreated samples both before and after exposure. The dopes in common use are found to increase considerably the initial strength of the fabric and to decrease the extensibility: these being the two main purposes for which they are employed, apart from their water-proofing action. After somewhat considerable exposure, however, it is found that their effect in diminishing the extensibility at low tensions disappears, even though the breaking strength may not have been very seriously reduced. The fabric thus needs redoping fairly frequently. In addition some of the dopes appeared to have a directly weakening effect on the fabric, though the action was slow. The behaviour of doped fabrics after exposure and use will be the subject of further careful investigation in view of the reference received from the Monoplane Accidents Committee.

Various dopes have also been examined chemically with a view to elucidating effects observed relative to their action on fabrics; and experiments have been tried in the preparation of dopes for application to aeroplane fabrics. The use of certain fireproofing and bactericidal solutions on fabrics has also been investigated.

Other chemical work.—Among other chemical work which has been carried out for the Committee at the National Physical Laboratory may be mentioned the examination of different samples of castor oil, differing only slightly in purity, to explain inequalities in their behaviour when used as lubricants in aeroplane engines. The experiments led to the devising of a practical workshop test for the rapid estimation of the relative amount of impurity present in castor oil.

Light alloys.—A preliminary Report by Dr. Rosenhain on light alloys was included in the Report of the Committee for the year 1909-10. Since that date a large amount of work on light alloys has been carried out at the National Physical Laboratory, partly for this Committee, especially in the way of examination of special alloys submitted by the Constructive Departments, and partly for the Alloys Research Committee of the Institution of Mechanical Engineers. It has been thought desirable to embody the principal results of these investigations, so far as they are of special interest to aeronautical engineers, in a further report on light alloys, which is printed as an Appendix to this Report.

Experiments on floats for hydro-aeroplanes.—Early in 1912 application was made to the Committee by the representatives of the Admiralty and of the War Office for the carrying out of model tests to determine the best form of float for use on hydro-aeroplanes. An account of experiments made at Barrow by Commander Schwann on various floats in use on a hydro-aeroplane had been communicated to the Committee by Captain Sueter in December, 1911. No special allowance for such experiments on model floats had been made in the programme of work for 1912-13, which was necessarily prepared at an earlier date, but it has nevertheless been found possible to carry them out during the past year as an additional investigation to those for which provision had expressly been made. The tests were conducted in the William Froude National Tank under the direction of the Superintendent, Mr. G. S. Baker, and led to definite conclusions as to the form of float it was desirable to adopt. Floats of this form are now under construction, in order that full scale tests on actual aeroplanes may be made.

Special apparatus was designed and constructed for the purpose of these experiments, which commenced with the determination of the lift and resistance of a flat plate towed on the surface of the water at various angles. Twenty-five models of floats of different form were then tested, under conditions corresponding as closely as possible with those which would obtain in practice, comparative data for the lift, speed, &c., of the full sized machine being furnished by the Royal Aircraft Factory. The tests made included determinations of the effect of varying the load; "dryness" tests to evolve a form which would not exhibit a tendency to become submerged under the bow wave at low speeds; investigations into the influence of a number of variations in the shape of the bottom and sides of the float, and into the effect of varying the distance between two similar floats when employed in parallel; and acceleration tests. The effect of acceleration was determined by measurements made at a number of appropriately spaced speeds, which were of particular interest as showing the large amount of power required with certain forms of float to overcome the wave-making resistance, at certain speeds below the skimming velocity, during the acceleration period. An important part of the work lay in the effort made to reduce this hump in the horse-power curve by various modifications of the bow form.

Further suggestions have been made by the representatives of the Constructive Departments after examination into the results of these experiments, and the work will be continued during the coming year, being now included in the normal programme of work for the year.

It may be mentioned also that the forces and moments on some of the forms of float tested in the Tank were measured in the air channel to determine the effect of the floats on the behaviour of the machine in free flight after rising from the water. The results, for the form of float finally selected as the best tested, are given in this Report.

Full-scale work at the Royal Aircraft Factory.—In the Technical Report for 1911-12 some details were given of the evolution of the aeroplane types denoted by F.E.2, S.E.1, B.E.1, and B.E.2. The work at Farnborough, which is essentially of an experimental character, is carried on in close relation with the testing of models at the National Physical Laboratory, and it is thought that a somewhat fuller account of this work than has been previously given may be of general interest.

The technical work carried out at the factory may be classified under the following heads:—

(i.) Design, relating to (*a*) Airships and Equipment, (*b*) Aeroplanes, (*c*) Propellers.
(ii.) Physical investigations.
(iii.) Researches on fabrics.
(iv.) ,, on metals.
(v.) Experiments on engines.
(vi.) Inspection work generally.
(vii.) Testing.
(viii.) Flying.

Airships.—The progress which has been made in connection with the designing of airships may be briefly recapitulated as follows:—

In 1909 the airship "Baby" (23,000 c.ft.) was enlarged to the airship "Beta." The "Gamma" (80,000 c.ft.) was at the same time in progress with a single engine. The engines were changed, in the one case, for a newer engine of the same type (40 h.p. Green), and in the other case, for a pair of engines, to enable the ship to be brought home in the case of failure of one engine.

In 1910 "Gamma" was enlarged. Better swivelling gear for the propellers was put in, and a propeller and engine *unit* was employed. Three such units were made, all interchangeable, facilitating rapid repairs.

In 1910 "Delta" (180,000 c.ft.) was commenced, and was completed in 1912. The airship shape was evolved on the basis of the National Physical Laboratory water experiments and Royal Aircraft Factory air experiments, described in the Technical Reports for 1911-12 and in the previous Reports.

It will be seen that during three years the size of the airship handled was doubled each year.

The "Beta" took part in the manœuvres of 1910, flying several hundred miles, and experimental study led to various improvements in propeller and gear. The speed was step by step increased from 24 miles per hour to 32 miles per hour. With wear and tear a new envelope was required and was constructed in 1912. A new design was prepared, based on the model experiments above mentioned, and various alterations were made to the car, including the fitting of a new engine. The new "Beta" thus constituted was found to attain a speed of 35 miles per hour. It is capable of taking up three persons and can be manned by as few as two. It has proved itself very controllable and airworthy, and has recently made 4-hour and 8-hour full power trials, without hitch, as well as height tests and rapid ascent tests.

Similarly, with the lapse of time, the French envelope of the "Gamma" required replacement, and a new envelope was designed at the Factory. For training purposes, the ship is capable of taking up as many as 12 persons. The principle of rising and falling without loss of ballast and gas was evolved by experiment on this machine, this device being incorporated in an improved design in the "Delta."

The "Delta" (180,000 c.ft.) was laid down to fulfil the same conditions as the Lebaudy airship, though less than half its volume. These conditions, calling amongst other requirements for a speed of 35 miles per hour, were fully realised, a speed of 44 miles per hour, being 9 miles per hour in excess of the stipulated speed, being obtained. This result, in comparison with the known data for other airships of the same or greater size, appears very satisfactory. The engines, purchased two years ago, which were of the standard water-cooled White and Poppe type, 110 h.p., of that date, are, with their cooling apparatus, some three times as heavy for the horse power as the radial air-cooled engine of the present day; with correspondingly lightened engines this ship might carry some 300 h.p., and develop proportionately greater speed. The number of persons which has been taken up for training purposes is eight, and the crew required for working in one shift is five, including the wireless operator. The range of the ship is nine hours at full power and 14 hours at three-quarter power.

A large amount of experimental work on the employment of silk fabric, on the use of special stiffening girders, and in the way of alterations to evolve a convenient equipment for military purposes has been effected between the various trial flights.

It may be noted that no airship has led to any loss of life, nor has serious accident occurred to any military airship in this country.

Airship mooring.—A system of mooring airships which not only dispenses with the necessity for portable sheds, as far as wind protection is concerned, but which provides the means of riding out a high wind until such time as the airship can be housed has been evolved and successfully tried with all these ships. A procedure in many respects similar had previously been adopted by the Admiralty at Barrow. The shed cannot, however, be dispensed with permanently, owing to the depreciation of the material if left exposed to light and weather.

The mooring arrangement consists of a cone universally pivoted at the top of a mast and arranged so that the nose of the airship is dragged into the cone. Numerous experiments on various methods of flying the balloons "kitewise" have been attempted, but the irregularity of the wind has required the watching of the airship by numbers of men throughout any period when this system is employed.

The average pull on the nose of a moored balloon in a wind up to its flying speed does not exceed the pull exerted by its propellers at that speed, and this is many times less than the strength of the fabric to which the mooring rope is attached.

Airship dock.—Though the mooring mast facilitates the employment of the airship in much rougher weather than when it must be got into and out of a shed, since little risk is involved in getting the ship into and out of the mooring cone, it was nevertheless useful to study methods of housing in rough weather, and for this purpose a dock consisting of steel uprights and removable canvas shelter was designed at the Royal Aircraft Factory, and erected at the mouth of one of the sheds. The eddies over this in certain winds still require investigation both in the wind channel at the National Physical Laboratory, and on the full scale.

Portable shed.—The weight of such a shed as would be necessary to house the "Delta" would be some 400 or 500 tons, and, accordingly, a portable shed, capable of withstanding any wind up to 70 miles per hour on the ground had to be designed. As a preliminary to this, 12 model shapes were made and exposed to wind pressure in the air channel at the National Physical Laboratory, and a wind pressure distribution curve was also made in the old wind tunnel at the Royal Aircraft Factory. From this a shape was decided upon, and a portable shed was designed and erected. With adequate rough labour, erection in three weeks is considered feasible and formed part of the erection contract. The total weight is 75 tons.

Aeroplanes.—In addition to the work already alluded to, some eight experimental types of B.E. aeroplanes have been made, sometimes by utilising the parts of the original B.E.1 and S.E.1, sometimes by utilising parts which may have been made available by mishaps to other machines.

B.E.1 and 2 have been tried with various engines—the 60 Wolseley, 60 Renault, 60 E.N.V., and 70 Renault. It was also thought advisable to try the chief features of this design with the Gnome engine. The difference of shape and fixing required total re-designing of the fuselage, and at the same time a number of other improvements were incorporated, including a considerable extension of the passenger's ground view obtained by staggering the planes, simultaneously with a gain of about 5 per cent.

efficiency from the planes themselves (*see* Technical Report for 1911-12, p. 73).

Fin effect was studied—

(*a*) in relation to the radiators which had to be employed for the water-cooled engines, and

(*b*) by special fins put up for the purpose.

It was found easy by fitting suitable fins to obtain automatic banking by the action of the rudder alone, and to make this banking adequate to the turn, or excessive, at will. The instruments used for this research were made in the Physicist's Branch at the Royal Aircraft Factory, and the information acquired was utilised in the designs and verified by instrumental measurements in the air.

Dual control.—A desire for aeroplanes to cope with airships and therefore of such range that control by a single pilot for very many hours would be too fatiguing, led to the requirement of a machine with dual control. It was thought, moreover, that if the dominating control could be given to one of the pilots, the device might also be useful for instructional purposes. Various dual controls were accordingly designed and tried. With the advent of the machine of long air duration, this research will have to be further prosecuted.

To investigate the importance of the position of the wings and the amount of loading consequently supported by the aeroplane's tail, various positions were tried involving the movement of the wings forward or aft by a small amount.

A more important research, which required the construction of a large number of wings, was that connected with the automatic warping of the wings by the action of wind gusts. It had been found that the handling of B.E.2 was facilitated by the well known effect of the wind gusts in automatically warping the wings in the very manner required to maintain lateral equilibrium, and this was secured to a large extent without the interference of the flier. This result, commonly known to be obtainable in monoplanes, was not, when the experiments were started, known to be equally obtainable on biplanes.

With the improvement of the aeroplane generally, it became possible to fly in much higher and more gusty winds, flights on B.E.2 having been achieved in recorded wind gusts up to 54 miles per hour. The automatic movement then given to the aeroplane control lever by the gusts was found to be sufficiently large to be fatiguing to the pilot. It was surmised that this was largely due to the movement of the centre of pressure when warping occurred, thus leading to over-warping. This surmise was found correct. Wings not altered in other respects but having various positions of the main spar were made. The extreme forward position, which it is expected may be found satisfactory in extremely high winds, entirely cures the defect of excessive automatic warping. On the other hand, when this was obtained, pilots found themselves, in lesser winds, deprived of that suggestive movement of the wing which they had come to like, and accordingly an intermediate position for the wing spar was adopted, with success.

Wing shapes.—A number of studies of wing shapes was made at the National Physical Laboratory, and the best of these was selected for a new series of full scale experiments. An increase of the section of the rear spar which was desired by the designing department, solely for purposes of strength, led to a further alteration of the wing profile, thus evolving the section R.A.F.6, which proved on testing in the wind channel, to be an improvement on any of the previous models. The best position of the wing spar on this model was again studied and found by full scale experiment.

On this improved wing shape, experiments are being made simultaneously in the wind channel and on the full scale, by alterations to the trailing edge and shape generally, to regulate the movement of the centre of pressure.

It is thought that these experiments may lead to results of great practical value.

Controls.—The Royal Aircraft Factory fliers have taken occasion from time to time to fly machines fitted with the various types of control.—

(1) The universal lever with foot steering.

(2) A wheel warp with to-and-fro movement of the wheel for elevation, combined with foot steering.

A number of small variants of these has been tried and also a third control consisting of foot warp and wheel steering combined with to-and-fro wheel movement for elevation. It is understood that the standardisation of a good control is much desired by the Royal Flying Corps, but in this matter so much depends on individual experience and opinion that some half-dozen machines will be appropriately equipped and handed to Army fliers for prolonged test.

Tails.—A long series of researches was made, based upon the N.P.L. and Eiffel wing shape results, to secure at all times an appropriate longitudinal righting couple from the tail. A large number of different tails were made, having various cambers, and eventually a shape was obtained which was preferred by all those who tried it on the B.E.2 type of aeroplane. This tail has accordingly been called for on the machines which are being made under contract by the various aeroplane manufacturers.

Physical investigations.—Under this head may be grouped a large amount of auxiliary work of which only a brief outline can here be given. This section is concerned with the designing of experimental apparatus for obtaining various measurements on aircraft in flight, the designing of standard instruments for use on airships and aeroplanes, the consideration of modifications affecting stability, the preparation of the standard aeroplane charts of resistance and power, the working up of records, the examination of National Physical Laboratory results with a view to their application in design, as well as a large amount of testing and experimental work in connection with fabrics and methods of proofing, dopes for aeroplane fabrics, varnishes, oils, woods, wires and cables, attachments, light alloys, &c.

Among the instruments which have been devised for experimental research on aeroplanes may be mentioned one which has been termed a "ripograph," which is a combination of apparatus for use in the investigation of stability. It records photographically the air speed, and clinometer readings to give both the fore and aft inclination and also the lateral inclination of the machine. In addition the wing warping, the movements of rudder and elevator, and the rolling of the aeroplane are simultaneously registered on the same paper. Another apparatus, the "trajectograph," gives records of the air speed and the height above the ground, which can be used in determining gliding angles and rate of climbing. Other instruments devised are a wire tautness meter, a micromanometer of diaphragm type, a "yaw" meter, various types of velocity meters, &c. The thrustmeter for recording propeller thrust was referred to in last year's report. In connection with some of this work the Aircraft Factory has had the assistance of members of the Committee, and of the National Physical Laboratory.

Investigation into stability in connection with the full scale experiments.—In relation to the work of the physical section special attention has been given to the question of stability. The investigations made have been carried out in close connection with the researches at the National Physical Laboratory, and various modifications suggested by these researches, as well as by other theoretical investigations into the stability of the aeroplane have been tested. Various forms of tail planes and fins for use on machines of different types have been designed and tried in flight. Work has been done towards the computation of lateral resistance from the National Physical Laboratory results for struts and body models, and the checking of this information in flight.

An investigation into the phenomena connected with "turning" is in progress and it is hoped this will lead to valuable information as to lateral stability. Records of the rolling and of the warping and rudder movements of B.E.2 in winds have been taken with the "ripograph," affording evidence as to steadiness and control.

Other aerodynamical investigations.—The further aerodynamical research has been concerned chiefly with measurements of the resistance of aeroplanes. Gliding angles have been measured on B.E.2 and B.E.4 with the trajectograph and on B.E.2 with clinometer and velocity meter. Propeller thrust has been recorded by means of the thrustmeter. The results are of importance as giving higher values of the thrust than was anticipated, and arrangements are being made in conjunction with the National Physical Laboratory to investigate the matter more fully.

Tests to determine the propeller resistance during gliding will be made at the laboratory, and the gliding angle results will then be of great value in checking the accuracy of the Royal Aircraft Factory charts. The effect of side winds on propellers is under investigation and promises to show important results.

Fabrics.—Much attention has been devoted at the factory to providing suitable fabrics both for aeroplanes and for airships. In the case of aeroplane fabrics various types have been tried with a view to obtaining the greatest strength with the minimum of weight; special designs of weaving to produce high resistance to tearing have been tested. The extension and contraction of fabric due to heat and damp have been examined, as well as the effect of various varnishes and dopes, and of weathering. A large amount of experience has been gained in connection with airship fabrics, and it is hoped that a fabric has been obtained which will combine in a high degree the necessary qualities of strength and impermeability, with minimum weight.

In addition a great amount of investigatory work has been carried out on canvas for aeroplane and airship sheds, and on methods of proofing to diminish shrinkage and to reduce the effects of exposure to weather.

Engines.—A number of different types of engine have been experimented with and information as to their behaviour has been accumulated. A complete testing plant for the trial of motors for aeronautical purposes has been installed and was placed at the disposal of the Committee for the tests of motors in the Alexander Prize Competition of 1911.

Hydro-aeroplanes.—Progress has been made with the experimental work on hydro-aeroplanes, and in conjunction with the experiments in the William Froude tank already referred to different forms of float for hydro-aeroplanes have been constructed and tried. This work will be continued during the coming year.

The foregoing notes relate purely to the experimental work of the factory; the constructional work—construction of airships, airship sheds, aeroplane sheds and tents, &c.—cannot here be dealt with. Details with regard to some parts of the experimental work are given in an Appendix to this Report.

Meteorological work.—The accommodation at South Farnborough for the branch of the Meteorological Office which it is proposed to establish there at the request of the War Office with the sanction of H.M. Treasury has not yet been completed.

In the meantime Mr. J. S. Dines has been continuing his experimental work at Pyrton Hill, the central station of the Metecrological Office for the investigation of the upper air.

By way of commencement of operations at South Farnborough, Mr. Dines was directed to make a trial there of the arrangements which are desirable for the organisation of the supply of information for the use of airmen at the Aircraft Factory and the Flying School. The visit was also utilised to carry out a series of pilot balloon ascents—three each day except Sundays—for nearly four weeks in October and November. Mr. G. Dobson, of Gonville and Caius College, Cambridge, Graduate Assistant for the time being at Kew Observatory, was detailed to assist in the observations. The hours of observation were 7 a.m., 1 p.m., and 4 p.m., and the immediate object of the investigation was to ascertain the facts about the vertical extension of the calm which is experienced morning and evening as compared with the stronger winds of the middle of the day.

The method of sending observations by telegraph with a view to the construction of a map locally was tried and was found to be preferred to the transmission by railway post of a manifold copy of a map prepared in the Office; partly because time was saved and partly also because the actual observations enabled the local meteorologist to deal more satisfactorily with the questions arising on the spot. Upon the application of the War Office, authority was obtained to give priority to telegrams on this service, but as the messages had to be delivered by hand from the Marlborough Lines office, it is clear that the period required for the transmission of the messages from the Meteorological Office to the Aircraft Factory could be abbreviated with advantage. After the conclusion of the investigation telegraphic information was continued at the expense of the Branch Office. Mr. J. S. Dines has drawn up a report upon the results of the pilot balloon investigation which exhibits clearly the difference of rate of increase of wind velocity with height in the early morning, middle day, and evening respectively, grouped according to cloudy and clear days. The paper, which is printed as an Appendix to this Report, makes a notable addition to our knowledge of this interesting part of the subject.

At Pyrton Hill the anemometer for recording the direction as well as velocity at a height of 98 feet by means of a pressure-tube anemograph fitted with a direction recorder has been continued in operation throughout the year. An arrangement has been made for getting a very open time scale of about ¼ inch to a second in order to examine more closely the details of the variation of wind velocity as given by the anemometer and to determine the dynamical influence of the instrument upon the record.

A note has been prepared giving an account of the apparatus by which the direction is recorded, and instructions have been given to Mr. Munro, Engineer, of Cornwall Road, Tottenham, to produce the combined direction and velocity recorder in a marketable form. The first specimen of the instrument was ordered by the Meteorological Office and erected at Kew Observatory for the purposes of trial and inspection. It has recently been re-erected at Spurn Head and placed in charge of the Light-keepers who, by permission of the Elder Brethren of Trinity House, act as observers for the Telegraphic Reporting Station which exists at that exposed point. Another instrument on the same lines has also been delivered for erection at the Central Flying School at Upavon, and one with a modified pattern of direction-recorder has been exhibited in connexion with the Aviation Exhibition at the Science Museum, South Kensington. Among other subjects to which attention has been devoted may be mentioned endeavours to obtain some information about "cliff-eddies" due to buildings or other obstacles which cause turbulent motion in a current of wind. Mr. Dines examined, by means of a tethered balloon, the eddy due to a stable building at Pyrton Hill caused in a broadside wind of 15-20 miles per hour; and Mr. H. Harries, of the Forecast Division of the Meteorological Office, made use of the occasion of a visit to Gibraltar to study the effect of the eastern cliff upon the wind from the east, both when it was light and when it reached something like gale force. The observations were made by letting loose toy balloons, balls of cotton wool or wadding, in the air current, and watching the result. It was found that in the case of a light wind most of these objects after travelling upward a little way were brought back again in a closed curve to the observer, but in a gale of wind they were carried up with great rapidity to a height of two or three hundred feet and then passed away seaward. The observations are to be the subject of a paper to be presented to the Royal Meteorological Society.

Other subjects of investigation have been the preparation of a curve showing the variation of gustiness with height, and a diagram showing the relation of surface winds to gradient winds at Pyrton Hill and Southport, and a number of observations of pilot balloons and tethered balloons.

It is intended to commence regular observations at the Branch Office at South Farnborough with the new financial year, and the Treasury Grant for the maintenance of the Branch Office will be borne on the Meteorological Office Vote. In addition the special meteorological investigations carried out as required by the Advisory Committee will be continued with the aid of observers working under the supervision of Mr. J. S. Dines, instructed by the Director of the Meteorological Office.

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.—

On a determination on the whirling arm of the pressure-velocity constant for a Pitot (velocity head and static pressure) tube; and on the absolute measurement of velocity in aeronautical work.—By F. H. Bramwell, B.Sc., E. T. Relf, A.R.C.Sc., and A. Fage, A.R.C.Sc.

Surface cooling and skin friction.—By F. W. Lanchester.

Experiments on Wind Channels.—

An investigation into the steadiness of wind channels, as affected by the design both of the channel and of the building by which it is enclosed or shielded.—By L. Bairstow, A.R.C.Sc., and Harris Booth, B.A., A.M.Inst.C.E.

The new four-foot wind channel; with a description of the weighing mechanism employed in the determination of forces and moments.—By L. Bairstow, A.R.C.Sc.; J. H. Hyde, A. M. Inst. C. E.; and Harris Booth, B. A., A.M.Inst.C.E.

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

Experiments on models of aeroplane wings:—

(i.) Determination of the lift and drift of aerofoils having a plane lower surface and camber 0·100 of the upper surface, the position of the maximum ordinate being varied.
(ii.) Experiments on the effect of thickening the leading edge of an aerofoil.
(iii.) Report on tests of four aerofoils.
(iv.) Investigation into the effect of thickening an aerofoil towards the trailing edge.
(v.) Experiments on the variation of the lift and drift coefficients of a model aerofoil as the speed changes.
(vi.) Experiments on small scale models of large aerofoils tested at the Aerotechnical Institute of the University of Paris.
(vii.) An experiment on the effect of changing the roughness of the surface of a model aerofoil.
(viii.) Experiments on a warped aerofoil.
(ix.) Experiments on an aerofoil with reversed curvature towards the trailing edge.—

By the Aeronautics Staff in the Engineering Department of the National Physical Laboratory.

Investigation of the distribution of pressure over the entire surface of an aerofoil.—By B. Melvill Jones, B.A., and C. J. Paterson, B.Sc.

Experiments in the wind channel to determine the wind forces and moments on parts of aeroplanes:—

(i.) Determination of the forces acting on struts of different forms, when inclined at various angles to the relative wind.
(ii.) Determination of the forces and moments on models of aeroplane bodies.
(iii.) Determination of the wind forces on an aeroplane wheel.
(iv.) Tests on a model of a tail plane, with elevating planes attached.
(v.) Further experiments on the resistance of wires.—

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Method of experimental determination of the forces and moments on a model of a complete aeroplane; with the results of measurements on a model of a monoplane of Bleriot type.—By the Aeronautics Staff in the Engineering Department of the National Physical Laboratory.

Photographic investigation of the flow round a model aerofoil.—By E. F. Relf, A.R.C.Sc.

Stability.—

Investigation into the stability of an aeroplane, with an examination into the conditions necessary in order that the symmetric and asymmetric oscillations can be considered independently.—By L. Bairstow, A.R.C.Sc.; B. Melvill Jones, B.A.; and A. W. H. Thompson, B.A.

The experimental determination of rotary coefficients.—By L. Bairstow, A.R.C.Sc., and L. A. MacLachlan, A.M.I.M.E.

An examination into the longitudinal stability of a monoplane of Bleriot type, based on the data furnished by the model experiments.—By L. Bairstow, A.R.C.Sc.

Discussion of lateral stability, in connection with experiments on the same monoplane model.—By L. Bairstow, A.R.C.Sc.

Note relative to gyroscopic couples on aeroplanes.—By Mervyn O'Gorman, Superintendent of the Royal Aircraft Factory.

Propellers.—

Determination of the change in efficiency and thrust of a propeller caused by a change in the form of the blade section, the plan form and pitch remaining constant.—By F. H. Bramwell, B.Sc., and A. Fage, A.R.C.Sc.

Experiments on the effect of varying the angle of attack of the blades of a propeller; with a comparison between the actual performance of a propeller and that calculated with the aid of data obtained from experiments on aerofoils of appropriate sections.—By F. H. Bramwell, B.Sc., and A. Fage, A.R.C.Sc.

Strength of Construction.—

A preliminary note on methods of calculation which may be employed in the determination of the stresses in the spars of aeroplane wings.—By L. Bairstow, A.R.C.Sc., and L. A. MacLachlan, A.M.I.M.E.

Memorandum relative to the stresses in the fabric, and on the attachments of the fabric to the ribs, of an aeroplane wing.—By B. Melvill Jones, B.A.

Note on wing covering.—By Mervyn O'Gorman, Superintendent of the Royal Aircraft Factory.

Hydro-aeroplanes.—

Report of experiments carried out with a hydro-aeroplane, with notes and suggestions for further experiments. By Captain Murray F. Sueter, R.N.

Some experiments in connection with the design of floats for hydro-aeroplanes. — By G. S. Baker, late R.C.N.C., M.Inst.N.A., and G. H. Millar, B.A., A.Inst.N.A. With an appendix on tests in the wind channel to determine the wind forces on hydro-aeroplane float No. 43B.—By L. Bairstow, A.R.C.Sc.

Full Scale Experiments.—

Report on full scale work.—By Mervyn O'Gorman, Superintendent of the Royal Aircraft Factory.

Fabrics.—

On the leakage of mixtures of air and hydrogen through balloon fabrics, with a description of a new form of permeability apparatus.—By Guy Barr, B.A., B.Sc., and J. Thomas, B.A., B.Sc.

Note on a rapid and convenient method of determining the lifting power of samples of hydrogen.—By Guy Barr, B.A., B.Sc., and J. Thomas, B.A., B.Sc.

On the use of gelatine as a proofing for balloon fabrics.—By J. Thomas, B.A., B.Sc.

Experiments on aeroplane fabrics.—By Guy Barr, B.A., B.Sc., and J. Thomas, B.A., B.Sc.

Other Materials of Construction.—

Report on light alloys.—By W. Rosenhain, D.Sc., F.R.S.

Meteorology.—

Fourth Report on Wind Structure. Papers by J. S. Dines, M.A., contributed by the Director of the Meteorological Office, comprising:—

(i.) The diurnal variation of wind velocity, examined by means of pilot balloons at South Farnborough, October-November, 1912.

(ii.) Description of a combined velocity - direction anemograph erected at Kew Observatory, 1912.

(iii.) Cliff eddies.

(iv.) Comparison of gradient and surface winds at Pyrton Hill and Southport.

Note on wind velocity and gusts.—By H. R. A. Mallock, F.R.S.

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.