AERONAUTICS.

TECHNICAL REPORT

OF THE

ADVISORY COMMITTEE FOR AERONAUTICS

FOR THE YEAR 1911–12

(WITH APPENDICES).

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Bushy House,
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Middlesex.

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* Rear-Admiral Bacon resigned his position as an additional member of the Committee in December, 1911.

† Captain Sueter served as a member of the Committee until the middle of February, 1912.

REPORT FOR THE YEAR 1911–12.

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

SIR,

THE Report of the Advisory Committee for Aeronautics for the year 1910–11 was presented to Parliament in May, 1911. The aim of that Report was to give a general account of the work of the Committee during the year 1910–11, and of the results arrived at in the scientific and technical investigations proceeding under their control. Fuller details of these investigations were published later in the Technical Report of the Committee for the year 1910–11.

Following the procedure thus established, it is proposed in the present Report to give a general survey of the work of the Committee during the year 1911–12, reserving the detailed accounts of the experimental work, with other papers of general interest which have been laid before the Committee, for publication in the Technical Report* for the year 1911–12.

The Committee regret to have to record that in December, 1911, Rear-Admiral Bacon resigned his membership of the Committee, under the conditions attaching to his appointment as an additional member; and that Capt. Sueter's membership terminated in February, 1912. The Committee desire also to express their regret at having lost the assistance of their Chairman, Dr. R. T. Glazebrook, during the last six months of the year, owing to his serious illness.

Acting Commander Charles R. Samson, R.N., has been appointed to act as Naval Member of the Committee in succession to Capt. Sueter.

During the year 1911–12 the Committee has held ten meetings, in addition to meetings of Sub-Committees, dealing with the conditions for tests of motors, the arrangements for full scale experimental work, and other special matters.

The functions of the Committee, as defined in the statements made by the Prime Minister in the House of Commons on May 5th and May 20th, 1909, are to superintend the investigations at the National Physical Laboratory; and to advise generally on the scientific problems arising in connexion with the work of the Admiralty and War Office in aerial construction and navigation, and referred to the Committee by the Executive Officers of the Navy and Army Construction Departments. As was anticipated at the date of the appointment of the Committee, the problems arising in this way have been both numerous and varied; and a large portion of the labours of the Committee, and of the staff engaged in experimental work at the National Physical Laboratory, has been devoted to the solution of specific questions arising out of the work of the Construction Departments. During the past year there has been a considerable increase in the number

* Herewith included as Appendices to this Report.

of questions thus referred to the Committee, in regard to many of which experimental data were urgently required to enable constructional work to proceed on a satisfactory basis. The Committee has consequently found it necessary to recommend some addition to the equipment at the National Physical Laboratory, to which reference is made below.

An intimation has been received from the Lords Commissioners of H.M. Treasury that provision will be made in the Estimates for 1912–13 for the additional expenditure involved. It is hoped, on the completion of this additional apparatus and with some increase in the Laboratory Staff, that the accumulation of the experimental data desired may proceed more rapidly than has hitherto been possible.

Arrangements have also been made, with the co-operation of the War Office, for the systematic prosecution of experiments on full scale aeroplanes, both with a view to determining the effect of variation of constructional details, and to obtaining, if possible during flight, reliable measurements of the various quantities a knowledge of which is essential for the explanation of the behaviour of a given type of machine. These full scale experiments are proceeding at Farnborough, under the direction of the Superintendent of the Royal Aircraft Factory.

Equipment for experimental work at the National Physical Laboratory.—The equipment originally provided for experimental work at the National Physical Laboratory consisted of the following:—

(i) An air channel, 4 ft. square in section, in which a current of air can be maintained at speeds ranging up to about 30 miles an hour.

(ii) A whirling table of 60 ft. diameter for tests of model propellers.

(iii) A testing plant for endurance and efficiency trials of light petrol motors.

(iv) Two experimental wind towers, for tests on large models in the open, and for the study of the lateral variations in the velocity of the wind.

(v) Apparatus for tensile and bursting tests of fabrics and for permeability determinations.

For the housing of this equipment a new wing was added to the engineering building, while a special shed was constructed for the accommodation of the whirling table.

In addition to the above, the following apparatus, previously constructed at the Laboratory for other work, has also been available for experiments in aeronautics:—

(vi) A vertical air channel, of circular section, 2 ft. in diameter.

(vii) A small water channel for experiments on models in a current of water.

The additions to this equipment during the year 1910–11 were mainly of a minor character; they included a circular rotating water tank, a small water channel for the study of the flow round totally immersed bodies by visual and photographic methods, with improved equipment for tensile tests of fabrics, and apparatus for testing fabrics under combined bursting and tensile stress.

The most important addition to the equipment now under contemplation is the provision of a new air channel, of section 6½ ft. square: these dimensions will facilitate access to the model under test. For this air channel a special building will be provided. The aims of the Committee in recommending this provision are two-fold. On the one hand, as already stated, the urgent demand for a large variety of experimental data has necessitated an increase in the apparatus available for making such experiments. On the other, it is felt that the relatively small scale of the models which can be tested in the present 4-ft. channel renders extremely difficult the attainment of accurate results in certain classes of work, while the information to be obtained from the comparison of tests of similar models in the two channels will be of very great value. The provision of the larger channel will thus not only greatly increase the rate at which experimental results can be obtained, but will open up new fields for investigation.

With a view to ensuring that the new air-channel shall be as efficient as possible, an extended study of the conditions to be observed in the construction of an air-channel, in order to obtain the best results, has been in progress over a period of several months during the past year. A large number of temporary channels of different types have been constructed, and the conditions of flow investigated. In order further to test the conclusions arrived at from this experimental research, the 4-ft. channel is now being rebuilt. It is hoped that a marked improvement in the steadiness and uniformity of the air current may be attained; and if the conclusions arrived at from the preliminary investigations with small scale model air-channels are thus justified, the construction of the 6½-ft. channel will be undertaken without delay.

In addition to the water channel above mentioned, a small vertical air channel for visual and photographic work, 6 inches square in section, has been constructed during the past year. This has rendered valuable assistance in connection with the aeroplane experiments in the four-foot channel, and a larger channel of section 9 inches square, with improved arrangements for illumination and for obtaining photographs, is now in course of erection.

Some alterations and additions to the whirling table equipment were referred to in the Report for 1910–11. These included the provision of a motor of greater horse-power to drive the propeller, and a new dynamometer capable of taking a greater propeller thrust. These alterations were found to necessitate some modifications in the whirling arm itself, which have been made during the past year.

Experiments on Airship Models.—The Technical Report for the year 1910–11 contained an account of experiments made to determine the head resistance of a series of airship models. In the same paper were given the results of measurements of the forces acting on some of the same models when inclined to the direction of motion.

An account was also included in that Report of an investigation into the moments acting on an airship model when inclined at different angles to the relative wind, and into the amount of fin area necessary, and the best disposition of such fins, to give a restoring moment in the event of any deviation of the airship from her course. An interesting discussion of the conditions affecting the steadiness of the motion of an airship, and of the action of fins and rudders, is given in some "Notes on Steering" by Rear-Admiral Bacon, which are printed in an Appendix to this Report.

During the past year further experiments have been made on the resistance of airship models, and on the forces and moments acting on inclined models of different forms. The resistance measurements included some tests of special shapes, made at the request of the Superintendent of the Royal Aircraft Factory; and an investigation to determine the effect of bluntness of tail on the relative air flow and on the resistance. From visual observations and photographs of the flow past models in the small water channel, made with the aid of coloured streams, it was noted that the flow in the tail region even of an elongated model was very slow. It was inferred that truncation or modification of the tail within this "dead" region should have little effect on the head resistance. A model was accordingly made in which successive sections of the tail were removable, and it was found, as expected, that the effect of the removal of portions of the tail within the "dead" region was negligibly small. In the model tested, the full length of tail was about twice the maximum diameter, and it was found that a length of 0·8 of the diameter, from the tip, could be removed without appreciable effect on the head resistance. It follows, therefore, that within this region the tail may be rounded off or otherwise modified without loss of speed; a gain in lifting power is thereby secured, while the less pointed form presents advantages from the constructional point of view.

The investigation into the moments acting on inclined models was made in response to a request from the Royal Aircraft Factory, and related to twelve models which had been previously tested for head resistance. The object of the experiments was to obtain an estimate of the "manœuvring capacity" of the different forms. The results obtained are given in an Appendix to this Report. For the purpose of these experiments, a new form of apparatus for the determination of "moments," different from that previously employed, was designed and constructed.

In addition to the model experiments above described, an interesting series of determinations of the head resistance of eight different airship forms was carried out at the Royal Aircraft Factory. These models were made of goldbeaters' skin and were about 18 ft. in length, and 3 ft. in diameter. The method employed was to tow the models horizontally through the air at different velocities, the speed being maintained by means of a falling weight. The conclusions arrived at from these experiments were generally in accordance with those deduced from the measurements made on small models of the same forms in the water channel at the National Physical Laboratory. From the point of view of total balloon resistance alone, a fineness ratio, or ratio of length to maximum diameter, of $6\frac{1}{2}$ to 1 was found to be most efficient; but taking into account the other resistances in the completed airship, it was concluded that it might be desirable to reduce the fineness ratio to about $5\frac{1}{4}$ to 1.

The difficulties of obtaining results of high accuracy by the method of towing light models of this character through the air are very great, but nevertheless a comparison of the measurements of head resistance thus made on models of 3 ft. diameter, with those given by tests in water of ebonite models of 1 inch diameter, is of much interest. The difference between the densities of the two media, air and water, is not a source of difficulty in such comparison: the relative resistances are directly proportional to the densities of the media, and allowance for the difference in density is thus readily made. According to the law of dynamical similarity, referred to in previous Reports, and clearly enunciated by Lord Rayleigh in the Report for 1909-10, the quantities on which variation in the resistance coefficient may be expected to depend are the relative dimensions, the relative velocities, and the "kinematical viscosities." The velocities in the two sets of experiments, made at the Aircraft Factory and the National Physical Laboratory respectively, were 20 ft. per second and 1·78 ft. per second. The kinematical viscosities of air and water are in the ratio of 13 to 1. Employing the law of dynamical similarity the two series of experimental determinations enable a provisional estimate to be formed of the effect on the coefficient of head resistance of change in velocity, and of change in dimensions. Mr. Bairstow, of the National Physical Laboratory, has made the calculation, and employing the data so obtained, has estimated the resistance of a full-sized balloon, with smooth surface, of 40 ft. diameter and of specified form, with fineness ratio of 6 : 1, when travelling at the rate of 40 miles per hour, to be 320 lbs. weight.

To obtain further information on this important question of the variation of the resistance coefficient with dimensions, a large wooden model of an airship, 6 ft. in length and 1 ft. in diameter, has been made at the Laboratory, and its resistance will be determined by towing tests in the William Froude National Tank. These experiments are now in progress. A further model 4 inches in diameter and 2 ft. long is also under construction for towing tests in the Tank, and it is hoped that a comparison of the various experimental results available may lead to valuable conclusions as to the relation between the resistances of models and of the full scale machines, and may furnish data sufficient to enable the prediction, from observations on models, of the absolute magnitudes of the forces acting on full-sized airships and aeroplanes to be made with more confidence than is at present possible. One of the "Abstracts" printed in this Report gives an account of experiments made, during flight, to determine the total head resistance of the Zeppelin airship "Schwaben." From the particulars given in the original paper describing the experiments, they would appear to have been remarkably successful, and a comparison of such results, obtained in flight, with those given by tests of small and similar models in the laboratory should furnish the data necessary to enable the discussion of the effect of dimensions to be completed. At the moment, however, the necessary comparative data are not yet available.

Experiments on models of planes and aerofoils.—The experiments to be described under this head constitute the major portion of the work carried out at the National Physical Laboratory during the past year. They comprise the following:—

(i) Complete investigation of the pressure distribution, in a median section, over the upper and lower surfaces of (*a*) a thin flat plate of aspect ratio 5 : 1; (*b*) an aerofoil of specified form of aspect ratio 5 : 1.

(ii) Determination of the effect of the separate variation of the upper and lower surfaces of an aerofoil.

(iii) Lift and drift determinations for some aerofoils of specified forms.

(iv) Determination of the effect on the lift and drift of variation of the spacing of the two "planes" in a biplane.

(v) Determination of the effect of "staggering" the planes in a biplane, that is, of setting back one plane relative to the other.

(vi) Effect of dihedral angle between the wings of an aerofoil.

(vii) Lift and drift determinations for planes and aerofoils of different aspect ratios.

(viii) Effect of variation of the camber of the upper and lower surfaces of an aerofoil.

In connection with some of this work, and as an aid to the explanation of results obtained, investigations have been made by visual and photographic methods, in the special channel provided for this purpose, of the flow past aerofoils of different forms.

Investigation of the pressure distribution round a thin plate and an aerofoil.—The object of these experiments was to examine closely the character of the air flow round a thin plate or an aerofoil, and to investigate the way in which the total 'lift' and 'drift'—apart from friction—on the whole plate are built up from the pressures, or 'suctions,' at different regions of the upper and lower surfaces. The experimental difficulties are considerable, and the amount of work involved in a complete series of measurements for a single aerofoil is very great. Readings were taken in the case of the flat plate for each of six points on each of the upper and lower surfaces, and in the case of the aerofoil for each of eight points on each surface, for all angles of attack from 0° to 25° at intervals of 2½°. The aspect ratio was in both cases 5 : 1, and the pressures were determined over a median section. It is proposed later to take readings over the whole surface, so as to determine the effect of the edges. It was thought that more valuable information might be obtained at first by careful examination of the flow in the case of a single aerofoil for different inclinations, than by a less complete examination of a number of different types.

In conjunction with the pressure measurements, visual observations were made, and photographs taken, to determine the nature of the flow at different angles, and to assist in the discrimination of the 'critical' angles at which marked changes in the character of the pressure distribution appeared to take place.

The detailed results and distribution curves which are given in the Appendices exhibit many points of interest, and of importance in aeroplane design. Thus for the aerofoil tested there was a particular angle at which the upper, convex, surface gave its maximum contribution towards the total lift, and another, different, angle at which the under, concave surface gave the maximum effect. It thus appeared to be a possibility that by variation of one of the surfaces improved efficiency could be obtained.

The nature of the pressure distribution on the convex surface of the aerofoil presents some remarkable features. At inclinations commonly occurring in flight practice, from 5° to 10°, the negative pressure on the convex surface is a maximum, and reaches a very high value, at a point immediately behind the leading edge of the 'plane.' The same fact is shown in the distribution curves for different aerofoils at an angle of 6° given by M. Eiffel, who has also carried out a large number of experiments in the plotting of pressure distribution, to which the National Physical Laboratory measurements may be regarded as complementary. M. Eiffel's results were obtained for various aerofoils at an angle of 6°, regarded as a mean angle of attack in flight; the Teddington results give information for a number of aerofoils forming a connected series at a wide range of angles. This particular feature of the high negative pressure near the leading edge is no doubt of great importance as giving guidance to the designer as to the direction in which to look for the most efficient form.

The superiority of a curved aerofoil over a flat plate depends very largely on the existence of a component of the air pressure, along the chord of the aerofoil, in the forward or "up-wind" direction. This up-wind component shows a marked development at angles in the neighbourhood of 12½°, due directly to the very uneven distribution of pressure over the convex surface at these angles. In the report on these experiments the inference is drawn that when designing for efficiency it is essential to make this uneven distribution as marked as possible. It may be noted that M. Eiffel draws a somewhat different conclusion from the same experimental results.

Another interesting feature of the results obtained for the aerofoil is that at an inclination of about 12½° there is a marked change in the pressure intensity on the convex surface, and from 12½° to 20° the conditions of flow appear to be so unsteady that no readings of the pressure intensity could be made, the pressure varying incessantly and erratically within wide limits. This critical region is also indicated, in a less marked manner, by the measurements made on the concave surface. For fuller particulars of these and other interesting results deduced, reference must be made to the discussion of the experiments given in the Appendices to this Report.

Effect of separate variation of the upper and lower surfaces of an aerofoil.—In continuation of the investigation above described, into the pressure distribution, the effect has been examined of varying one surface only of the aerofoil, the curved under surface of the afore-mentioned aerofoil being replaced by a plane. The pressure distribution over this new aerofoil was determined in the same manner as before. A comparison of these results with those for the original aerofoil, and with the measurements for the flat plate, enables some conclusions to be drawn as to the effect of variation of either the upper or the under surface. The information obtained from the pressure plotting was also supplemented by direct measurements of the total lift and drift.

The general conclusion arrived at is that, as a first approximation, each of the surfaces of an aerofoil can be independently designed; the second approximation, due to interaction between one surface and the other, is sufficiently small to be regarded as of the nature of a correction.

The curves obtained for the lift and drift, and the ratio of lift to drift, show clearly the effect of replacing a cambered under surface by a plane one. Over the useful range of inclinations from 7° to 12°, the ratio of lift to drift is nearly the same for both aerofoils, but the lift coefficient at 10° decreases from 0·48 to 0·42. It follows from this that about 14 per cent. increase in wing area would be required to produce the same lift.

Lift and drift determinations for some aerofoils of specified forms.—M. Eiffel has made a considerable number of experiments on thin aerofoils of different forms. From these he came to the conclusion that the feature of importance in a thin aerofoil as determining the forces acting on it in a current of air is the amount of camber. For two aerofoils of the same camber the form of section, whether, say, circular or wing-shaped, does not greatly affect the efficiency, though the angle of attack may be affected. The amount of camber giving the best results was found to be 1 in 13·5.

The aerofoils which have been tested at the National Physical Laboratory are of appreciable thickness; a connected series of aerofoils with varying camber of the upper surface has been examined up to a maximum camber of about 1 in 6.

Details of the results obtained in the National Physical Laboratory experiments are given in the Appendices. The results in one case are of special interest. A wing form of a Blériot type was tested, precisely similar to a model aerofoil tested by M. Eiffel and for which his results are given in the first section of his work "La Résistance de l'Air et l'Aviation." The values found at the National Physical Laboratory for the 'lift' at different angles were consistently higher than those given by M. Eiffel, the differences being of the order of 15 per cent. Differences in the 'drift' were also found. Both series of differences were sufficiently great to need explanation, and a careful examination has been made into the details of the experimental methods employed, which were not similar in the two cases. It would appear possible that the explanation of the differences is to be found in observational errors; the matter will be further investigated, and great care will be taken to secure and to maintain a sufficiently high degree of accuracy in the experiments at Teddington. In the values deduced for the ratio of lift to drift the differences, within the range of inclinations of importance for practical purposes, are not so great; the maximum value of the ratio of lift to drift found at Teddington is 13·5, while the maximum found by M. Eiffel is somewhat over 14.

Effect of variation of the spacing of the two planes in a biplane.—These experiments were made with two facsimiles of the Blériot aerofoil mentioned above, and the 'gap' between the two planes was varied from 0·4 to 1·6 times the breadth of either plane. The results were corrected for the resistance of connections. They show appreciable loss of lift per unit area as compared with the single plane; when the 'gap' is equal to the breadth of either plane, the loss is 17 per cent. Even with a 'gap' equal to 1·6 times the breadth, the loss is still as much as 10 per cent. The 'drift' values for the biplane do not differ greatly from those for the single plane: the percentage losses in the ratio of lift to drift are thus nearly of the same magnitude as those in the lift.

The advantage that might be gained by employing a wider spacing than the usual one, with a gap equal to or slightly greater than the breadth of a plane, is, of course, to some extent, counterbalanced by the increased resistance and added weight due to the extra length of struts necessary. The best spacing depends on the conditions of design, and is different if the speed be required to be kept constant from that most suitable for a machine having wings of fixed area.

A general discussion of the question is given in an Appendix to this Report, from which it appears that for flight speeds ranging from 40 to 60 miles an hour the best biplane spacing is in the neighbourhood of that most commonly adopted, with a 'gap' approximately equal to the chord.

Effect of setting back one plane relative to the other in a biplane.—The biplane used in this investigation had a 'gap' equal to the breadth of a plane. It was found that when the lower plane was set back relative to the upper through a distance equal to 0·4 of the 'gap,' an improvement of about 5 per cent. was obtained in the lift and in the ratio of lift to drift. The setting back of the lower plane also presents some advantages from a constructional point of view, and on account of the wider range of vision rendered possible for pilot or passenger. The resistance of struts set obliquely is also somewhat less than when they are at right angles to the direction of motion.

Effect of dihedral angle between the wings of an aerofoil.—Experiments to determine the effect of dihedral angle were made with each wing of an aerofoil turned up through 7°, and also turned down through 6½°. No measurable difference in lift or drift was found in either case from the results for the same aerofoil with the wings level. Any advantage in lateral stability that may be obtainable by dihedral angle between the wings can thus be gained without any loss of lift or increase of head resistance. The experiments were made up to angles of attack exceeding 10°.

Lift and drift determinations for planes and aerofoils of different aspect ratios.—The earlier of these experiments were made on flat plates, with bevelled edges, of aspect ratios ranging from 1:1 to 5:1. The results shew an increase in both the lift and the drift per unit area as the aspect ratio increases. The variation in the ratio of lift to drift with change in aspect ratio was, however, found not to be important. The values obtained in these measurements were generally in good agreement with those of other observers, among whom may be mentioned especially Eiffel, Prandtl and Froude. Froude's experiments were made in water; those of Eiffel and Prandtl in air.

Experiments have also been made on a series of aerofoils of the same profile of aspect ratios ranging from 3:1 to 8:1. These shew only a slight increase in the lift coefficient with aspect ratio. As the aspect ratio is increased the lift coefficient corresponding to the maximum value of the ratio of lift to drift increases slightly, and the drift coefficient decreases appreciably; the maximum value of the ratio of lift to drift thus increases with aspect ratio. From the experiments made it would appear that at an aspect ratio of 8:1 the limit of this increase has not been reached; the greatest ratio of lift to drift actually observed was about 15:1.

Effect of camber.—The effect of variation of the camber of the upper surface, and also of the lower surface, has been investigated. As already stated, it had been previously shewn that, to a first approximation, the upper and lower surfaces might be independently designed. The experiments on the variation of camber of the upper surface were made on aerofoils having their lower surfaces plane. The amount of camber of the upper surface giving a maximum value of the ratio of lift to drift was found to be about 1 in 20, as compared with Eiffel's value of 1 in 13·5.

The experiments on the effect of varying the camber of the lower surface were made on an aerofoil in which the camber of the upper surface was about 1 in 10. It was found that the ratios of lift to drift were practically unaltered by the change of camber in the lower surface, but the lift coefficient at a given angle of incidence increased steadily with increase of camber, the gain in lift amounting to about 17 per cent. for a lower surface camber of 1 in 16, as compared with a plane under surface.

Wind Resistance of some Aeroplane Struts.—The results of measurements of the wind resistance of smooth wires and ropes were given in the Report for 1909-10. At the request of the Superintendent of the Royal Aircraft Factory measurements have been made during the past year of the resistance of a number of aeroplane struts of various cross sections. A calculation was made from the results to determine the effect of replacing one set of sixteen 6-ft. vertical ash struts by others of a better 'stream-line' form. Assuming that the gliding angle was kept the same and that the improvement was utilized to carry extra weight, it was found that the gain resulting was 79 lbs. The figures suggest that further improvements in speed and gliding angle may be attained by the systematic reform of all the accessory air resistances of an aeroplane.

It may be remarked that in the design of struts several different factors have to be taken into account. Thus it may be possible to increase the lifting power of an aeroplane, and at the same time on add to the weight of the struts to an extent equal to or greater than that necessitated by the additional strength required, by adopting a form of lower head resistance. The point is discussed in the detailed account of the tests.

Another result of interest is that the resistance of a strut inclined to the wind is less than that of a strut normal to the wind.

Other Experiments in connection with Aeroplanes.—Mr. O'Gorman has placed before the Committee a considerable programme of further experimental work on aeroplane models, in relation to questions which have arisen in connection with constructional work proceeding at Farnborough. Experiments are desired on the movement of the centre of pressure for different relative wind directions, the effect in a biplane of making the upper plane longer than the lower, the effect of variation of plan form, of thickness, of double curvatures of various types, measurements of body resistance, distribution of air pressure, and the determination of a variety of other data, the collection of which even at the most rapid rate of experimentation advisable must necessarily occupy the experimental department for a considerable period. A scheme for further work has been approved by the Committee, and this will be proceeded with as rapidly as circumstances permit. The Committee held that the necessity of advancing more rapidly with these experiments rendered imperative the provision of another air channel; and, as already stated, it has been arranged to build a channel of section 6¼ ft. square, for which provision will be made by the Treasury. The increased accuracy in measurement which it is hoped to attain by improved design in the reconstruction of the four-foot channel will also, if realized, appreciably increase the rate at which experimental data can be obtained.

Air and Water Channels for visual and photographic work.—In the Report for the year 1910-11, a description was given of the apparatus used for studying the flow past an obstacle in a fluid medium and some preliminary experiments were described and photographs reproduced showing the eddies caused in a stream of water at low velocities by a square plate and by an airship model.

It was thought desirable to repeat these experiments in air and for this purpose a small air channel was constructed with which it was possible to demonstrate the similarity of flow in the two media.

Some further observations have been made in a third apparatus in which the air velocity attainable is of the order of 20 ft. per second, and these experiments have shown that useful information regarding the flow past aerofoils at even higher velocities might be obtained with improved apparatus.

The chief difficulty in these earlier experiments has been to obtain satisfactory illumination for photographic work. To overcome this a special illuminating apparatus has been designed and installed, and with its aid a series of photographs illustrating the flow past planes and aerofoils at various angles in the water channel has been taken. As already stated these have been of great assistance in connection with the air resistance experiments above described.

In connection with this work a new method of studying the direction of motion and velocity of small particles in flowing water has been developed, and a comparison of photographs of these moving particles with those of 'filament' lines obtained with coloured fluid shews clearly the difference, except in those regions where true stream line flow exists, between the direction of these lines and the actual direction of motion at any point in the fluid.

Friction in pipes.—In continuation of his research on air friction in pipes, described in the Report for 1910-11, Dr. Stanton has made some experiments on the relative frictional resistances of surfaces in air and in water. The law of dynamical similarity requires, in order that the results for air and water shall be comparable, that the quantity here called the viscosity ratio, viz., the product of velocity and linear dimensions divided by the 'kinematical viscosity,' shall be the same for the two sets of observations. In order to obtain a strict comparison of this kind, considerable time was spent in the reduction of the results of different experimenters on the friction of air and water in pipes. It was found, however, that differences in roughness of the surfaces experimented upon rendered any exact comparison misleading, and it appeared evident that experiments should be made on the same surface, first with one fluid and then with the other.

The opportunity presented itself of making these experiments under a wide range of conditions by the use of the smooth and artificially roughened pipes fitted up for the air friction experiments. It was found, as was anticipated from the theory, that when the values of the viscosity ratio were the same in the two cases, the coefficients in the equation expressing the frictional force in terms of the square of the velocity were directly proportional to the densities of the two media, within the limits of accuracy attainable, which, in the method of experiment employed, was of a much higher order than would be required for practical purposes. A comparison of the values for air and for water, flowing in pipes of the diameter employed, at equal speeds comparable with those obtaining in these experiments, without taking into account differences in the value of the viscosity ratio, would, in the case of the smooth pipes, have shewn very marked disagreement. The disagreement would, however, not be so marked at high speeds, or in pipes of large diameter, and this apparently explains the fairly close agreement between Froude's and Zahm's results for boards when the values of the respective viscosity ratios were widely different.

In the case of the experiments in an artificially roughened pipe, the results with air shewed unmistakably that the friction over the range obtained varied as a power of the velocity somewhat greater than two, and the small variation was also clearly brought out by the water experiments.

The Law of Dynamical Similarity and the Use of Models in Aeronautics.—The theory relating to dynamical similarity explained by Lord Rayleigh and by Mr. Lanchester in the first of the Annual Reports of the Committee is of fundamental importance in all applications of the method of models to the determination of the forces acting on bodies moving in air or in water, and some papers by members of the Aeronautics Staff of the Laboratory discussing the application of this theory in special cases of experimental investigation are included in the Report. Reference has already been made to other work which has been done with a view to determining in certain instances what may be called the 'transformation factor' for passing from the model to the full-sized machine; or to establishing the conditions under which the results for the model and for the full-sized machine are directly comparable. The conditions shewn to hold for the flow in pipes are probably applicable in the case of many other aeronautical problems.

From such information as is at present available, it would appear that the 'transformation factor' for deducing the magnitudes of the forces acting on a full-sized aeroplane from the results of the model experiments above described is approximately unity; in other words, the results may be applied, without alteration, to the full scale machine. This is confirmed by M. Eiffel in a recent communication.

Whirling Table and Propeller Tests.—Mention was made in the previous Report of the Committee of modifications introduced in the propeller-testing apparatus to obtain greater range and sensitiveness. As already stated, constructional alterations have been found necessary in the whirling table itself, and these have been carried out during the past year. The whole apparatus is now in working order, and the measurements can be effected with much greater facility than hitherto.

Effect of Blade Area and Pitch on Propeller Efficiency.—In addition to tests made on isolated propellers, the series of tests referred to in the Report for 1910-11, to determine the effect on propeller efficiency of varying the width of blade, has been continued.

The propeller employed for the purposes of these tests was one supplied by Messrs. Vickers, Ltd.; in its original form it was an exact model, on a scale of 2 in 15, of a propeller 15 ft. in diameter, with a pitch of 10 ft. 6 in. at the leading edge, and 11 ft. 6 in. at the trailing edge; the pitch, however, being constant along any radial line. The model propeller of 2 ft. diameter, as supplied, had square tips, the blade having a constant width of 6⅝ in. from the tip to about 7 in. from the axis.

The series of five propellers tested was obtained from the above propeller by variation of the blade width and rounding it off on a consistent plan, the blade widths ranging from 6⅝ in. to 2⅝ in. at one-inch intervals.

Complete details of the tests on these five propellers are given in an Appendix to this Report. It is noted in the discussion of the results that, at a constant translational speed, the departure from maximum efficiency is negligibly small over a fair range of blade widths, from about 3·4 to 4·8 inches. The change of thrust under the same conditions is also small.

Tests have also been made on two series of propellers of different blade widths, in which the pitch was varied somewhat on either side of that obtaining in the original design. Some effects of increase in pitch may be inferred from these experiments: with the wider blades an improvement in efficiency was obtained with the increase in pitch, and in the experiments made the limit of improvement did not appear to have been reached. With the narrower blades the maximum efficiency obtained was for a ratio of pitch to diameter of about 0·80. The investigation of the effect on the efficiency of variation in pitch will be continued.

In addition to the account of the experiments on model propellers at the National Physical Laboratory, papers have been included in the Appendices by Mr. Bolas, of the Royal Aircraft Factory, and by members of the staff of the Laboratory, in which some discussion of propeller theory is given. The 'Abstracts' also contain summaries of papers on propeller theory by various writers. Though some of the theoretical work may be open to criticism, the papers have been thought of sufficient interest to be included. A general account of propeller theory and practice presented by Sir George Greenhill is also printed as an Appendix to this Report.

Tests on Motors for Aeronautical Purposes.—In the Report for 1910-11 it was stated that Mr. Patrick Y. Alexander had for the second time offered a prize of £1,000 for an aeronautical motor, to be awarded after a competition under conditions generally similar to those laid down for the earlier competition which took place in 1910. The conditions on this occasion required the engines to be of somewhat higher horse-power than previously, and the competition was open to any engine whether of British, Colonial, or Foreign manufacture. The help of the Committee was again sought in carrying out the necessary tests. In view of the great interest and importance of such tests to the Government Departments responsible for work in the field and of their general public utility, the Committee were glad to give their assistance, and undertook to report on the results of the tests; and it was arranged that the award should be made by a Joint Committee of the Aeronautical Society, the Royal Aero Club and the Aerial League, in conjunction with Mr. Alexander.

For the purpose of these tests, the Superintendent of the Royal Aircraft Factory kindly placed at the disposal of the Committee the motor-testing plant which has been installed at the factory. This is designed for the testing of engines up to 100 H.P. The tests were carried out at Farnborough by the staff of the Aeronautics Division of the National Physical Laboratory.

Eight engines were entered for the competition, but of these only two were delivered by the date fixed by the Committee, September 30th, 1911. With one exception the entrants were British firms. The two competitors were the E.N.V. Motor Syndicate, the brake horse-power of whose engine was declared as 60, at 1,120 revolutions per minute, and the Green Engine Co., who entered an engine of brake horse-power declared as 65, at 1,150 revolutions. The test included two runs of 12 hours each. The E.N.V. engine completed the first 12-hour run, giving a mean B.H.P. of 61·2 at 1,105 revolutions, with a single stop of 8¼ minutes to repair a broken coupling to the water pump. During the second 12-hour run it failed owing to the cracking of a cylinder.

The Green engine satisfied all the conditions set out in the regulations for the trials, completing the two twelve-hour runs without any stop or attention to the engine, giving a mean B.H.P. of 61·6 at 1,150 revolutions, against the minimum of 58·5 B.H.P., 10 per cent. less than the declared B.H.P. allowed by the regulations. In a maximum power test this engine developed 67·8 B.H.P.

at 1,210 revolutions during a seven-minutes run, while in two tilting tests of one hour each, in which the engine was tilted through 15 degrees about a longitudinal axis and a transverse axis respectively, the mean brake horse-powers measured were 62·3 and 60·4.

In reporting on the trials the Committee thought it of interest to call attention to the fact that the competition was open to engines of British, Colonial, or Foreign manufacture, and that the competitor, whose engine had fulfilled the conditions, is a British firm. They also expressed their congratulations to the Green Engine Co. on the good performance of their engines in this, and in the earlier, competition.

A full report on the trials has been published, together with reproductions of records taken during the tests, and a description, with diagrams, of the testing plant at the Royal Aircraft Factory.

Balloon and Aeroplane Fabrics.—The tests on fabrics have been continued generally on the same lines as indicated in the previous report. The complete scheme of exposure tests there mentioned has been brought to a satisfactory conclusion. It has recently been possible to give more attention to aeroplane fabrics, and systematic tests of some of these are in progress. The effects of low temperatures on balloon fabrics, and on joints, have also been studied.

Tensile Tests.—The method of making these has been previously explained, and no further remarks are at present necessary. The investigations as to the effect of weathering, and other researches, have included a considerable number of such tests.

Compound Stress Tests.—From the commencement of the work importance has been attached to the testing of balloon fabrics under combined stresses at right angles, since this condition obtains in an airship envelope. In the previous report some preliminary work was described, carried out with an apparatus for making tests of cylinders of balloon fabric under combined bursting and longitudinal stress. Subsequently an exhaustive set of compound stress tests was made on a series of bags of parallel doubled rubbered cotton fabric.

The object of the investigation was to find the law according to which the stress ultimately causing breakdown is lowered by the presence of a less stress in the direction at right angles. It was also hoped that a knowledge of the laws of compound stress might enable bursting tests to be dispensed with in future, at least in the case of single or parallel doubled fabrics. These objects may be considered to have been satisfactorily attained. It was shewn that for a parallel doubled fabric the limits of compound stress may, with an allowance of five per cent., be taken as the limits of simple tensile strength of warp and weft, the limits of tensile strength being those obtained from tests of elongated specimens.

The degree of closeness of agreement between the simple and compound stress tests performed on the fabric is indicated by the following results. The mean strength of warp specimens 12½ inches long under simple tension was 95 lbs. per inch width. The lowest mean warp stress under compound loading (at different ratios of stress) was 92 lbs. per inch width, but would reach 91 lbs. at equal stresses. This shews an error of 4 per cent. in applying the tensile test on an elongated specimen to any case of compound loading. The variability of strength from one specimen to another under compound stress was observed to be as great as 12 per cent. on either side of the mean, while the greatest variation of tensile strength observed for this fabric was 15 per cent. Hence for this particular fabric the error in using the tensile test to represent the strength under actual working conditions is only one-third of the uncertainty, due to variation in the fabric, of a strength test.

At a later date a similar series of tests was carried out on cylinders of diagonally doubled rubbered cotton fabric, generally similar to the preceding, except for the arrangement of the layers. The results were somewhat inconclusive from the point of view of an attempted theoretical explanation which was applied both to this and to the previous series of tests, though not inconsistent with it. The interpretation of the results was, however, a matter of some difficulty, and with the existing data, in the case of diagonally doubled fabrics, deductions from the results of tensile tests cannot be taken to supersede bursting tests. It is clear, however, that for these fabrics the effective strength in practice is considerably higher than the strength given by a simple tensile test. In some experiments made at the Royal Aircraft Factory, described in the Report for 1910-11, the mean strength of a number of cylinders of diagonal material tested under bursting stress was found to be about 1·4 times the mean strength of the same materials as determined by simple tensile test. The figures obtained in the recent experiments at Teddington are generally in agreement with this, and as a rough approximation for working purposes this number may reasonably be used as a transformation factor.

Tearing Tests.—In addition to the tearing tests described in last year's Report, some experiments have been made on the tearing of fabrics under compound stress conditions. The method of applying the compound stress for this purpose was one originally suggested by Mr. Horace Darwin. The results shewed that for single, or parallel doubled, fabrics of any kind the factor of safety for tearing, for a given type and size of wound, under actual service conditions as regards stress, may be taken as that determined in simple tension according to the method described in the Report for 1910-11.

Under present circumstances, however, this conclusion cannot be extended to diagonal fabrics.

Permeability Tests.—The method of making permeability tests during the past year has remained the same as previously described, and though a number of different fabrics have been tested during the year, no specially noticeable results have to be recorded.

Effect of Low Temperatures.—The effect of low temperatures on the permeability of both rubbered and other specially proofed fabrics has been examined. Temperatures as low as -25° C. did not produce any appreciable effect in the case of rubbered fabrics, but oilskin fabrics, if crumpled when cold, shewed a marked increase in permeability. Samples with or without seams gave similar results. The oilskin samples, however, recovered their good gas-containing qualities on return to normal temperature, and if *not* crumpled when cold did not lose their gas-tightness even at the low temperatures.

Permeability of fabrics by mixtures of hydrogen and air.—Some tests are in progress to determine the effect on the permeability of increasing impurity in the hydrogen. For this purpose a special apparatus has been devised, which may be generally useful for permeability experiments, in which smaller samples of fabric can be employed. The experiments are still proceeding, and an account of them must be deferred for a later Report.

Weathering Tests.—A very complete series of weathering tests has been completed during the year. The fabrics exposed included five rubbered double cotton fabrics; two fabrics of the oilskin type; and goldbeaters' skin, of six layers' thickness. Of the rubbered fabrics three had an external protective colouring of yellow, one was proofed outside with red rubber, and one had no protective colouring. Two sets of samples were exposed; one set only in fine weather, while the other was left out in the rain, and, further, watered on days when no rail fell. None of the samples was exposed, however, in violent winds or excessive rain; or at night.

Tests were made at intervals both for permeability and for tensile strength; the tensile pieces, five of which were used for each determination in order to obtain a satisfactory mean result, were so distributed in the square of fabric used for the whole series of strength tests that the mean values for the several tests after successive exposure intervals might be fairly comparable, and give a reliable indication of the effect of exposure. Each interval corresponded roughly to about 24 equinoctial days of bright sunshine. Chemical analyses of the rubber were also made to enable the course of the perishing to be followed more clearly.

The most noteworthy deduction from these experiments is that rubbered fabrics usually shew a marked improvement in impermeability at a stage when they are almost completely perished, which is followed by very rapid deterioration and complete loss of gas tightness. This was shewn especially clearly by the fabric with no protective colouring, but clear evidence of its occurrence was obtained also in the case of some of the protected fabrics, at a much later period of the exposure, especially in the wet series of tests. Hence any marked improvement in the gas-tightness of a rubber-proofed balloon must be regarded with grave suspicion.

The beneficial effect of a yellow colouring was plainly shewn; the loss of tensile strength in the unprotected or badly protected fabrics is very much greater than in the yellow pigmented cloths. The injurious effect of rain and light together is appreciably greater than the effect of light only.

In only three fabrics out of the eight examined was the decrease in tensile strength after 100 days less than 30 per cent. One of these was an oilskin of relatively low initial strength; the proofing of this appeared to be very satisfactory and without harmful effect on the fabric. The same proofing applied to material of stronger type might be expected to yield highly satisfactory results.

Experiments on proofing materials.—A research has been in progress with a view to the discovery of good proofing materials. Various substances have been tried and valuable information obtained. An important feature in connection with such work is the obtaining of a satisfactory joint.

Adherence of Water to Fabrics.—Experiments have been made to determine the amount of moisture that will adhere to fabrics of different types. The information is of importance in practice in the case of a balloon envelope exposed to a shower of rain. The results recorded in the Appendices show marked differences between the fabrics tested.

Aeroplane Fabrics.—A series of tests on a number of selected aeroplane cloths is in progress. Preliminary determinations of weight, strength, and moisture absorption were made with a view to choosing suitable fabrics. The further qualities examined include extensibility, waterproofness, liability to waterlogging on prolonged soaking, water adherence after dipping or spraying, and permanent stretch when exposed taut to alternate wet and dry weather. Weathering tests are also being made, with measurements of the loss in tensile strength and extensibility, and the increase in weight and in water adherence. Some of the results obtained are given in an Appendix to this Report, but the tests are not yet completed.

Experimental Work on Full-sized Aeroplanes.—It was mentioned in last year's Report that arrangements had been made for conducting full scale experiments. These were commenced early in 1911 under the direction of the Superintendent of the Royal Aircraft Factory. The earlier work was directed to the determination of the effect of various modifications in an existing machine. An aeroplane of Farman type was available for the purpose, and the alterations made aimed at diminution of head resistance by various means; the increase of mechanical efficiency by improvement of propeller design and correct correlation of propeller and engine; improvement in the design of the wings; increased ease of control; and improved directional stability. In all these respects satisfactory results have been attained; the alterations have effected a marked improvement in ease of control, stability and speed, with increase of available lift. In connection with this work a standard form of "speed-resistance" and "speed-horse-power" curves has been adopted for setting out the qualities and performances of aeroplanes, which is described in an Appendix to this Report. This has been found very convenient for purposes of design.

Attention is also being given to the problem of obtaining during actual flight measurements of the principal quantities affecting the behaviour of the machine, and a knowledge of which is necessary to enable the conditions of flight to be accurately analyzed. Apparatus has been designed for recording the propeller thrust on machines in flight, and measurements are also being made of the relative wind velocity and the gliding angle, while the effect on the stability of modifications in design is being specially studied. In connection with this work, members of the Committee have visited Farnborough on various occasions to render assistance in the designing of apparatus, and to give advice on the procedure to be followed in the investigations.

A further programme of full scale work has been prepared for the coming year, which includes the construction of experimental aeroplanes of different types, in order that their relative advantages and characteristics may be examined, with a view to the continued improvement of existing machines. The constructional work undertaken at Farnborough will thus be essentially of an experimental character, and it is hoped will give the private constructor, who must be relied upon for the production of the machines required for use in the field, valuable assistance towards improvement in design, while in no way interfering with the advantages derived from unrestricted competition.

Stability.—The theory of aeroplane stability has received attention from numerous writers during the past year, and the discussion of this subject has been given recently a further impetus by the publication of Prof. Bryan's volume "Stability in Aviation." Summaries of some of the more important papers lately published are included in the "Abstracts." A valuable paper by the Superintendent of the Royal Aircraft Factory, on "Problems relating to Aircraft," dealing especially with the question of stability, was communicated early in 1911 to the Institution of Automobile Engineers. Special attention is being devoted to this question, and practical knowledge of the factors affecting stability will be accumulated in the course of the experiments on full-sized aeroplanes. It is hoped also that it may be possible to investigate the subject further in the Laboratory by means of experiments on model 'gliders.'

Meteorological Work.—The investigations outlined in the programme of work referred to in the previous report have been continued during the past year by Mr. J. S. Dines at Pyrton Hill, under the control of the Director of the Meteorological Office. The results of the experimental work are given in three papers prepared by Mr. J. S. Dines, constituting the Third Report of the Committee on Wind Structure. These papers are included in the list on page 29, and a brief account of the conclusions derived from them is given below.

In May, 1911, at the request of the Admiralty, Mr. Dines visited Barrow to give advice and assistance in the erection of apparatus for recording the velocity and direction of the wind. Mr. Dines has also given similar assistance at Shoeburyness, and in June, 1911, was engaged in conducting the ascents on sounding balloons at Mungret College, near Limerick, in order to advise the College authorities in the management of upper air investigation. In November and December, 1911, Mr. Dines gave assistance to Mr. C. J. P. Cave in the Scilly Isles in connection with an investigation by means of pilot balloons of the structure of the atmosphere over the sea with little disturbance on account of land. Forty-one ascents were observed. Surface winds from all points of the compass were experienced.

During the year a number of instruments have been designed and constructed for the purposes of the experimental work carried out for the Committee.

In connection with the work done for the Committee a volume entitled "Forecasting Weather," was published in December last by Dr. W. N. Shaw, which gives much information of value for aeronautical purposes. A discussion of various questions of interest connected with the structure of the atmosphere and the gustiness of winds was given by Dr. Shaw in two lectures before the Royal Institution, which have since been printed in the January number of "Science Progress."

In April, 1911, the Lords Commissioners of H.M. Treasury sanctioned the establishment, by arrangement with the War Office, of a branch of the Meteorological Office, in connection with the Royal Aircraft Factory, at South Farnborough, to supply meteorological information to those engaged in field work, and to carry on the investigation of the upper air for the Advisory Committee under the direction of the Meteorological Office. Mr. J. S. Dines was appointed by the Meteorological Committee as Meteorologist in Charge of this branch office. Suitable accommodation for this experimental observatory was included in plans prepared for additional buildings at the Aircraft Factory.

This new branch of the Meteorological Office, for which accommodation is to be provided during 1912, is designed to fulfil three functions:—

(i) To supply meteorological information and forecasts in a form directly applicable for the guidance of airmen.

(ii) To carry on the experimental work for the Advisory Committee.

(iii) To act as an observing station for the Meteorological Office.

The instrumental equipment will include the usual recording and other apparatus of a meteorological station, with pilot balloon equipment, comprising two self-recording theodolites, small balloons and auxiliary tackle; sounding balloon equipment for occasional observations with larger balloons and recording instruments, &c.; kite equipment; together with tools and laboratory appliances.

The work in connection with (i) will be of two kinds. First, to put together existing information about the diurnal variation of wind, relations of humidity and sunshine, and other meteorological facts that are serviceable, and to extend the information by suitable observations. The second part of the work will consist in an endeavour to use knowledge recently acquired for the application of forecasting to the current requirements of airmen. For this purpose it will be necessary for the Branch Office to be in communication by telephone or otherwise with the Meteorological Office, which will supply sufficient material for drawing a working chart at the Branch Office in anticipation of the daily weather report ("Forecasting Weather," Chapter I.). Further, an arrangement will be entered into with other suitable observing stations to report by telegram occurrences of the line-squall type ("Forecasting Weather," pp. 222, 240).

With reference to (ii) the experimental work carried out for the Committee during the current year has included the completion of a pair of self-recording theodolites; the construction of an anemograph to record direction and velocity on the same sheet; the investigation of vertical motion in the atmosphere, and, incidentally to the last-mentioned, the registration of wind velocity in kite ascents, &c., by the pull of a ball on a string, or by observation of the limiting ascensional velocity of a free balloon. These investigations will be continued with a view to clearing the way to decisive experiments about vertical and rotary motion.

The Central Station of the Meteorological Office for upper air research will remain at Pyrton Hill, but Farnborough offers special facilities for determining the question of a suitable form of instrument for recording temperature, humidity, and pressure in the upper air by means of a captive balloon, the use of instruments travelling along a kite wire and other subjects of similar interest.

As regards (iii) the new establishment is intended simply to take advantage of the facilities which will exist on other grounds, and which justify the Meteorological Office in undertaking the responsibility for the administration.

Vertical motion in the air.—Experiments on vertical air currents have been carried out during the past year by means of balloons tethered to a point on a steel tower 95 feet above the ground, with a view to the determination of the angular deviation from the horizontal of air currents at a moderate height. The method consists in following the motions of such a tethered balloon with a recording theodolite. The analysis of the records shows that the inclination of the wind direction to the horizontal does not normally exceed 20°, though on one occasion a downward current was observed making an angle of 43° with the horizontal, corresponding in this instance with a vertical component of the wind velocity of about 8 miles an hour. As a rule the larger deviations from the horizontal were not met with on days of strong winds.

The series of pilot balloon ascents which was commenced in the autumn of 1910 has also been continued through 1911, and the results obtained are discussed in the third of the three memoranda relating to Wind Structure given in the Appendices to this Report. The method of working at first adopted was found satisfactory, and has been adhered to with small alterations in detail. The movements of the balloons have in all cases been followed by two theodolites fitted with self-recording gear, enabling those ascents which showed fluctuations in the vertical velocity of a specially pronounced character to be worked up in greater detail than that normally adopted in pilot balloon work, *i.e.*, from readings taken at one minute intervals.

An account is given in the report of some of the difficulties met with, more especially with regard to the rate of ascent of the balloons, which proved to be very variable, rendering it impossible to determine with great accuracy the absolute values of the vertical velocities experienced. The ascents have first been treated as a whole, and the average conditions worked out for the variations in wind velocity and direction with height above the surface of the earth for winds blowing from different quarters. After this a discussion of some of the more interesting individual ascents is given, with especial reference to the vertical currents in the air.

The Study of Gusts.—Some account was given in the previous report of the variation found in the gustiness of the wind at different levels. A comparison has been obtained during the past year of the gustiness at two points respectively 36 and 98 feet above ground, the measurements being made by means of a pressure tube anemometer head. The gustiness at 36 feet was found to be about 30 per cent. greater than that at 98 feet, for the site where the experiments were made.

In connection with the work on vertical motion, records of wind velocity were taken with a more open time scale than is usual, and these have given some further information of value with regard to gusts. In a gusty wind of normal type, a rise of wind velocity is usually followed almost immediately by a fall of approximately equal amount. In some of these observations, however, cases were found in which a sudden access of wind velocity persisted for at least one minute. Thus a case is recorded in which the wind rose suddenly from 13 to 23 miles per hour, followed by a slight fall and then a further rise to 28 miles per hour; the wind remaining above 20 miles per hour for more than one minute after the first rise. Attention is called to this special type of velocity change on account of the probability that similar phenomena, though possibly of greater intensity, in the upper air currents may explain one of the types of conditions known to airmen as "holes in the air."

An account given in an Appendix to this Report by Dr. T. E. Stanton of experiments which have been in progress on the wind towers, also gives some valuable information as to the width of gusts, *i.e.*, as to the lateral variation in the velocity of the wind. From observations taken at two points 40 feet apart in a line approximately at right angles to the direction of the wind, the conclusion is drawn that the pressures due to the wind velocities at the same instant at two points 40 feet apart may differ by as much as 50 per cent., and will frequently differ by 25 per cent. Differences of corresponding amount must, therefore, occur in the velocities of the natural wind striking the two wing tips of an aeroplane; thus, in a wind of 10 miles an hour, for an aeroplane travelling at 50 miles an hour, the difference between the pressures at the wing tips might amount to 10 per cent. The observations were, for the most part, taken in strong winds of the order of 30 miles an hour, but the same proportionate variation has been found in lighter winds, though with diminution in the mean velocity of the wind the gusts become of less importance.

Reports and Memoranda.—The Appendices to this Report contain as usual a number of Reports and Memoranda which have been presented to the Committee since the date of the last Report. The majority of these are accounts by the experimental or construction departments of investigations which have been carried out during the year. A few papers of a theoretical or a more general character are included, and among these may be mentioned an account of screw-propeller theory, by Sir George Greenhill.

The following is a list of the Reports and Memoranda printed as Appendices to this Report, grouped as in previous Reports:—

General questions in Aerodynamics.—

The use of models in Aeronautics.—By the Staff of the Aeronautics Department of the National Physical Laboratory.

Notes on the properties of aerofoils as deduced from the results of the various aeronautical laboratories.—By L. Bairstow, A.R.C.Sc., and B. Melvill Jones, B.A.

Note on the relative frictional resistances of surfaces in air and water.—By T. E. Stanton, D.Sc., M.Inst.C.E.

Notes on Steering.—By Rear-Admiral R. S. H. Bacon, C.V.O., D.S.O., R.N.

Experiments on airship and aerofoil models, &c.—

Experiments on airship models:

(i) Measurements of the head resistance of some airship models, and of the forces acting on a model inclined to the current.

(ii) An investigation into the effect on the head resistance of an airship model of truncating the tail.

(iii) Determinations of the moments acting on a number of airship models when inclined to the current.—By L. Bairstow, A.R.C.Sc., and C. G. Eden.

Notes on the resistance of airship shapes, leading to considerations as to the advisability of shortening the length, *i.e.*, diminishing the fineness ratio below 6 to 1.—By Mervyn O'Gorman, Superintendent of the Royal Aircraft Factory.

Experiments on models of aeroplane wings.—By L. Bairstow, A.R.C.Sc., and B. Melvill Jones, B.A.

This comprises the following papers :—

(i) Complete investigation of the pressure distribution, in a median section, over the upper and lower surfaces of three specially chosen aerofoils, with an analysis of the results which indicates to what extent the upper and lower surfaces may be independently designed.

(ii) Determination of the lift and drift of a De Havilland aerofoil, and of a plane of the same aspect ratio; and of the lift and drift and centre of pressure of a Bleriot aerofoil (number XI bis).

(iii) Determination of the effect on the lift and drift of a variation of the spacing in a biplane formed with two aerofoils of the form Bleriot (number XI bis).

(iv) Determination of the effect of "staggering" the same two aerofoils in a biplane, that is, of setting back one plane relative to the other.

(v) Determination of the effect of a dihedral angle between the wings (in a monoplane) for the same aerofoil.

(vi) Lift and drift determinations for aerofoils (including flat plates) of different aspect ratios.

(vii) Determination of the lift and drift of aerofoils having a plane lower surface and variable camber, the upper surfaces being obtained by varying the ordinates in a constant ratio.
(viii) Experiments on a series of aerofoils having the same upper surface, and lower surfaces of different camber.

The wind resistance of some aeroplane struts and an examination of their relative merits.—By Harris Booth, B.A., A.M.Inst.C.E., and C. G. Eden.

Investigation by visual and photographic methods of the flow past plates and models, including:—
(i) Description of a photographic method of investigating the direction and velocity of flow in a fluid medium.
(ii) Investigation of the change in the flow past a flat plate in a current of water when its inclination to the current is varied.
(iii) A comparison of the flow past obstacles in air and in water.—By C. G. Eden.

Full Scale Experiments:—
(i) Preliminary discussion of possible full scale work to be undertaken.
(ii) First report on aeroplane research on full-sized machines. —By Mervyn O'Gorman, Superintendent of the Royal Aircraft Factory.

Propellers:—
Screw Propeller Theory.—By Sir G. Greenhill.
Experiments on model propellers:—
(i) Results of a series of tests on two model Clarke propellers.
(ii) On the results of tests to determine the effects of variations in blade width and of small variations in pitch on the efficiency and performance of propellers.—By F. H. Bramwell, B.Sc., J. H. Hyde, A.M.Inst.C.E., and J. H. Neal, A.R.C.Sc.

Some notes on the possible efficiency of propellers.—By F. H. Bramwell, B.Sc.

Some notes on the effect of size on the efficiency and performance of propellers.—By F. H. Bramwell, B.Sc.

Notes on Aerial Propellers.—By H. Bolas.

Motors for Aeronautical Purposes:—
Report on the tests of petrol motors in the Alexander Motor Prize Competition, 1911.*

Materials of Construction, Fabrics.—
The elasticity and ultimate strength of rubbered cotton balloon fabrics under compound stress.—By Harris Booth, B.A., A.M.Inst.C.E., and J. H. Hyde, A.M.Inst.C.E.

Some experiments on tearing of fabrics under compound stress conditions.—By Harris Booth, B.A., A.M.Inst.C.E.

Weathering tests on balloon fabrics.—By Guy Barr, B.A., B.Sc., and J. Thomas, B.A., B.Sc.

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* See footnote on page 3.

Other tests on balloon fabrics:—
(i) Experiments on the behaviour of balloon fabrics at low temperatures, including some tests of seams.
(ii) Experiments on the adherence of water to fabrics.
By Guy Barr, B.A., B.Sc., and J. Thomas, B.A., B.Sc.

Some tests on aeroplane fabrics:—
(i) Tests on moisture absorption and adherence.
(ii) Experiments on the sagging produced in different aeroplane fabrics by alternate wetting and drying.
By Guy Barr, B.A., B.Sc., and J. Thomas, B.A., B.Sc.

Meteorology.—
Third Report on Wind Structure, comprising papers on the following subjects:—
(i) Experiments on vertical air currents 95 feet above the ground at Pyrton Hill, Oxon., with an analysis of certain open time-scale records from the anemograph at 98 feet.
(ii) Comparison of velocity and gustiness of the wind at 36 feet and 98 feet above the ground.
(iii) A discussion of the results obtained from pilot balloon ascents at Pyrton Hill, 1910-11.
By J. S. Dines, M.A., Meteorologist for the Branch of the Meteorological Office at South Farnborough.
Notes on the lateral extent of the maximum velocity of gusts.—By T. E. Stanton, D.Sc., M.Inst.C.E.

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.