AERONAUTICS.

TECHNICAL REPORT

OF THE

ADVISORY COMMITTEE FOR AERONAUTICS

FOR THE YEAR 1910-11

(WITH APPENDICES.)

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REPORT FOR THE YEAR 1910-11.

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

SIR,

THE Advisory Committee for Aeronautics was appointed in April, 1909. The first Report of the Committee was prepared in April, 1910, and presented to Parliament in July of that year. At the date of the preparation of that Report no very large amount of experimental work had been completed: the first year's work was necessarily largely devoted to an examination of the ground to be covered, with a view to the determination of the questions upon which experimental information was most urgently required, and to the design and construction of the necessary apparatus.

The aim of the present Report is to give a general account of the work of the Committee during the year 1910-11. The technical papers giving the detailed results of the various investigations which have been carried out by the experimental department, with other reports and memoranda of general interest which have been laid before the Committee, are included herewith as Appendices to this Report.

During the year 1910-11 the Committee has held ten meetings, one of which was at the works of Messrs. Vickers, Limited, at Barrow, one at the National Physical Laboratory, and the remainder at the War Office. In addition meetings have been held of Sub-Committees formed to deal with specific questions.

In November, 1910, an Interim Report was presented, giving a general account of the experimental work in progress. With this was included the report made by the Committee to the Aerial League of the tests of the motors for aeronautical purposes entered in the competition for the prize offered by Mr. Patrick Alexander.

During the past year the Committee has had under consideration a large number of questions which have arisen in connection with the constructional work in progress at Farnborough and at Barrow. At the National Physical Laboratory, also, a considerable proportion of the experimental work has been directed towards the solution of specific problems of airship design and the determination of the necessary experimental data. In addition, research of a somewhat more general character has been carried out, and some results of fundamental importance with reference to the future work to be undertaken have been arrived at.

Equipment for Experimental Work.—The principal apparatus which has been installed at the National Physical Laboratory for the purpose of the researches in aeronautics now in progress was described in the Report of the Committee for 1909-10. In addition, in connection with the Report on the Alexander Motor Competition, an account was given in the Interim Report of the

special equipment for testing motors for aeronautical purposes under an approximation to practical working conditions. It is not now necessary to say anything further with regard to these chief items of the equipment already installed. Some changes and additions have, of course, been made in details, where experience has shown that modification was desirable: the more important of these alterations are referred to in the various papers printed as Appendices to the present Report.

The most interesting and novel addition to the equipment during the past year is a circular rotating water channel, to be used for determining the forces acting on plates and small models in a circular stream of water. It is hoped that, with the aid of this, certain data of fundamental importance in connection with the motion of an airship may be determined, and in general that the forces acting on aircraft when executing turning movements in the air may be investigated.

In addition, a special water tank has been provided for the study, by visual and photographic methods, of the eddying motion in the rear of plane and curved surfaces, balloon bodies, &c. Some interesting results have already been obtained, of which a brief account is given in an Appendix to this Report.

The equipment for strength tests of fabrics has been improved by the addition of an Avery testing machine, and apparatus has also been constructed for tests of fabrics under combined bursting and tensile stress.

The further account of the work done may be most conveniently classified, as previously, in relation to the particular apparatus employed in carrying it out.

Air and Water Channels.—The laboratory has now at its disposal for resistance experiments two air channels—the larger air channel of 4 ft. square section, specially constructed for the aeronautical work, and the circular channel of 2 ft. diameter, previously employed by Dr. Stanton in his researches on the resistance of models in a current of air—and a water channel which continues to be of much value for obtaining results from which the corresponding data for air can be immediately deduced.

With these various means a large amount of experimental work has been carried out throughout the year. This work has included the determination of the resistance of a number of airship bodies of different forms, and the measurement for these forms of the "lift" and "drift" at various angles to the wind; the investigation of the relative stability of different airship models, and of the stabilising action of fins of different area and in different positions; the determination of the efficiency of various types of rudders and lifting surfaces, plane and curved; the air resistance of wires, stationary and vibrating, of stays and ropes, of model gondolas, model radiators, &c.; the investigation of the forces due to the wind acting on models of dirigible sheds of different forms; and of the forces acting under various conditions on a model of a girder of the type employed in the new Paulhan aeroplane.

A large part of this work has been carried out in response to specific requests from the Government Constructive Departments for experimental data necessary for purposes of design.

Resistance and Directional Stability of Airship Models.—Perhaps the most interesting investigation among those enumerated above is that on airship models. The investigation has comprised a large series of observations on models of different forms, carried out at intervals throughout the year. The work has been directed to the determination of the head resistance for motion parallel to the axis, the "lift" and "drift" for motion oblique to the axis, the magnitude of the moment tending to increase the obliquity—called hereafter the negative righting moment—when the ship is at different angles to the relative wind, and the amount of fin area necessary to give a positive, in place of a negative, righting moment.

The work has been carried out in co-operation with the Superintendent of the Army Aircraft Factory, who provided the models for the tests, the head and tail curves for which were systematically varied according to a plan devised by him. The object of the tests for head resistance was to determine the amount of change in resistance due to specific alterations of the curvature in head or tail, and ultimately to determine the forms of minimum resistance for a given gross lifting power and for a given net lift. The experiments led to the adoption of certain curves for head and tail, with a ratio of total length to maximum diameter of about 6 : 1.

The experiments on models inclined to the current determined the amount of dynamic lift obtainable owing to the inclination of the airship to the horizontal, as distinct from that directly due to the elevating planes, and at the same time the increase in head resistance owing to the obliquity.

The complete investigation of the conditions affecting the stability of path of an airship will no doubt take a considerable time to complete, but results of practical importance have been obtained in the determination of the negative or positive righting moments acting on models of airships of different forms. If an elongated model of the customary fish-shaped form be supported in a current so that it can turn about an axis through its centre of gravity, it tends to set itself at right angles to the current; when it is oblique to the current a moment acts on it tending to increase the obliquity. The amount of this moment has been investigated for different angles of obliquity in the case of several models; combined with the measurements of "lift" and "drift" this enables the magnitude and line of action of the resultant force on the model at any obliquity to be determined.

The next step was to find the amount of fin area necessary, and the best position for the fins, to give a positive, in place of a negative, righting moment. Experiments for this purpose have been carried out, and have led to interesting results. It was found, even with a considerably elongated tail, that if the fin were placed towards the rear of the tail and close to the body the portion of the fin nearest the body was comparatively inactive, owing to the slow movement of the stream in this region. This slow motion of the stream near the tail was confirmed by photographs taken to investigate the nature of the flow past fish-shaped models (*see below*, p. 9).

These experiments have enabled the amount of fin area necessary to give a positive righting moment to be determined. Other questions which have to be investigated in connection with the general problem of stability are the effect of the instability of the wake, which does not leave the tail symmetrically when an airship body

is moving parallel to its axis; and the "damping" action of the air as regards any motion which involves rotation, as when oscillations are set up, or in turning. Apparatus has been constructed with the aid of which it is hoped that the damping coefficient may be determined, and the effect of wake instability examined.

Air Resistance of Wires and Ropes.—The experiments which have been carried out on wires and ropes have also furnished results which will probably be of general interest. The tests were made on a large number of wires and ropes, including smooth wires of diameters ranging from ·04 to ·25 inch, with wire ropes of five or six strands and hemp ropes of three strands of diameters ranging from ·1 to ·6 inch.

The air resistance of the stranded ropes, per unit of the sectional area exposed to the wind, is found to be of approximately the same amount as that for small square plates. No great difference was found between wire ropes and hemp ropes at the same velocity. In the case of smooth wires the resistance per unit of sectional area is appreciably less, the difference being of the order of 20 per cent.

Experiments were also made on the air resistance of vibrating wires; no appreciable effect on the air resistance was found at the vibration velocities reached, whether the wires were made to vibrate in a plane parallel to the direction of motion, or perpendicular to it. It may be inferred, therefore, that in practice the air resistance of wires can be calculated on the basis of the values given for stationary wires in the table printed in the account of these experiments given in an Appendix to this Report.

It is of interest to note that the values found at the National Physical Laboratory are in close agreement with the results obtained, also during the past year, for the resistance of stationary wires and ropes, at the well known aerodynamical laboratory at Göttingen under the direction of Professor Prandtl. The work on airship models, and the results for the resistance of inclined plates, are also in general accordance with the observations of a similar character which have been made at Göttingen.

Wind Resistance of a Radiator of Honeycomb Type.—Experiments have also been made on the wind resistance of the honeycomb form of radiator. For the purpose of these tests a scale model was made and its resistance compared in the wind channel with that of a solid block of the same external dimensions. The conclusion was that the wind resistance of such a radiator in which the net area is about 25 per cent. of the total area is approximately one half that of a flat board of the same dimensions.

It was considered of some interest to determine also the velocity of the air flow through the tubes of the honeycomb, and its variation with the length of the tube. In these experiments the tubes of the actual radiator were employed, and with a tube length of about four inches the wind velocity in the tube was found to be about three-fourths of the mean wind velocity outside. Reducing the length of the tube by one half produced an increase of only about 15 per cent. in the air velocity through the tube.

The general conclusion was that the honeycomb form of radiator is fairly efficient, and it does not appear that any considerable

increase in efficiency can be obtained by diminishing the length of the tubes, or by increasing the ratio of diameter to length beyond the value, viz., 1 : 12, which obtained in the type tested.

Other Tests in the Air Channel.—Among the other investigations which have been made in the air channel may be mentioned a series of tests on models of dirigible sheds of different design, to determine the resultant force on each due to the wind; tests to determine the wind resistance of a model gondola; and a number of experiments on a model of the girder designed by Fabre and used in the new type of Paulhan aeroplane. The experiments on this girder were directed to the determination of its head resistance at various angles to the relative wind, and also of the lift obtained from it when inclined about an axis parallel to its length. It was found that the efficiency of the girder, regarded as a small biplane, was about 50 per cent.

Small Water Channel for Visual and Photographic Work.—A small water channel has been constructed with a view to the investigation of the nature of the flow round an obstacle in a fluid medium. In this a steady stream of water is kept in motion, into which small models of plates, aerofoils, airship bodies, &c., can be introduced, and the nature of the flow can be studied with the aid of colouring matter added locally to the water.

With this apparatus interesting photographs have been obtained of the flow past plates and balloon models, some of which are reproduced in an Appendix to this Report. These have shown that even for an elongated fish-shaped airship model, the relative velocity of flow near the tail is considerably less than in the main stream, thus explaining the relative inefficiency, as regards the production of a righting moment, of the portion of a stabilising plane close to the body in this region.

Some valuable information has also been obtained with this apparatus as to the eddy formation in the rear of plane and curved plates, and the experiments on these will be continued.

Wind Pressure on Square Plates.—In connection with questions arising out of the model tests and the determination of the correction factor, if any, to be applied in passing from the results obtained in small model experiments to the corresponding full scale values, an examination has been made by Messrs. Bairstow and Booth, of the National Physical Laboratory, into the experimental results obtained by different observers for the air pressure on square plates. Both Eiffel and Stanton in their experiments on square plates have found that the wind resistance per square foot of a small plate is less than that of a large plate, the difference, according to Stanton, as between plates 2 inches square tested in the wind channel, and plates 10 feet square exposed in the open, being about 20 per cent.

In the Report of the Committee for the year 1909–10 (p. 38) Lord Rayleigh pointed out the general form which, according to dimensional theory, the law of variation of resistance with dimensions must assume, and showed that such a variation as found by Stanton for square plates involved also a departure from the law according to which the resistance of a plate in a current of air is

taken to be proportional to the square of the velocity. Messrs. Bairstow and Booth have shown that a formula can be found, falling under the general type indicated by Lord Rayleigh, which accurately represents the results both of Eiffel and Stanton over the whole range to which their experiments extended, when both the dimensions of the plate used and the air velocity at which the results were obtained are taken into account.

The question is one which is at present mainly of theoretical interest, and the importance of which lies in the light it may throw on the comparison of water and air resistances. Lord Rayleigh, in a second note also printed as an Appendix to this Report, has discussed the matter further, and has pointed out some difficulties in reconciling the general formula with certain conclusions from experiment. Some evidence is furnished by results recently obtained by Dr. Stanton in experiments on the flow of air in pipes, of which a short account is also given in an Appendix to this Report, and by the study, by visual methods, of the flow past obstacles in a water channel, but the matter demands further investigation before a final conclusion can be arrived at.

Friction of Air in Pipes.—Among the reports included in the Appendices is a preliminary communication by Dr. Stanton of some results obtained for air friction by means of experiments on the flow in pipes, in which the effect of changes in the dimensions and roughness of the pipes is discussed. Some of the pipes tested were artificially roughened by cutting right and left handed screws along the inner surface of the pipes, of pitch and depth proportional to the diameters. It is interesting to note that the dimensional relation for these artificially roughened pipes is precisely similar to that found by Messrs. Bairstow and Booth in their examination of the experiments on the normal resistance of flat plates of different sizes, referred to above.

Whirling Table and Propeller Tests.—A description of the whirling table and of the design of the dynamometer was given in the Report of the Committee for the year 1909–10. A number of tests on propellers of different types have been carried out with the apparatus there described, and particulars of some of these tests are given below. Recently, with a view to obtaining increased propeller speeds, up to 3,500 revolutions per minute, and a greater range and sensitiveness in the measurements, a motor of greater horse-power has been provided to drive the propeller, and a new dynamometer has been designed and constructed. A brake has also been added, since at high propeller speeds the propeller alone in some cases drives the whirling arm faster than is desired.

With a view to reaching as high an accuracy as possible in the future tests, especially at the higher speeds of translation, a careful study has been made of the motion set up in the air of the whirling table shed by the rotation of the whirling arm. As a result of the experiments it was found that when the end of the arm was travelling at a speed of 35 miles per hour the mean velocity of the air in the shed at the boundary of the circle described by the arm was about 2 miles per hour, while the velocity of the air into which the arm was entering was 1·6 miles per hour. The air velocity was

also found to be approximately proportional to the arm speed. The second figure gives the air swirl correction to the arm speed at 35 miles per hour required for the purpose of the propeller tests. In all future tests a direct determination of the swirl velocity will be made and the necessary correction applied.

Effect of Blade Area on Propeller Efficiency.—At the request of Captain Sueter a series of tests was made to determine the effect on propeller efficiency of varying the width of blade. The tests were made on model propellers designed and supplied by Messrs. Vickers, Limited, whose representative visited the National Physical Laboratory for a few days in order to take part in the work. Messrs. Vickers were also good enough to furnish the results of tests made at Barrow on a full sized propeller, in order that these might be compared with the results of the small model experiments made at the Laboratory.

For comparison with the full scale results, a test was first made on the corresponding model propeller at a speed of translation having a ratio to the test speed of the full sized propeller equal to the ratio of the square roots of their linear dimensions. It was found that, for the same slip, the thrust and efficiency given by the model experiments differed only by a small amount from the values they should have as deduced by calculation from the full scale tests. The experiment is important from the point of view of the prediction of full scale results from small model tests, but the work so far done is not sufficient to justify any general conclusion as to the validity of the "model" law which proved in this instance to be correct. It is hoped that further comparisons may be carried out shortly.

The further tests on the series of models were made at the speed of translation suggested by this preliminary work, and by reducing the width of blade from that used in the above experiment an increased efficiency was obtained. It was found that the maximum efficiency was reached at a disc area ratio of approximately ·19.

Other Propeller Tests.—A series of tests has been made for the Superintendent of the Army Aircraft Factory on some Ratmanoff propellers, to the design of M. Drzewiecki, who also paid a visit to the Laboratory. These tests are not yet entirely completed, the intention being to carry them up to speeds of the propeller tip in the model equal to those occurring in practice with the full sized propeller. For this work the new apparatus recently installed is required.

The particulars given in the detailed account of the propeller tests of the work so far done will, however, be found of interest. As is well known, the aim in the design of this propeller is that each element of the blade should strike the air at the same angle of maximum efficiency, the propeller being run at a definite ratio of translational speed to speed of rotation. The maximum efficiency reached with any of the propellers tested, at the propeller speeds attainable at the time when the tests were made, was 67 per cent., at a speed of translation of about 30 miles per hour.

In addition to the above, other experimental tests have been made, and some propellers have been tested for private firms or individuals.

Tests on Motors for Aeronautical Purposes.—The Report for the year 1909–10 gave particulars of the projected tests of petrol motors in the competition for a prize offered by Mr. Patrick Alexander, and some description of the testing plant it was proposed to instal for the purpose of these tests. The trials were commenced in September last, and a complete account of the tests was given in November in the Interim Report of the Committee, together with a full description of the testing equipment. It is therefore not necessary to include in this Report any further particulars of these tests. The testing plant included special devices for obtaining a continuous record of the speed and torque of the engine under test, thus giving the horse-power throughout the run, and the traces obtained during the engine trials, which are reproduced in the Interim Report, will, it is thought, be found of considerable interest. The testing equipment proved entirely satisfactory, and throughout the tests, one of which lasted for 24 hours continuously, it was never found necessary to stop for adjustments or repairs.

In January of the present year the Committee were informed by the Aerial League that Mr. Alexander desired to offer a second time a prize of £1,000 for an aeronautical motor, to satisfy conditions generally similar to those laid down for the previous competition; the competition on this occasion to be for engines of somewhat higher horse-power, and not to be restricted to motors of British manufacture. The Aerial League again asked the assistance of the Committee, and in view of the great value of such comparative tests, both in connection with aeroplanes and dirigibles, the Committee agreed as before to carry out the trials, and to report the results to a Joint Committee of the Aeronautical Society, the Royal Aero Club, and the Aerial League.

The conditions for the tests were drawn up by the Committee in conjunction with Mr. Alexander, and were issued in March. The entries will be completed by the end of June, and the tests will be commenced early in October of the present year.

Balloon and Aeroplane Fabrics.—A considerable amount of work has now been carried out at the National Physical Laboratory in connection with the testing of fabrics. A general account of the experiments has been from time to time laid before the Committee, and in the particulars of this work published in the Appendices to this Report two summaries are given of the results obtained in the two successive half-years.

The materials tested have included rubbered fabrics by various makers, oilskin, varnished silk, and other fabrics with special proofing, goldbeaters' skin, &c.

Strength Tests.—The apparatus employed for tensile tests has been supplemented by a testing machine by Messrs. Avery. This has been modified to enable wide variations in the rate of loading to be obtained. The dimensions of the test specimen now regularly employed are 20 cms. between the jaws of the testing machine by 5 cms. wide, and the usual rate of loading is such as to fracture the specimen in not less than two minutes.

Experiments to determine the effect of varying the rate of loading have been made, and it was found, for a particular fabric, that

the ultimate strength found by rapid loading was about 14 per cent. higher than that found by slow loading. The rate indicated above as that now employed is practically equivalent to a dead slow rate.

The existence of the speed effect just mentioned suggested the probability of a fatigue effect, and this question was also investigated. Some difficulty was experienced in devising a satisfactory method of test, as owing to the large and unavoidable variations between one sample and another, the usual methods of making fatigue tests are not applicable. With the method finally employed it was found that the strength of the particular fabric tested to withstand repeated applications of stress was about 11 per cent. lower than the strength taken on a single specimen loaded to rupture.

Bursting Tests.—Difficulties were originally found in making bursting tests owing to the fact that most of the earlier cylinders tested broke at the join. Finally a cylinder of diagonally doubled material was obtained which did not burst at the join and which broke at very high stresses. Damage done in this test led to the redesigning of the apparatus, and in the new apparatus arrangements have been made to enable the cylinder to be subjected to longitudinal tension in addition to internal pressure.

An account is given in an Appendix to this Report of an interesting series of tests carried out with this apparatus. In these tests the ratio of the circumferential to the longitudinal stress varied from 2 : 1, corresponding to a pure bursting test, to 0 : 1, corresponding to a pure tension. The tests appeared to indicate that the strength in warp or weft is approximately independent of stress applied in the direction at right angles. The behaviour of fabrics under various ratios of compound stress is being further examined by a graduated series of tests on a number of bags of a specially selected fabric.

In the above tests it was found that bags of parallel doubled material and of the same material diagonally doubled appear to be of nearly the same strength for a 1 : 1 ratio of stresses, while the tensile strength of the latter determined in the usual way is only half that of the former.

An account is also given by Mr. O'Gorman in an Appendix to this Report of a large number of bursting tests carried out at the Army Aircraft Factory on a variety of fabrics. The object of these tests was to obtain a comparison with the ordinary tensile tests. The results showed that, on the average, the bursting tests on parallel doubled rubbered cotton gave results a little higher than the tension test, while for diagonally doubled fabrics the mean of the bursting tests was about 1½ times as great as the tension test. For single oilskin the bursting test gave a slightly lower figure than the tensile.

Tearing Tests.—Some tests have been made to determine the effect of a small wound in the fabric on its strength, with a view of indicating, if possible, the factor of safety necessary to ensure that such a wound or tear shall not immediately spread. The disturbance of stress distribution caused by such a wound is accommodated within a large but finite area of the fabric, which may be called the "danger rectangle." It was expected that the applied stress causing rupture of a specimen containing a relatively small

cut of fixed magnitude would be independent of the dimensions of the specimen provided it were at least as large as the "danger rectangle"; and the results obtained were in agreement with this theory. The necessary factor of safety for wounds of different sizes was given, for the particular fabric tested, as the result of these experiments. The work was limited to wounds of small size, which would, however, include ordinary bullet holes; apparatus is under construction to enable the work to be extended to wounds of larger dimensions.

Permeability Tests.—A large number of rubbered and other fabrics have now been tested for permeability by hydrogen. The apparatus employed continues to give satisfactory results, which can be relied upon to a high degree of accuracy. The practical conclusions to be drawn from these tests, especially when considered in conjunction with the weathering tests, would appear to be of considerable importance.

In the case of rubbered fabrics, the permeability is found to be more or less directly dependent on the quantity of rubber employed; the lighter rubbered materials show a higher permeability, a number of samples tested exceeding the maximum of 10 litres per square metre per 24 hours usually allowed in French specifications. This is especially the case with the parallel doubled cloths examined, and the work done points to the superiority of diagonal doubling from this point of view. The permeability of rubbered fabrics increases rapidly with rise of temperature, the increase being as much as 9 per cent. per degree centigrade in the samples tested.

Samples of oilskin, varnished silk, and of other fabrics proofed in various ways have also been tested for permeability. The exact nature of the proofing is not in all cases known. Some of these have shown excellent qualities as regards their hydrogen holding capacity, the permeability in many of the samples being less than 1 litre per square metre per 24 hours, and in some instances not exceeding a quarter of this amount, with a less weight than that of the lighter rubbered fabrics above referred to. In some of these fabrics the hydrogen holding capacity appeared to improve with rise of temperature.

Tests have also been made on a number of samples with joins. In the rubbered fabrics tested, and in some of the others, the permeability of the join was no higher than that of the rest of the fabric, but with proofing other than rubber the join has sometimes been found to have a much higher permeability. This is a point, therefore, to which attention must be paid. The joins have also sometimes shown a deficiency in tensile strength.

Weathering Tests.—The weathering tests of fabrics have been directed to the determination of the rate of loss of tensile strength, and the rate of increase of permeability due to exposure in the open. The rate of diminution in tensile strength does not show any very important difference between the rubbered fabrics tested, and those proofed in other ways. It is of interest, however, to note that the rate of deterioration was usually found to be most marked during the second month of exposure. Thus for one fabric the losses in strength in the first three months of exposure were

approximately 9, 28 and 10 per cent., and similar figures have been obtained for other fabrics.

As regards the effect of exposure on permeability, the difference between the rubbered fabrics tested and some of the fabrics proofed in other ways has been very marked. In unprotected rubbered fabrics the deterioration in hydrogen containing capacity has usually been comparatively rapid. The effect of the usual yellow protective colouring is, however, considerable. In several uncoloured samples after 50 days' exposure in the open the hydrogen leakage has been found to exceed 100 litres per square metre per 24 hours. A number of yellow fabrics, however, which have been exposed for some five or six months are still moderately gas tight; and, further, as regards tensile strength, are only a little weaker than the unexposed samples. From the more recent tests, it appears that sunlight is the most important factor in producing deterioration.

On the other hand, the oilskins, varnished silk, &c. tested have not in general shown any appreciable increase in permeability with exposure. If taken down for test on a warm day their hydrogen holding capacity has often been found to have improved. In some cases where a sample has shown deterioration, it has again improved after further exposure, the temporary increase in permeability being probably due to crumpling when cold.

A very complete scheme of tests on rubbered and other fabrics is now in progress to examine more closely the rate of deterioration with exposure, and to distinguish between the relative effects of sun and moisture. Tests of various proofing materials are also being carried out at the Laboratory, and some satisfactory results have been obtained.

Other Tests on Fabrics.—Tests of a number of fabrics for moisture absorption have also been made and are included in the general account of the work on fabrics. A few preliminary tests for diathermancy of different materials have been carried out; these show that the reflecting power for heat of some of the fabrics is appreciably improved by the addition of aluminium powder to the proofing mixture. Some experiments on the relative inflammability of different fabrics have also been made.

Light Alloys.—A considerable amount of experimental work has been carried out on light alloys intended for structural work on airships and aeroplanes. Samples of the alloy known as "Duralumin" have been supplied by Messrs. Vickers, Limited, and the mechanical tests made on these were in general agreement with the results found at Barrow. Samples of channel bar tested at the National Physical Laboratory gave a tensile strength of 25·7 tons per square inch, and samples of wire 30 tons. Further investigation of this alloy will be undertaken, including ageing, fatigue and corrosion tests, special attention being paid to the question of the permanence of the material. Tests of this kind are being made by the Metallurgy Department in conjunction with similar work on light alloys prepared in the Laboratory. Some of these at present being studied in connection with the work for the Alloys Research Committee of the Institution of Mechanical Engineers are showing very promising results, tensile strengths up to 34 tons per square inch having been obtained,

together with reasonable ductility, and without recourse to special thermal treatment. When these new alloys have been more fully studied it is hoped that some of them will prove of service for aeronautical construction.

Meteorological Work.—The preliminary programme of experimental work adopted by the Committee upon their appointment included the following items :—

(32) General information relating to the variation of wind velocity and phenomena connected with gusts of wind.
(33) Relative variation in speed and direction of the wind at different heights above the earth's surface.
(34) Vertical movements in the air.
(35) Rotary movements in the air.
(36) Electrical phenomena.
(37) Formation of clouds, snow, hail, &c.

The items numbered (32) to (35) were dealt with provisionally in a memorandum on details of wind structure, &c., by Dr. Shaw, presented with the Report of the Committee for last year. This has been followed up by further experimental work on vertical motion and rotary motion in the atmosphere at Pyrton Hill, by J. S. Dines, under the direction of the Meteorological Office. The results of the investigation are presented by three memoranda included among the Appendices to this Report (*see* below, p. 19).

Electrical phenomena in connection with ballooning have been the subject of various communications to the Committee.

A resumé of the present state of our knowledge of the formation of clouds, snow, hail, &c., in relation to current weather, as affecting aeronautical work, forming item (37) of the programme, has, by arrangement with the Meteorological Committee, been included by Dr. Shaw in a work on "Forecasting Weather," which is now in course of publication by Messrs. Constable & Co., Ltd.

The Committee have made provision for the continuation during the coming year of the experimental investigation of the various meteorological subjects which bear directly upon aeronautical work.

Vertical Motion in the Air.—With reference to the first of the three memoranda above mentioned, the method which has up to the present been employed for the study of vertical motion in the air consists in observing, by means of self-recording theodolite, the variations in azimuth and altitude of a pilot balloon. With two such theodolites the path of the balloon can be determined both as regards its horizontal and its vertical motion, and the changes in vertical velocity due to air currents can be identified.

For the purpose of this work special self-recording gear was designed for attachment to an existing theodolite ; two theodolites fitted with this self-recording gear, and specially constructed for the work, are now being provided. The apparatus is one which may be useful for many purposes besides that which has immediately led to its construction. The azimuth and altitude at any instant can be read off from the record with an accuracy of about one-tenth of a degree ; this is sufficient for the purpose. The process of observing is thus simplified ; with the self-recording

instrument a balloon can be followed continuously without moving the eye from the instrument, and, further, the record can be taken by one observer only, whereas two are necessary in working with the eye-observing instrument.

A considerable number of records with this apparatus have already been obtained, and the results are in every way satisfactory. The records furnish definite evidence of the existence of vertical currents, but it is not yet possible to give any general discussion as to the conditions affecting vertical motion in the air, as deduced from these observations.

Rotary Motion in the Air.—For the study of rotary motion in the atmosphere a special anemometer head has been designed to indicate both velocity and direction, with an apparatus to record automatically vector diagrams of the wind, from which the velocity and direction at any instant can be read. Full details of the construction are given in Mr. Dines' description.

In the earlier observations the head was mounted at a height of 36 ft. above the ground; more recently a steel windmill tower has been erected for the purpose of these observations, and the head is now mounted on this at a height of 98 ft. above the ground. There is no noticeable difference in the character of the diagrams taken at the two levels. The observations do not support the idea that eddy motion is the cause of the gustiness of the wind.

Some interesting particulars are given in Mr. Dines' report of comparisons between simultaneous records of velocity obtained from this anemometer and from a standard anemometer mounted on a house at a distance of 150 yards. As was anticipated from the work of previous experimenters, the individual gusts were not, as a rule, in agreement on the two records, but it is surprising to find that in certain cases squalls of five minutes' duration recorded by the anemometer on the house did not appear at all on the 98 ft. record. A possible explanation of these differences is that an increase of wind velocity of as long as five minutes' duration may be confined to quite a narrow belt.

Gustiness of the Wind.—To aid in the study of gustiness, apparatus has been designed to register simultaneously the pull of a kite wire and the length of wire paid out. The tension record shows the fluctuations due to gusts, while, from the length of wire, with a knowledge of the vertical angle, the height of the kite can be approximately determined. A number of records have been obtained with this apparatus, and the discussion of these records by Mr. Dines will, it is thought, be found of great interest.

The mean gustiness found at altitudes from 500 to 1,000 ft. was 60 per cent. of the gustiness from 0 to 500 ft. Above 1,000 ft. no certain rule can be deduced from the observations. Easterly winds gave uniformly high gustiness factors; the anemometer at Pyrton Hill, where these records were obtained, is situated at the foot of the western slope of the Chiltern Hills, so that the gustiness of this easterly group of winds may be due to the previous passage of the air over the range. The decrease of gustiness with height does not appear to be dependent upon direction to any noticeable extent.

Experimental Work on Aeroplanes.—It may be mentioned that arrangements are being made for carrying out, under the direction of the Superintendent of the Army Aircraft Factory, experiments with full-sized aeroplanes. A preliminary programme of experiments has been prepared; the effect of modifications in different parts of the machine will be tried, and, if possible, the relations between head resistance, lift, speed, and H.P. expended will be investigated. The question of stability, and the factors affecting readiness in manœuvring, will also receive attention.

Reports and Memoranda.—The series of reports and memoranda has been continued, and a number of these are printed as Appendices to this Report. These consist for the most part of accounts by the experimental or constructive departments of investigations which have been carried out during the year. Some papers of a theoretical character are, however, included, among which may be mentioned especially those dealing with the application of the dimensional theory in the discussion of the experimental results obtained by different observers for the wind resistance of square plates, to which reference has already been made. The paper relating to the stresses in a balloon envelope also presents features of interest.

The following is a list of the Reports and Memoranda printed as Appendices to this Report, grouped as in the Report for 1909–10:—

General Questions in Aerodynamics—

The principle of dynamical similarity in reference to the results of experiments on the resistance of square plates normal to a current of air.—By L. Bairstow, A.R.C.Sc., and Harris Booth, B.A.

The principle of dynamical similarity in reference to the results of experiments on the resistance of square plates normal to a current of air.—By Lord Rayleigh, O.M., F.R.S.

Note on the frictional resistances of surfaces in a current of air as affected by the dimensions and roughness of the surface.—By T. E. Stanton, D.Sc., M.Inst.C.E., and J. R. Pannell.

Some theorems on stresses and deformations in the envelope of a dirigible, with a suggested "model" method for their determination.—By Harris Booth, B.A.

Experiments on Models of Airships, Stabilising Planes, &c.—

Experiments at the National Physical Laboratory on the resultant force and moment acting on a model dirigible when the axis is inclined to the direction of motion.—By L. Bairstow, A.R.C.Sc.

Experiments on wires and ropes :—

(i) The resistance of wires and ropes in a uniform current of air.—By B. Melvill Jones, B.A.

(ii) Comparison of the resistance of stationary and vibrating wires.—By T. E. Stanton, D.Sc., M.Inst.C.E.

Other Tests in the Air-channel :—

(i) Wind resistance of a radiator of honeycomb form.

(ii) Lift and drift of an inclined "Paulhan" girder.

Apparatus for the visual and photographic study of the distribution of the flow round plates and models in a current of water.—By C. G. Eden.

Propellers—

Determination of the movement of the air in the whirling table shed due to the motion of the whirling arm, with and without propellers.—By L. Bairstow, A.R.C.Sc., F. H. Bramwell, B.Sc., and W. E. G. Sillick, A.R.C.Sc.

Experiments on the thrust and efficiency of model propellers, with a note as to a comparison with tests of a full-sized propeller. —By L. Bairstow, A.R.C.Sc., F. H. Bramwell, B.Sc., and W. E. G. Sillick, A.R.C.Sc.

Motors for Aeronautical Purposes—

An account of the tests of motors entered for the Alexander Motor Prize Competition, with description of the testing apparatus, is given in the Interim Report of the Advisory Committee for the year 1910–11*.

Materials of Construction—Fabrics—

Report from the National Physical Laboratory on the Testing of balloon fabrics, October, 1910.

Further report of tests on balloon fabrics, March, 1911 :—

(i) Mechanical tests.
(ii) Permeability, durability, &c.
(iii) Note on the thermal properties of balloon fabrics.
(iv) Note as to tearing tests of fabrics.

Bursting tests of fabrics, by Mervyn O'Gorman, Superintendent of the Army Aircraft Factory.

Meteorology—

On a theodolite with gear for recording the altitude and azimuth of pilot balloons.—By J. S. Dines, M.A.

Apparatus for obtaining the simultaneous changes in velocity and direction in the wind, with the results of observations at 36 feet and 98 feet respectively.—By J. S. Dines, M.A.

A self-recording counter and dynamometer to record on the same chart the length of wire attached to a kite and its tension ; with a discussion of the results obtained. By J. S. Dines, M.A.

The report by Sir G. Greenhill on the "Theory of a stream-line past a plane barrier, with an application to the theory of an aeroplane" was referred to in the Interim Report. This has since been issued as a Stationery Office publication.

The Abstracts of technical papers on aeronautical subjects have been continued and are printed in this Report. Translations of the papers issued by the Göttingen Aerodynamical Laboratory have also been prepared by the Secretary with a view to their publication in the English technical press.

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* Cd. 5453.

Visit to Barrow.—On February 13th and 14th the Committee visited the works of Messrs. Vickers, Limited, at Barrow, to inspect the airship under construction. They were very kindly received by Sir Trevor Dawson, Mr. McKechnie, and other members of the firm, and by Captain Sueter, the Admiralty representative on the Committee, and given every facility for seeing the work which is proceeding under Captain Sueter's charge. The Committee are also much indebted to Messrs. Vickers, Limited, for the assistance they have rendered in connection with the experimental work in progress at the Laboratory, especially with regard to the propeller tests.

Signed on behalf of the Committee,

RAYLEIGH,

President.