AERONAUTICS.

TECHNICAL REPORT

OF THE

ADVISORY COMMITTEE FOR AERONAUTICS

FOR THE YEAR 1915-16.

(With APPENDICES).

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REPORT FOR THE YEAR 1915–16.

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

Sir,

A large increase in the amount and extent of the work carried out under the control of the Advisory Committee for Aeronautics has taken place as a result of the war.

Mr. Tennyson d'Eyncourt, Director of Naval Construction, was recently appointed an additional member of the Committee. The names of the present members of the Committee are given on the opposite page.

Some new problems have required attention during the course of the past year, but in the main the work has been directed to meeting the immediate needs of the Services in regard to the design and development of aircraft. The main principles to be followed in design, and the more immediately necessary general data required in their application, had been determined previously, but the developments in detail have been very numerous, and the detailed information required as to the aerodynamic properties of a number of different types of machine, with the proposed modifications arising in the course of design, have entailed a great amount of experimental work. Progress with a number of investigations of more general character, and of considerable importance, has in consequence been unavoidably delayed, but the increased facilities recently provided, to which reference is made below, will, it is hoped, render possible a more rapid advance with researches relating to the general aerodynamic characteristics of the aeroplane, which have a direct bearing on the improvement of all types of machine.

Provision for experimental work at the National Physical Laboratory.—The fundamental necessity, in the development of aircraft, of proceeding on the basis of exact knowledge derived from accurate investigation under experimental conditions is now clearly recognised in this country, and the demand for exact information has led to continuous growth in the provision made for experimental work at the National Physical Laboratory. This provision now covers four main branches of research:—(1) Aerodynamics, including the determination of the forces acting on models of aircraft, and of their various parts, as well as general investigation of the motion of bodies through fluids. (2) The study of fabrics for use in the construction of aircraft, and of methods of proofing and protection, the examination of dopes, varnishes, protective pigments, etc., and other chemical work. (3) The investigation of materials, especially light alloys, for use

in aircraft construction, and their production under manufacturing conditions. (4) The examination of special questions which arise in connection with airships or seaplanes in relation to their use at sea. In addition to these four principal sections of the work, a large number of special questions receive attention from time to time at the Laboratory, *e.g.*, those relating to instruments or accessories for use on aircraft, the investigation of breakages, etc.

The principal equipment available, at the commencement of the period under review, for research in aerodynamics, comprised three air channels, a 3-foot, a 4-foot, and a 7-foot, together with a whirling arm for tests of propellers, and some small air and water channels for the photographic investigation of fluid motion. Under the conditions existing these have not been found sufficient during the past year to enable the requirements of the Services to be met, and, at the urgent request of the Admiralty and War Office, additional channels have recently been constructed, and are now in use. The 7-foot channel had been found of great service in general experimental work, and, after careful consideration, it was arranged that a second 7-foot channel should be provided, as well as another 4-foot, together with the necessary machine tools for model-making, and other incidental equipment. New buildings had to be erected for these channels, as well as for the increased office and workshop accommodation necessary. The erection of these buildings, the construction of the channels, and the provision of much of the equipment was undertaken, with the consent of the Treasury, by the Office of Works, and the Committee is much indebted to Mr. Baines, the Principal Architect of the Office of Works, for the rapid and successful completion of the work. The necessary provision has been made by the Treasury for the increased staff required for working the new channels.

Some additions to the staff and equipment have also been necessary in the Departments dealing with fabrics and chemical work, and light alloys, respectively. The rolling mill, to which reference has been made in previous reports, has been at work for some time, and its value has been very fully demonstrated during the past year.

By express desire of the Admiralty, provision has also been made for a considerable increase in the experimental work, in connection with seaplanes, carried out in the William Froude National Tank.

As a result of the experience gained with the earlier channels, some improvements have been introduced, in the new equipment, in the design of the channels and of the measuring apparatus employed. Continued experience has confirmed the accuracy and convenience of the methods of measurement adopted. A recent report of the Smithsonian Institution states that the Massachusetts Institute of Technology, after careful study of existing channels in other countries, has adopted in its Aeronautics Laboratories a channel and balance of the N.P.L. type,

with but slight modifications. Drawings of the balance for the 7-foot channel have also recently been furnished, at their request, to the Navy Department at Washington.

Experimental work in aerodynamics.—The work done in the air channels has been largely directed to the determination of data immediately required for purposes of design. A considerable amount of information of general value has, however, been obtained and will be published later. Use of the 7-foot channel has enabled the range of values of vl/ν at which experiments are conducted to be appreciably extended, thus throwing further light on the exact numerical relation between the full scale and model coefficients which define the wind forces. Experiments on spheres have been made, both in the wind channels and in a natural wind, and the results compared with those obtained in other laboratories, especially those of Eiffel and Prandtl. The urgency of other work has, however, prevented the complete interpretation of the varying results obtained for spheres of different sizes, at different wind-speeds: it is hoped that opportunity will arise later of carrying to a successful conclusion this investigation, which is of great theoretical interest and may throw light on other questions of more immediate practical importance. Similar series of experiments have been conducted on struts and fair-shaped wires, as well as on wing forms; while the effect of change of scale on the region of unstable flow has been examined for aerofoils of special type.

Much time has been devoted to measurements of the wind-forces on complete machines, and examination of the results of modification of individual parts. The results thus obtained will be of general interest, and of importance in future design.

A new apparatus for the measurement of moments has been designed and constructed, and enables higher accuracy to be attained than that hitherto employed.

Apparatus has also been devised for measuring the velocity and direction of flow in the air current at any point in the neighbourhood of a model. This will facilitate the study of the velocity distribution and the character of the flow round models, and will assist in the explanation of observed variations in the wind-forces on auxiliary surfaces.

Some further questions in connection with the stability of the aeroplane have been investigated. Continued application has been made of the theory previously developed, and some improvements in detail have been effected. In particular, the effect of the use of the controls has been examined.

Experiments on models of kite balloons have been made, and the conditions affecting the equilibrium of more than one type examined. The stability of these balloons has also been investigated. The conclusions reached are of definite practical importance, and, when applied in practice, should overcome some of the difficulties hitherto experienced in the manipulation of kite balloons.

Air-screws.—With a view to securing increased accuracy in the designing of air-screws to fulfil specified conditions, new apparatus has been designed for the testing of air-screws in a wind channel, and for determining the distribution of pressure over the blades. Careful comparison has been made between the results of air channel measurements on air-screws, and those obtained from experiments on the whirling arm. In connection with this work, close examination has been made into the degree of accuracy obtained in the experimental methods employed in tests of air-screws on the whirling arm. The result of these investigations was to confirm the satisfactory character of the results obtained in the observations on the whirling arm, and to shew that channel measurements on air-screws, under the conditions adopted, can also be relied upon to give accurate results. In view of the great saving of time and labour, it is proposed, in general, in future, to employ air channel methods in the testing of air-screws.

The continued use of the existing air channels on more immediately urgent work has delayed somewhat the further prosecution of the experiments on air-screws. With the additional channels now available, it is hoped that it may be found possible to resume the investigation at an early date.

Strength of construction.—The considerations affecting the views held as to the "factor of safety" to which manufacturers should work in aeroplane design and construction, have been somewhat complicated by the introduction of new factors arising out of the conditions and dangers of active service in the field. The preliminary figure laid down by the Committee has, however, been found convenient in general as a basis for design. Considerable attention has from time to time been given to improvements in detail, and continued investigation into all questions affecting the strength and durability of the machine tends constantly to increased security. In particular, a number of cases, of theoretical interest, have been investigated of fracture or failure occurring owing to vibration originated by the engine or other cause, with synchronisation and resonance in the part affected.

A large number of investigations have been carried out during the year, at the request of the Service Departments, into methods and processes employed in the construction of aircraft and engines. Among these may be mentioned the use of autogenous welding, the annealing of hard drawn steel tubes, methods of soldering in connection with light alloys, etc. Some of these investigations have led to important results of more general value.

A suggestion was made to the Committee that certain Australian timbers exhibited special properties which might render them of value in aeroplane construction. By the courtesy of the Agent-General for Western Australia, specimens of some of these timbers are being placed at the disposal of the Committee, and will be submitted to trial.

Experimental work in the William Froude National Tank.—A number of investigations in relation to aircraft have been carried out during the year in the Froude Tank. In particular, the experiments on floats have been continued and extended. In view of the importance of this work, an urgent request was made by the Air Department of the Admiralty for increased facilities, and additions have accordingly been made to the staff and equipment, for which special provision has been granted by the Lords Commissioners of H.M. Treasury.

Fabrics.—The work done by the "fabrics" department of the Laboratory includes the examination of the strength, permeability, and other properties of airship and aeroplane fabrics, the investigation of methods of gas proofing and waterproofing, and of dopes, varnishes, paints, etc. The work during the past year has been exceptionally heavy, and numerous matters have arisen requiring special investigation. The Committee is indebted to the Autotype Company and to the North British Rubber Company for assistance rendered in the experimental investigation of methods of proofing fabric, and of preventing deterioration.

Interesting results have been obtained from the examination of fabrics exposed in the tropics. The experiments have been carried out with the co-operation of the Air Department of the Admiralty.

Light alloys for aircraft construction.—The systematic study of light alloys for aircraft construction has been continued. In this connection, the experimental rolling mill recently provided, and referred to in previous reports, has been of the greatest value, and has enabled the examination of these alloys to be continued beyond the laboratory stage, under conditions closely approximating to those which arise in manufacturing practice, but with greater facilities for the precise control of the various factors affecting the quality of the product, such as the exact constitution of the alloy, the temperature of rolling, etc.

A number of special questions relating to alloys have been referred to the Department for investigation, and it has been necessary to ask for an increase in the provision made for such work.

Special matters.—Experiments have been carried out on the aerodynamic properties of bombs, and investigations and calculations have been made with regard to the flight of bombs, with a view to increased accuracy of aiming. The Commandant of the Central Flying School has furnished valuable assistance and information to the Committee in this connection, from the results of experiments there undertaken.

Questions connected with the aeroplane compass were laid before the Committee by the Superintendent of the Royal Aircraft Factory in the autumn of 1913. These led to an examination into a number of points connected with the use of compasses on aircraft, in which members of the Committee assisted, while

a close study of the conditions affecting the aeroplane compass, with a view to its development and improvement, was undertaken at the Royal Aircraft Factory by Dr. Keith Lucas, F.R.S. As a result of these experiments, which commenced early in 1914, various modifications from the compass previously in use were suggested and adopted, and a type of instrument specially adapted for employment on an aeroplane under the varying conditions which arise in flight was ultimately produced and standardised. Fliers are much indebted to Dr. Lucas for the success attained in this investigation. The Committee desire also to thank the Admiralty Superintendent of Compasses for information recently furnished to them with regard to the type of compass adopted for Naval use on aircraft.

Other questions which have been the subject of special investigation relate to the properties of permanent magnets as affecting their use in magnetos, the design of sighting apparatus, both for bomb dropping and in connection with aerial musketry, etc.

A number of special matters have been investigated at the request of the Board of Invention and Research and the Munitions Inventions Department. The Committee has also given assistance to these bodies in the examination of patents and designs submitted to them, relating to projected improvements in aircraft.

Full scale work at the Royal Aircraft Factory.—Full scale research by experiment and observation upon aeroplanes in flight has been continued, and written records of the flight path, both controlled and uncontrolled, have been obtained. Many improvements in engines, air-screws and controls can only be made as the outcome of experiment upon actual machines, and these tests occupy the larger part of the flying time of the necessarily restricted number of aeroplanes available.

As regards aerodynamic qualities, it has become increasingly important to predict with accuracy the performance and stability of an aeroplane while it exists only in drawings, and to be able to arrange that the movement of its centre of lift, the size and position of fins, the position of its centre of gravity, etc., are such as to ensure that it shall have adequate stability and control.

It has been possible, by the issue at the outbreak of war of complete working drawings, to obtain strong, stable and serviceable aeroplanes in quantity from firms who had no previous experience of aircraft building.

By the analysis of observations taken in experiment upon aeroplanes in the air in climbs, glides and level flights, progress is being made towards determining the aerodynamic characteristics of the aerofoil and other parts, so that a guide may be available for correctly interpreting the model results and linking them with the full scale data.

Strength of construction.—The value of strength and good construction in saving aeroplanes from damage and reducing

the amount of work required for their efficient upkeep in the field has been fully borne out by the experience of the Expeditionary Force. In view of considerations of safety of a different kind, which render necessary the sacrifice of all possible weight in the interest of the highest performance, the instruction calling for a strength factor of six, to be increased, if possible, to twelve, has been varied in practice, so as to admit in some cases a substantially diminished factor. This lower factor demands that still greater precision in calculation of strength shall be used. Instruction and information as to these calculations has been freely given to aeroplane constructors and designers.

Recent Laboratory tests have shewn that raf-wires of the type developed at the Factory shew little or no aerodynamic disadvantage as compared with wires of stream-line section, and in view of their mechanical advantages and easier production they have accordingly been standardised and their use has been put at the disposal of aeroplane constructors. Universally jointed end fittings have been employed as an additional precaution against the effect of vibration. The reliability of the wires, when properly heat treated, has been assured by vibration tests at the Laboratory.

Great attention has been paid to the thorough testing of all metals used in aircraft construction, and a specimen from every bar is individually tested. Owing to the high demand for mild steel of less good quality for shells, the difficulty found in obtaining the better class of material required for much of the work on aeroplanes has been overcome by micrographic and temperature studies of the metal at the Factory, and the treating of the steel as delivered till the better quality is secured. Advice and assistance has been given to constructors with regard to their heat treatment plant.

Design and construction of aeroplanes.—New machines and new wing sections have been designed to take advantage of new knowledge, and appreciable improvement for a given engine power and weight has been obtained. Development proceeds by the making of a few trial machines, and four main types have been standardised for contract purposes. In new types guidance has been received from the experience of the Royal Flying Corps in the field, and in all cases it has been found possible to secure stability under ordinary flight conditions. Certain aeroplane constructors have taken advantage of a new device for saving weight in design, of a fair-shaped design of tail, a steerable rear skid and other details. Special attention has been given to the provision of suitable landing gear, and in large machines an air and oil recoil mechanism has been successfully introduced. The improvement of air-cooled and of water-cooled engine design and construction has been the subject of continued study, resulting in new designs and their development, with the help of the firms concerned. Two new devices are being tested for improving the performance at heights.

Instruments.—Owing to the greatly increased demand for aeroplane instruments, the work in this connection has been very much augmented, the labour of correction and adjustment of deliveries being considerable, and much instruction and assistance has been given to instrument firms. A new air speed indicator of the metal diaphragm type has been designed and tested. Improvement has been made in the system of electric lighting of instruments. The National Physical Laboratory method of test of instrument dials painted with luminous paint has been of great assistance, and the test is now specified as standard by the Royal Aircraft Factory. The temperature and lag errors in aneroids are being investigated and their remedy considered. An improved engine speed indicator is designed and is under construction. The investigation relative to the aeroplane compass, already referred to, has led to the production of the R.A.F. Mark II. Compass, which is now being made by contract in large numbers for the Royal Flying Corps.

Two wireless telegraphy sets of very light weight have been designed and tested, and the investigations relative to finding the true vertical on aeroplanes in flight have progressed satisfactorily, as well as the evolution of optical systems for convenient observation of bomb dropping from aeroplanes.

Whirling arm.—The whirling arm at the Royal Aircraft Factory has been used for tests of full scale air-screws, and modifications made to give speeds up to 70 miles per hour. The results have been valuable in studying the relation between model and full scale observations taken on aeroplanes in flight. Comparative experiments are also in progress at the National Physical Laboratory.

Fabrics and dopes.—Experiments with various types of fabric have been in progress in connection with visibility and with a view to lowering the weight of the fabric covering of wings, and decreasing the amount of the tightening and protecting film necessary. It has also been found that a method of abandoning the use of poisonous ingredients can be relied upon. Protracted experiment has led to the conclusion that the greater part of the deterioration of the film on aeroplane wings is due to the actinic portion of the sun's rays, and it has been found that effective protection can be obtained by the application of a finishing varnish containing pigment, and that advantage is gained by the avoidance of drying oils in contact with fabric. The use of the pigment is also serviceable in certain cases in rendering aeroplanes, when on the ground, less visible from above.

Other matters.—A large number of special tests have been made on oils and petrols, the design of magnetos, in which assistance has been given by experiments at the National Physical Laboratory, the design of spark plugs, the design of shell for special purposes, gun mounts, fire grapnel, etc., on thin tubular struts, on sound detection, on the stability of bombs,

on the gas distribution in engines, the use of air-screws of variable pitch, and many other problems. A special speed measuring course has been laid out for determining aeroplane speeds at heights.

NAVAL WORK.—The assistance of the Committee has been given to the Air Department of the Admiralty in connection with a number of important problems, in which laboratory experiment was desired in conjunction with investigatory work proceeding on the full scale. Among the questions dealt with may be mentioned the design of airships, both rigid and non-rigid, the mooring of airships over the sea, points in connection with the design of seaplane-carrying ships, the design of wind screens near airship sheds, and the equilibrium and stability of kite balloons. The National Physical Laboratory has also been working in co-operation with the Air Department in relation to airship fabrics, dopes for aeroplane fabrics, the production of light alloys, and other matters.

As mentioned earlier, a request was made by the Air Department of the Admiralty for an increase in the facilities for tests of seaplane floats and flying boat hulls. The necessary provision has been made for this, and the full scale work on machines of new types is being carried on in conjunction with model tests in the William Froude Tank at the National Physical Laboratory. The utility of the model work has been fully demonstrated in the full scale tests.

New types of aeroplanes and seaplanes have also been developed by the Air Department, with the aid of wind channel tests at the National Physical Laboratory, and the co-operation of the Committee has been obtained with reference to a number of special matters, especially in regard to auxiliary apparatus for use on aircraft.

METEOROLOGICAL WORK.—The experimental work of the year has been mainly concerned with arrangements for the automatic recording of lightning flashes and ascertaining by wireless telegraphy the position of distant thunderstorms, with the object of giving warning of their approach to those interested. The Admiralty have arranged for the co-operation of the Naval Wireless Department, and the assistance of observers of weather in various parts of the country has been secured.

The work at South Farnborough is in charge of Temporary Captain C. J. P. Cave, of the Meteorological Section R.E., who is now meteorologist in charge of the Office at South Farnborough.

Arrangements are in progress for observations on the relation of various conditions of weather to visibility of near and distant objects.

In connection with the regular work of the Office at South Farnborough, information of various kinds as to the state of the atmosphere has been supplied to the Royal Aircraft Factory, information as to the structure of the atmosphere, as obtained

by pilot balloons, to the Royal Flying Corps, the Aeronautical Inspection Department and other centres.

The Office is in regular daily communication with the central Meteorological Office at South Kensington, for the transmission of the observations made locally and for the receipt and distribution of information collected and arranged at the Central Office. It has also been used for training meteorologists for duty with the Meteorological Section R.E.

There have been many changes in the professional staff. which now consists of Captain Cave and Mr. R. A. Watson Watt, B.Sc., of University College, Dundee.

Arrangements are in progress through Major G. I. Taylor, R.E., who has been appointed Professor of Meteorology, to improve the exchange of information between the air pilots and the Meteorological Service, and to enable the collected records of weather and the experience of airmen, which is at present unrecorded, to be used for the advantage of the Air Services.

Signed on behalf of the Committee,

RAYLEIGH,

President.

June, 1916.