AERONAUTICS.

TECHNICAL REPORT

OF THE

ADVISORY COMMITTEE FOR AERONAUTICS

FOR THE YEAR 1919-20.

(With APPENDICES.)

VOL. I.

General questions, Airships and model Aeroplane research.

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MEMBERS OF THE COMMITTEE.

March, 1920.

Sir RICHARD GLAZEBROOK, K.C.B., F.R.S. (Chairman).

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Professor J. E. PETAVEL, F.R.S.

Sir NAPIER SHAW, F.R.S.

Secretary, Mr. F. J. Selby,

Assistant Secretary, Mr. J. L. Nayler,

National Physical Laboratory,
Teddington,
Middlesex.

REPORT FOR THE YEAR 1919-20.

To the Right Honourable WINSTON CHURCHILL, M.P.,
Secretary of State for Air.

SIR,

1. The Advisory Committee for Aeronautics begs to submit its report for the year 1919–20.

2. At the two first meetings of the year, in April and May, 1919, the chair was occupied by the President, the late Lord Rayleigh. Lord Rayleigh was nominated President of the Committee on its appointment in April, 1909, by the then Prime Minister, Mr. Asquith, and during the ten years of his tenure of that position, except on rare occasions, when prevented from attending through illness or absence from the country, had continuously presided at its meetings. At the June meeting he was unable to be present owing to the illness which shortly afterwards proved fatal, and in their report for the year 1918–19, which was then passing through the press, the Committee were able to include a note giving the terms of the resolution in which they expressed their sense of the loss the country had sustained by his death. He had throughout taken the greatest interest in the work of the Committee and in the progress of aeronautical research, to the successful prosecution of which he had himself greatly contributed both as President of the Committee and by his own personal investigations. The Committee desire again to put on record their high appreciation of the invaluable services rendered to British science, and to aeronautics in particular, by their esteemed and honoured President.

3. Other changes have taken place in the *personnel* of the Committee since the date of the previous report. Sir Dugald Clerk resigned his membership and the chairmanship of the Internal Combustion Engine Sub-Committee at the end of March, 1919. Major-General Sir W. S. Brancker and Mr. E. C. Given retired during the course of the year under review. Air Commodore Brooke-Popham, Director of Research at the Air Ministry, now represents the Air Ministry on the Committee.

The names of the members of the various Sub-Committees are given below.*

* The following are the names of the members of the Sub-Committees :—

Engine Sub-Committee.—Lieut.-Colonel Mervyn O'Gorman, C.B., Major E. S. Saunders, Dr. T. E. Stanton, F.R.S, representing the National Physical Laboratory; Commander T. B. Barrington, R.N.V.R., and Captain G. W. A. Brown, representing the Air Ministry; Brig.-General R. K. Bagnall Wild, C.M.G., and Major G. P. Bulman, representing the Aeronautical Inspection Directorate; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Light Alloys Sub-Committee.—Professor C. F. Jenkin (Chairman); W. H. Dyson, representing the Royal Aircraft Establishment; Professor F. C.

4. This report is the final report of the Committee as at present constituted. In February, 1920, the Chairman of the Committee received the following communication from the Air Council :—

Air Ministry,
Kingsway, W.C.2.

Ref. No. A.8440. *9th February*, 1920.

" Sir,

" I am commanded by the Air Council to state for the information of the Advisory Committee for Aeronautics that they have had under consideration and have submitted to His Majesty's Government the question of the future arrangements to be made for the control of aeronautical research.

Lea, representing the Air Ministry ; Captain H. P. Philpot, representing the Aeronautical Inspection Directorate ; Mr. A. W. Johns, Chief Constructor, representing the Director of Naval Construction ; Dr. W. Rosenhain, F.R.S., representing the National Physical Laboratory ; Professor C. A. Edwards ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Aerodynamics Sub-Committee.—Sir J. E. Petavel, K.B.E., F.R.S. (Chairman) ; Sir G. Greenhill, F.R.S ; Professor H. Lamb, F.R.S. ; Lieut.-Colonel Mervyn O'Gorman, C.B. ; Lieut.-Colonel J. H. Landon, D.S.O., of the Air Ministry ; Dr. T. E. Stanton, C.B.E., F.R.S., and Mr. E. F. Relf, A.R.C.Sc., of the National Physical Laboratory ; Captain W. S. Farren, C.B.E. ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Meteorology Sub-Committee.—Sir Napier Shaw, F.R.S. (Chairman) ; Mr. G. M. B. Dobson ; Lieut.-Colonel Harries ; Mr. A. Mallock, F.R.S. ; Lieut.-Colonel Mervyn O'Gorman, C.B ; Sir J. E. Petavel, K.B.E., F.R.S. ; Dr. T. E. Stanton, C.B.E., F.R.S. ; Mr. G. I. Taylor, M.A. ; Mr. C. T. R. Wilson, F.R.S. ; Major H. E. Wimperis, R.A.F. ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Special Committee on the Electrification of Balloons.—Sir Napier Shaw, F.R.S. (Chairman) ; Lieut.-Colonel Cave-Brown-Cave ; Captain C. J. P. Cave ; Mr. A. Mallock, F.R.S. ; Lieut.-Colonel Mervyn O'Gorman, C.B. ; Sir J. E. Petavel, K.B.E., F.R.S. ; Lieut. W. H. Rose, of the Air Ministry ; Mr. F. E. Smith, O.B.E., F.R.S., of the National Physical Laboratory ; Mr. C. T. R. Wilson, F.R.S. ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Fire Prevention Sub-Committee.—Lieut.-Colonel Mervyn O'Gorman, C.B. (Chairman) ; Lieut.-Colonel Cave-Brown-Cave ; Mr. G. B. Cockburn, O.B.E. ; Wing Commander L. F. R. Fell, D.S.O., M.V.O., O.B.E. ; Sir J. E. Petavel, K.B.E., F.R.S. ; Dr. J. E. Ramsbottom ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*)

Load Factor Sub-Committee.—Sir Richard Glazebrook, K.C.B., F.R.S. (Chairman) ; Lieut.-Colonel W. D. Beatty, R.A.F., Squadron Leader F. H. Bramwell, R.A.F., representing the Air Council ; Mr. A. J. Sutton Pippard, M.B.E., M.Sc., A.M.I.C.E., Mr. L. Bairstow, C.B.E., F.R.S., representing the Royal Aeronautical Society ; Mr. F. Handley Page, Captain F. S. Barnwell, Mr. H. Smith, Mr. H. O. Short, representing the Society of British Aircraft Constructors ; Sir J. E. Petavel, K.B.E., F.R.S., Mr. F. W. Lanchester, M.Inst.C.E., Mr. R. V. Southwell, M.A., Dr. T. E. Stanton, C.B.E., F.R.S., representing the Advisory Committee for Aeronautics.

"As the Committee are no doubt aware, a Committee was appointed by the late Secretary of State for Air, under the chairmanship of Sir R. Glazebrook, to report on the whole question of aeronautical education and research after the war. The report of that Committee will shortly be laid before Parliament, and its recommendations have been approved by the Air Council.

"One of the recommendations is that the Advisory Committee on Aeronautics should be replaced by an Aeronautical Research Committee, with appropriate Sub-Committees, and with functions differing from those of the present Committee. The necessary steps are being taken for the formation of the new Committee, but some little time may be expected to elapse before it can function.

"The Air Council think, however, that it is proper to inform the Advisory Committee of the situation at the earliest possible moment, and I am to request that you will cause this letter to be communicated to them at their next meeting, with a request that they will continue their service to the State until the new Committee can be formally constituted.

"The Air Council would desire to take this opportunity of expressing their deep sense of appreciation of the magnificent services rendered to the cause of aviation by the Committee since its establishment and especially during the years of war. The Council feel that without the assistance of the Committee the progress which has put British aviation at the front of the world would have been impossible, and they desire me to convey to you and to every member of the Committee the most cordial message of appreciation and gratitude.

"I am, Sir,

"Your obedient Servant,

(Signed) "W. A. ROBINSON."

The work of the present Committee will be continued by the new Aeronautical Research Committee, with somewhat wider functions and extended powers. The Advisory Committee have no doubt that the future of aeronautical research will be well and wisely cared for by the Aeronautical Research Committee, under the chairmanship of Sir Richard Glazebrook, who has held the position of chairman of the Advisory Committee since its formation. They desire once again to emphasize the immense importance of research in aeronautics. The value of the work done in this country prior to 1914 was amply demonstrated during the war. It enabled the development and design of new types of aircraft to be accomplished rapidly and with accurate knowledge,

with the minimum of loss from defects due to lack of data and need of special investigation for which much time is necessary, which is not available in a national emergency. The best hope for the future of aeronautics, whether in its uses for commercial and civil purposes or for defence, lies in the continued development and extension of research. There is a wide field to be explored—as yet we have scarcely advanced beyond the border line—and no one can say what possibilities lie hidden in the unknown country beyond. But already we can see far enough to be assured that its exploration is of immense importance for the civilisation of the future and that no effort should be spared in carrying forward the work. At the moment the chief need would appear to be the improvement of the methods of propulsion, especially as regards the reliability and endurance of the engine. Much pioneering work is, however, still required in the development of the large aeroplane and of the airship.

5. *Equipment for Experimental Work at the National Physical Laboratory and at the Royal Aircraft Establishment.*—The two chief centres for aeronautical research in this country are at present the National Physical Laboratory and the Royal Aircraft Establishment. The National Physical Laboratory is equipped for experiments on models and for such other work as can suitably be carried out in a central research laboratory. The Royal Aircraft Establishment has devoted attention mainly to full-scale work on aeroplanes, engines, propellers, &c., in earlier days also on airships, but such work as is at present done in this direction is now carried out elsewhere (see below, § 6). During the war, however, the wind channel equipment at the R.A.E. was improved and extended, so that it is now able to carry out much of the model work required in connection with its full-scale experiments, and also to contribute to model research. The two institutions working in co-operation constitute a well-equipped centre for carrying out research in aeronautics, apart from the full-scale work required on seaplanes and on airships. The wind channels available at the N.P.L. comprise three 7 ft., two 4 ft., and one 3 ft. As stated in the previous report, a channel 14 ft. × 7 ft. in section is under construction ; progress with this has unfortunately been slow under the conditions which have existed during the past year, and it is not yet quite completed, though it will probably be in use before the date of issue of the present report. In addition the Laboratory is provided with a whirling arm, used earlier for tests of propeller models, for which, however, wind channel methods are now found in general more convenient ; the whirling arm is valuable for special tests required from time to time. There are also two wind towers, on which experiments can be made in a natural wind. Tests on models of seaplane floats and flying boats are carried out in the William Froude Tank. Tests are also made in the tank on models immersed in water, while tests of anemometers and other investigations can be made at moderate speeds on the tank carriage.

Other departments of the N.P.L. provide facilities for subsidiary classes of investigation. In the Engineering Department provision has been made for experiments on engines, though the greater part of this work is done at the R.A.E. Attention has been given especially to the problem of engine cooling, more particularly in the direction of determining the fundamental laws governing the transmission of heat from surfaces to fluids flowing over them; with this is also closely associated the research relating to the friction of fluids. The Engineering Department is also equipped for experiments on the strength of materials and of aeroplane parts, especially under repeated stress, impact, &c., at normal and at high temperatures; this work is of particular importance in aeronautical design. The Metallurgy Department affords full facilities for the study of alloys suitable for aircraft construction. With its furnace and foundry equipment, rolling mill, &c., it is provided with the means necessary for investigating the difficulties attending the production on a manufacturing scale of such alloys as are found to have valuable properties for constructional purposes. In the Chemistry Department equipment is available for the study of fabrics, proofings and dopes, and for other chemical work, such as the investigation of methods of examining the purity of hydrogen, the use of helium for airships and similar problems. In the Electrical, Heat and other Departments of the Laboratory special problems are investigated; much attention has been given, for example, to magneto research.

At the R.A.E. attention is directed to full-scale research on aeroplanes (both aerodynamically and for structural strength) engines and propellers. Much work is also done on the development of navigational and other instruments and auxiliary apparatus for use in aircraft, and research is conducted on the special dopes and varnishes required for wings, &c. There is also a metallurgical laboratory for investigation of materials. As is well known, the full-scale investigations carried out on aeroplanes at the R.A.E. have been of the highest value, demanding exceptional skill and audacity on the part of the flying officers and observers, and great experimental ability. All the main aerodynamical properties of the aeroplane, including stability, have been investigated on machines in flight; and the behaviour of engines and propellers has also been closely studied. The equipment of the R.A.E. includes two 7-ft. wind channels and one 4-ft., a complete installation capable of carrying out tests on aircraft engines of all sizes up to 1,200 h.p., including provision for tests under high altitude conditions, with variation of air pressure and temperature, for engines up to 250 h.p.; a whirling arm for full-scale propeller tests; foundry and factory facilities for the production of experimental aeroplanes and engines, and well-equipped chemical metallurgical, physical and engineering laboratories for the study of special problems. Attention was especially devoted at the R.A.E. during the war to the production of special types of instruments for use on aeroplanes. Many of these are, of course,

essential to the successful carrying out of the full-scale aeroplane research.

It is not necessary here to dwell on the facilities which exist elsewhere for laboratory research in aeronautics. Useful work has been done in the wind channel at the East London College; provision is being made in Cambridge, and at the London University, for research in relation to the training of aeronautical engineers.

Full-scale work on seaplanes and on airships has been carried out during the past year under the control or with the collaboration of members of the N.P.L. staff, and the necessary equipment, instruments, &c., have been constructed at the Laboratory. Reference is made elsewhere to the importance of continuing and extending this work, for which no provision of a permanent character at present exists. Mention is made in the supplement of the further investigations which have been carried out at the R.A.E. during the past year in relation to methods of wind channel construction. These have been directed mainly to the attaining of increased wind speeds with the minimum consumption of power. An air speed of 130 ft. per second has been reached in one of the R.A.E. wind channels. Various improvements have been effected in the auxiliary apparatus and in methods of measurement; in particular, attention has been devoted to obtaining increased accuracy in the determination of the resistance of airship forms, and in the measurements relating to stability.

6. *Aerodynamics.*—The demands for special tests have been somewhat less numerous during the past year, and it has been possible to make progress with researches of more general character. Among these may be mentioned specially the research on the properties of ailerons, the investigation of the resistance of airship forms and the relation between model and full-scale results, the study of propeller theory, and stability tests of complete models. These last have arisen from the necessity of investigating the stability of new types of aeroplanes. It has been arranged that a complete model of any new type shall be submitted to the N.P.L. for a thorough investigation of its stability, and one of the 7-ft. channels has been set aside for this work. This complete investigation necessarily occupies an appreciable time, but considerable progress has been made, and the results will no doubt be of general interest, and will form an important contribution to the study of aeroplane stability, more particularly in conjunction with the experimental investigation of the stability of the full-scale aeroplanes in flight, for which suitable methods have now been developed.

The research on ailerons deals with the questions of the best form and position, and with the balancing of ailerons for large machines. A complete report on the work has been issued. Considerable attention has been given to the subject of airship resistance, and a large number of observations have been made

on airships in flight. The matter is of great theoretical as well as of practical interest and importance, but further evidence is needed for the accurate correlation of full-scale and model results. The resistance to be measured in a wind channel is very small and the attainment of the necessary accuracy is attended with considerable difficulty, while the full-scale measurements are complicated by a number of practical considerations which render difficult the comparison with the model. In view of its importance it is necessary that this investigation should be continued until a successful conclusion is reached, and better facilities for the carrying out of the full-scale experiments should be provided. The work on airscrews has been of a fundamental character and has established the general accuracy of the momentum theory of Froude as applied to the airscrew.

Brief mention may be made of a few of the other more important investigations carried out. Preliminary experiments have been conducted on models of bird-like form. It has been suggested that this form would be efficient for moderately large aeroplanes of such dimensions that the engines could be housed inside the body. The results obtained in the preliminary experiments were promising and on the recommendation of the Committee arrangements were made by the Air Ministry for the preparation of a complete design. on which further tests will be undertaken.

Reference was made in the report for 1918–19 to the investigation of spinning. The work has included interesting experiments in an air channel on the auto-rotation of aerofoils and complete models, as related to the rate of spin of an aeroplane. A full report of the model and full-scale research on the subject of spinning has been published.

The investigation of " scale effect " for the aeroplane wing has been continued and systematic experiments to obtain a comparison between model and full-scale wings are in progress. Attention has been given at the R.A.E. to the improvement of the design of a dynamometer for the measurement of the thrust of an airscrew on an aeroplane in flight. Comparative measurements of the air pressure over the surface of a wing have also been made on the full scale, on an aeroplane in flight, and on models.

Much attention has been given to the problem of reduction of landing speed, and to the cognate question of the increase of control when near the ground. It will be understood that this is a subject of the highest importance in regard to the safety of machines. Experiments on methods of improving the control at low speeds have been arranged for, and the problem has been examined both theoretically and experimentally from various aspects. It may be of interest to mention in this connection the recent design of a new wing of exceptionally high lift coefficient.

In connection with the observations which have been made on full-scale airships in flight, the stability and control of airships

have been carefully investigated. As a result of these experiments it has been found possible to effect a considerable reduction in the control surfaces.

Some interesting investigations have been carried out with regard to eddy motion and have led to valuable information with regard to the size and rate of decay of eddies. The effect of eddies on the head resistance to the motion of an airship has been examined in the wind channel. The problem of the parachute has also received special attention ; forms designed on a theoretical basis have been tried on the full-scale and found efficient. The question of the stability of parachutes has been investigated and experiments have been made to determine the effect on the resistance of the porosity of the material used in their construction.

Among other matters to which attention has been given may be mentioned the effect of roughening portions of the surface of an aerofoil, the economic conditions for long flights, the mooring of airships, to which reference has been made in previous reports, and the effect of high tip speeds on the efficiency of airscrews. Professor G. H. Bryan has submitted a mathematical investigation into the effect of the compressibility of the air in relation to the airscrew. Mr. N. A. V. Piercy has presented an interesting report of experiments carried out in the East London College wind channel on the Venturi tube. Papers have been received from members of the N.P.L. staff on the theory of viscous flow ; and valuable results have been reached in the experiments on fluid friction and the flow of fluids over surfaces. Confirmation has been obtained in recent experiments of the view that the flow within a very thin layer close to the surface is laminar and that there is no slipping at the surface. For further details regarding this and other work mentioned above reference may be made to the supplement to this report.

Proposals have recently been put forward that arrangements should, if possible, be made for obtaining comparative tests in the principal wind channels in use in the different allied countries. Such experiments would be of great interest and value in co-ordinating results obtained by different methods and would, it is hoped, economise effort and accelerate the accumulation of reliable data for standard forms. The matter has been taken up actively, and it is hoped to obtain the co-operation of the various laboratories in carrying out such tests.

7. *Seaplanes.*—A number of researches in connection with seaplanes have been in progress in the William Froude National Tank during the past year and have been supplemented by observations on full-scale machines made by the tank staff with the assistance of the flying staff at the Isle of Grain and elsewhere. Among these researches may be mentioned especially those on the effect of beam and loading of floats on propulsive efficiency ; on the effect of impact on the water, including full-scale determination of the pressure over the float or hull ; and on the effect of

loading on stability and of diving at small angles. Experiments are also in progress on flying boat forms designed for alighting on land or water.

8. *Aeroplane Carrier Ships.*—Some further experiments have been carried out, at the request of the Director of Naval Construction, on the flow of air over the deck of an aeroplane carrier ship, and have been verified by observations made on the ship. In this connection it is interesting to note that a successful landing has recently been made on the deck of H.M.S. "Furious," which was designed in accordance with the information obtained from model experiments in the wind channel.

9. *Strength of Construction.*—Continued attention has been given to the important question of strength of construction, and a number of valuable papers dealing with the application of the theory of structures to aeroplane problems and methods of calculation have been discussed by the Aerodynamics Sub-Committee. In October, 1919, by the desire of the Air Ministry, a Load Factor Sub-Committee was formed "to consider and report as to the definite rules which should be adopted to govern the load factors required for all classes of civil aircraft, and upon which certificates of airworthiness may be based."

In addition to members of the Advisory Committee this Committee included representatives of the Air Ministry, the Royal Aeronautical Society and the Society of British Aircraft Constructors. The Committee was assisted by papers contributed by a number of experienced designers, and after full and careful discussion a report which received the unanimous approval of the Committee was communicated to the Air Ministry in January, 1920. For the purpose of the required rules, aeroplanes were divided into the two classes, "Commercial" and "General," the former including only machines to be used for commercial purposes involving straight flying, while the "General" class included machines suitable for military purposes which might at times be subjected to exceptional stress. Load factors and factors of safety were laid down for these two classes, and particulars were given as to the methods of calculation which would be employed in the examination of designs with a view to the issue of certificates. The report was issued to manufacturers by the Air Ministry. Some additional details will be found in the Supplement to this report (p. 43).

10. *Engines.*—During the war a large amount of research relating to engines was carried out at the R.A.E. for the Air Ministry, under the advice and control of the Engine Sub-Committee, of which Sir Dugald Clerk was Chairman. Sir Dugald Clerk resigned this position at the end of March, 1919. The investigation of engine problems has been continued at the R.A.E. during the year 1919–20; experiments on special questions, *e.g.*, cooling and magnetos, have also proceeded at the N.P.L.

One matter to which much attention has been given is the possibility of using fuels with a high flash point in place of petrol and thus reducing the risk of fire on aircraft. Suggestions for a programme of research were originally made by Sir Dugald Clerk and a considerable amount of information has been obtained. Arrangements were made at the R.A.E. for the preparation of a series of fuels of different flash point, and experiments have been carried out with a view to determining the type of engine most suitable for burning fuels of higher flash point. Trial has been made of methods of direct injection and the use of a vapouriser. The experiments are being continued.

One of the difficulties associated with the use of the heavier fuels is detonation. It has been arranged that a research on detonation shall be carried out at the N.P.L., and this has recently been commenced. Some delay occurred owing to the difficulty of obtaining an engineer with the necessary qualifications to undertake the work.

An important research has been in progress during the year in the high altitude test house at the R.A.E. on the effect of variation of compression ratio on the behaviour of an aero-engine at altitude. A report on this research has been received and will be published very shortly. The experiments were conducted over a wide range of conditions as to temperature and pressure, and the information gained is considered to be of much value.

Research on magnetos and ignition has been continued both at the N.P.L. and at the R.A.E. A number of papers have been presented to the Sub-Committee and have led to valuable discussions at meetings at which representatives of the leading manufacturers were present by invitation.

11. *Light Alloys.*—The investigation of light alloys for various purposes in the construction of aircraft and aircraft engines has been continued at the N.P.L. During the war a large amount of experimental work relating to aluminium alloys was very actively carried on at the N.P.L., the R.A.E., Birmingham and Manchester Universities and elsewhere, under the general control of the Light Alloys Sub-Committee which was formed by the Advisory Committee in February, 1917. With the termination of the war the members constituting this Sub-Committee returned to their normal duties, and pending the appointment of the new Aeronautical Research Committee the reconstitution of this Sub-Committee has been suspended. The study of the properties of aluminium alloys has, however, made good progress, and the material accumulated during the war has been collected and will be published at an early date. Sir Henry Fowler was succeeded in the chairmanship of the Sub-Committee by Professor Jenkin, who has prepared a carefully revised report, embodying the information available in the Technical Department of the Air Ministry, on the progress made in the investigation of light alloys,

steels, &c., chiefly as a result of war requirements in the construction of aero engines. This is now in the press and will be issued as an Advisory Committee report.

The work at the N.P.L. has included the further systematic investigation of some of the more promising alloys brought into use during the war which exhibit very valuable properties. Attention has been directed especially to overcoming difficulties which may occur in the production of these alloys on a manufacturing scale. The aluminium alloy containing 4 per cent. copper, 2 per cent. nickel and 1½ per cent. magnesium, which was found of considerable service for castings, has been developed as a wrought alloy, with very interesting results. The constitution of this and other alloys has also been investigated with a view to determining the conditions on which the improvement in properties depends, the mechanism of hardening, &c.

12. *Fire Prevention on Aircraft.*—Early in the year a request was made by the Air Ministry that the Committee would consider what measures might be taken to minimise the risk of fire occurring on aircraft. One measure considered was the use of a heavier fuel, and reference has already been made to the steps taken in this direction. In view of the importance of the matter a Sub-Committee was appointed to investigate the general question of fire prevention and to superintend such experimental work as might be possible in connection with any remedies proposed. The Sub-Committee had the active assistance of the Accidents Department of the Air Ministry, and examination showed that with rare exceptions the fires which have occurred on aeroplanes have been due to the crashing of the aeroplane on the ground, and that fires were much less frequent with rotary-engined aeroplanes than on aeroplanes fitted with stationary engines. Experiment indicated that this was mainly due to the fact that the rotary engine is usually divided by a bulkhead from the body of the aeroplane, and led to the recommendation that such a bulkhead should be provided on all aeroplanes.

The Sub-Committee has also investigated a number of other questions; the fireproofing of the magneto, the position and construction of the petrol tanks, the use of various fire-extinguishing materials, &c. A suitable fire-extinguishing material has been found, which it is believed from the experiments made will be effective in overcoming fires occurring in the air as well as on the ground. An important preliminary report has been presented, which has been communicated to manufacturers by the Air Ministry, and the work is being continued on the lines above indicated.

13. *Meteorology.*—The work of the Meteorology Sub-Committee has been largely directed to the promotion of means of securing systematic information as to the meteorology of the upper air, by means of and for the benefit of aircraft pilots. Considerable attention has been given to the preparation of a form of meteoro-

logical log for the use of pilots in keeping a record of air conditions prevailing on important air routes. The form of log adopted has been put forward for use on the London-Paris air service, and the information that will be accumulated in this manner will no doubt be of great service to Meteorology and of important practical value to pilots. The data recorded include height, temperature, wind velocity and direction, visibility, cloud height, general weather conditions, with remarks as to bumpiness or other peculiarities on special sections of the route.

Much attention has been given to recording and other instruments for use at altitude. The errors in altimeters and airspeed indicators due to variation in the temperature of the air have been investigated. Tables have been compiled for the estimation of the altitude from pressure and temperature records. Methods of determining the wind velocity and direction at heights over land have been investigated, and suggestions have been made as to suitable methods for the determination of cloud heights. Information has been collected as to the distribution of thunder and wind storms.

Enquiry has been made into accidents attributable to weather conditions. It would appear that almost all such accidents are directly caused by bad landings due to fog, or fog and cloud, while only a very small number were due to wind.

Reference has been made above (§ 6) to the study of eddies. The results obtained in the wind channel experiments have been compared with those derived from the investigation of circular storms and other natural phenomena, and it is believed that a valuable advance has been made in the general knowledge of eddy motion, which has an important bearing on meteorology and local meteorological conditions. A considerable number of papers on the subject of eddy motion have been received and are being prepared for publication.

By desire of the Sub-Committee arrangements have been made at the N.P.L. for an investigation relating to anemometers. Experiments will be made at Cambridge with regard to sextants for use in aircraft; and other instruments for use in air navigation have been investigated. The various papers which have been submitted to the Committee are being re-edited by the Staff of the Meteorological Office, and it is proposed to issue them in due course in a convenient form.

14. *Protection of Kite Balloons from Atmospheric Electrical Disturbances.*—As recorded in the previous report good progress had been made with the investigation of means for the protection of kite balloons from damage owing to atmospheric electrical discharges. Since the termination of the war, however, the staff engaged in conducting the full-scale experiments has been disbanded and it has not been found possible to make arrangements for the continuation of the work. An account of the earlier work has been published.

15. *Fabrics and Dopes.*—The experiments on dopes and fabrics have been continued at the N.P.L. and at the R.A.E. Further information has been obtained as to the deterioration of aeroplane fabrics in the tropics and the conditions on which such deterioration depends. Experiments upon the action of light on fabrics have been continued. The effect of small amounts of acid on the strength of cotton and linen has been examined at the N.P.L., and the inflammability of doped fabrics has also been investigated. A very complete investigation has been carried out at the Admiralty Fabrics Laboratory on the permeability of airship fabrics. The permeability of balloon fabrics by air has been investigated, and the effect of humidity on the weight of the fabric. Some of this work has been carried out in connection with a Sub-Committee of the British Engineering Standards Association, which has been engaged in drawing up specifications for fabrics. In the same connection the effect of the rate of loading, humidity, &c., on the strength of cotton fabrics has been examined. Research has been in progress at the N.P.L. on the physical properties of cellulose acetate, and in particular the advantages of using more viscous acetate, giving a greater film strength.

16. *Special Engineering Work.*—A number of special investigations have been carried out in the Engineering Department of the N.P.L. These include fatigue and impact tests at high temperatures of light alloys, and of valve and other steels ; special furnaces have been constructed for this work to enable tests to be made at temperatures up to 900° C. Low temperature impact tests on steels have also been made. The influence of scratches on the resistance of steels to repeated stress has been examined. The effect of fatigue on soft solders has been investigated in connection with work in progress in the Metallurgy Department. A series of tests has been carried out for the Fire Prevention Sub-Committee on fireproofing of magnetos and the liability of various types of magneto to fire an explosive mixture.

17. *Air Inventions Committee.*—The Air Inventions Committee has continued its work during the past year in close co-operation with the Advisory Committee. Periodical reports have been made to this Committee, and special inventions or designs submitted have been referred for consideration. Particulars as to the duties of the Air Inventions Committee were given in the previous report.

The names of the present members of the Committee are given below.*

* *Air Inventions Committee.*—Sir Horace Darwin, K.B.E., F.R.S (Chairman) ; Mr. L. Bairstow, C.B.E., F.R.S., Professor H. L. Callendar, F.R.S., Sir R. T. Glazebrook, K.C.B., F.R.S., Major A. V. Hill, O.B.E (M.I.D.), Professor B. M. Jones, Professor C. H. Lees, F.R.S., Sir J. E. Petavel, K.B.E., F.R.S., Mr. G. I. Taylor, M.A., F.R.S., Major H. E. Wimperis, O.B.E., R.A.F. (Technical Department), Brig.-General E. M. Maitland, D.S.O. (Airship Department, Admiralty). Secretary : Mr. E. L. Pickles

18. *Accidents Investigation Committee.*—The names of the present members of this Committee are given below.* In all their work the Committee have received most valuable assistance from the Accidents Department of the Air Ministry, who have systematically collected the necessary data with regard to accidents, and have pursued with great energy and determination and with conspicuous success enquiries into the causes of accidents in particular cases.

Investigations of great importance have been carried out during the year 1919–20. The first of these relates to accidents resulting, in the case of certain machines, from inverted flight. The circumstances in which these accidents have been found to occur have been carefully examined, and as the result of experiments carried out in the wind channel, and in flight, modifications in design have been made to remove the danger. Great assistance in this investigation was rendered by the Accidents Department and by the flying staff of the R.A.E., who reproduced in flight the conditions likely to lead to accident and demonstrated how recovery might be effected. A report on this work is being prepared for publication.

Accidents due to the starting of propellers on the ground have also been under the attention of the Committee. A report on these was submitted to the Air Ministry early in the year, and precautions to prevent their occurrence were suggested.

The accidents to the Felixstowe Fury and to the Tarrant triplane are among other specific cases investigated. These have led to somewhat extensive experiments in the tank and wind channels respectively and the enquiries are not yet completed. Preliminary reports on the experiments have been submitted, and complete reports on the results of the investigations will be presented to the Air Ministry in due course.

19. *Publication of Reports.*—Much progress has been made with the publication of information accumulated during the war. Practically the whole of the available material presented to the Committee has either already been issued or is now in the press. A list of the reports published up to March 31st, 1920, has been printed (R. & M. 650) and is obtainable from H.M. Stationery Office. Individual reports presented to the Committee are published as early as possible after presentation, and particulars of these are included in the monthly list of publications issued by H.M. Stationery Office and are communicated to the Technical Journals.

In presenting this their final report the Committee desire to express their high appreciation of the valuable researches in aeronautics carried out at the N.P.L. and at the R.A.E., respectively. The researches at the N.P.L. have been notable for the

* *Accidents Investigation Committee* —Lieut.-Colonel Mervyn O'Gorman, C.B., D.Sc. (Chairman); Sir J. E. Petavel, K.B.E., F.R.S.; Mr. G. B. Cockburn, O.B.E.; Mr. L. Bairstow, C.B.E., F.R.S.; Mr. H. Pippard, M.C.; Mr. B. Thomson (Secretary.)

development of accurate wind channel methods, the investigation of stability, the study of the flow of fluids over surfaces and the solution of many special problems in aerodynamics; the determination, on a definite experimental basis, of the most suitable forms of seaplane floats and hulls; the continuous study of new light alloys suitable for the construction of aircraft and aircraft engines and the perfecting of methods for their commercial production; and for valuable auxiliary work in the investigation of the properties of fabrics and dopes. The work has been attended with success from the first and has aided greatly the rapid progress of flying and of aircraft construction: its value and importance have received well merited recognition from the experts in other countries engaged in the study of aeronautics. The full-scale work carried out at the Royal Aircraft Factory, later the Royal Aircraft Establishment, has been no less valuable. The Royal Aircraft Factory initiated in this country full-scale experimental research on aeroplanes and airships, and devised methods which have been conspicuously successful for the investigation on aeroplanes in flight of the many difficult problems associated with the science and art of flying. During the war its staff rendered notable service in the development of aeroplane design and construction and in the study of special manœuvres in flight, facing known risks with an intrepidity no less admirable than that of the fighting pilots and observers of the R.A.F. Many valuable lives were lost in this work, but the results attained justified the sacrifice made and greatly reduced the loss of life due to imperfect knowledge in the design of machines for service use. Very valuable assistance was also given to the Committee as well as to the fighting services by the staffs of the experimental stations at Kingsnorth, Pulham, Felixstowe, the Isle of Grain, Orfordness and elsewhere.

The Committee wish also to acknowledge the help which they have constantly received from the Staff of the Air Ministry, which has been of the greatest importance for the efficient discharge of the functions undertaken by them on behalf of the Ministry.

Finally, the Committee desire to record their indebtedness to their Secretaries, Mr. F. J. Selby and Mr. J. L. Nayler, for the successful manner in which their arduous work for the Committee has been conducted. Mr. Selby has acted as Secretary to the Committee since its appointment in 1909. Mr. Nayler has given great assistance in the work during the later years, and, on Mr. Selby's retirement, has been nominated to act as Secretary to the newly constituted Aeronautical Research Committee of the Air Ministry.

Signed on behalf of the Committee,

R. T. GLAZEBROOK,

Chairman.