AERONAUTICS

TECHNICAL REPORT

OF THE

AERONAUTICAL RESEARCH COMMITTEE

FOR THE YEAR 1933–1934
(With APPENDICES)

VOL. I
Aerodynamics

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Frontispiece.

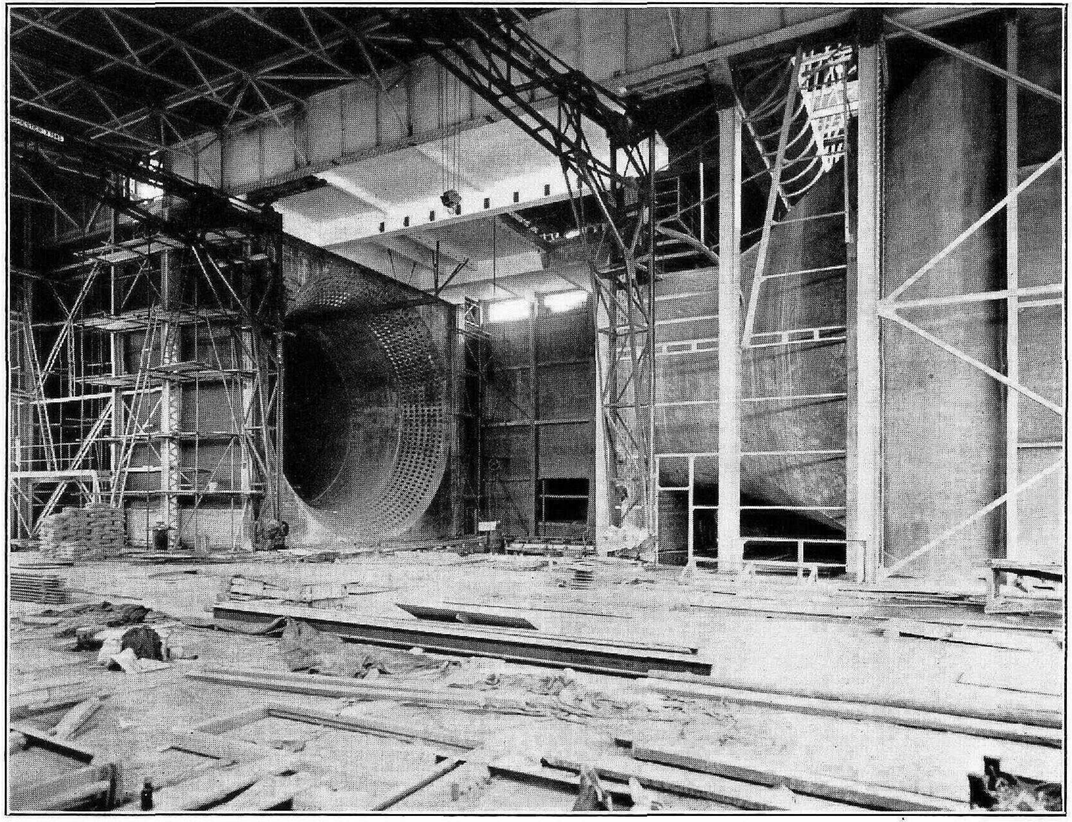

FIG. 1.—The R.A.E. 24-ft. Open Jet Wind Tunnel.

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Reports and Memoranda Nos. 1566 and 1575 are Monographs and will not be included in this report.

Reports and Memoranda No. 1550 is a list of R. & M's published between 1st April, 1932 and 1st September, 1933.

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*These Reports and Memoranda are abstracts of papers published in detail in outside journals.

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AERONAUTICAL RESEARCH COMMITTEE

Report for the year 1933–34

30th May, 1934.

The Most Hon. the Marquess of Londonderry, K.G., M.V.O.,
Secretary of State for Air.

My Lord Marquess,

We, the Aeronautical Research Committee, have the honour to submit our report for the year 1933–34.

During the year we have met thirteen times. We have held two formal meetings with representatives of the Society of British Aircraft Constructors, and two informal meetings, one at the Royal Aircraft Establishment and the other at the National Physical Laboratory. We also paid visits during the year to the Royal Aircraft Establishment, the National Physical Laboratory, the Aeroplane and Armament Experimental Establishment, and the Marine Aircraft Experimental Establishment. We take this opportunity to record our thanks to the individuals concerned for the admirable arrangements they made to enable us to see and to discuss the various researches in progress.

We also held a special meeting last autumn to discuss technical problems of aircraft transport with representatives of Imperial Airways. This meeting proved very useful, and we propose in future to hold a similar meeting every year, so as to maintain direct contact with operating companies. In view of this decision, our Air Transport Sub-Committee has been dissolved.

Research Equipment.—Considerable progress has been made with the construction of the new 24 ft. open jet wind tunnel at the Royal Aircraft Establishment (*see* frontispiece, Fig. 1). The main building is now complete, and the balances and other requisite apparatus are in an advanced stage of construction. The new high speed open jet tunnel at the National Physical Laboratory has been completed, and tests have shown it to be satisfactory in every respect. A second similar tunnel is now under construction. One of the existing 7 ft. tunnels at the Royal Aircraft Establishment is to be converted to an open jet tunnel of larger size and higher wind speed. The Compressed Air Tunnel at the National Physical Laboratory has been in operation throughout the year, and several reports on the work are now before us. The R.A.E. Seaplane Testing Tank has already fully proved its value for the investigation of important problems of seaplane design. Although the tank is only 9 ft. in width, it has been shown that the effect of side wall interference is negligible if the model under test is not more than 9 ft. in length.

We have been informed that nearly half the time available for work in the wind tunnels at Farnborough last year was spent on tests required by aircraft constructors. While we are glad to note that aircraft manufacturing firms value independent tests at a Government research establishment, we regret to find on enquiry that less than half of the prominent firms in this country possess wind tunnels of their own. It is, in our opinion, essential for the future well-being of this new industry that its scientific equipment and personnel should be developed on a scale commensurate with its importance as an organisation for national defence, and as a growing export industry. The yearly intake by the Aircraft Industry of highly trained scientific personnel is at present lamentably small.

SAFETY OF AIRCRAFT

Many of the investigations initiated and co-ordinated by the Committee have as their main object the increase of safety in flight. One of our Sub-Committees, the Accidents Sub-Committee, is concerned solely with the investigation of accidents which cannot be explained without special and often prolonged enquiry. Most of our other Sub-Committees are engaged on some problem directly connected with safety in flight. References to work of this kind will be found in the Technical Supplement attached to our report ; but we think it will be of interest if we group together some of the more important researches, in an endeavour to give a general review of the present situation.

Though only thirty-one years have passed since the first flight of an aeroplane was made, flying may now be regarded as a safe means of transport. This is due, on the one hand, to the steadily increasing reliability of aircraft engines, and on the other, to the satisfactory development of rules of design which go far to ensure the stability and the control of an aeroplane, and the safety of its structure under normal conditions of use. It is seldom that a single-engined machine, and very rarely that a multi-engined machine, is forced to land outside an aerodrome by reason of partial or complete engine failure. Further, it is only on rare occasions that an aeroplane gets out of control, or that part of its structure breaks and causes a serious accident. But it must be admitted that this relative immunity from accidents has been attained mainly by the age-long process of trial and error, and at the cost of much loss of life. We feel it to be our chief duty, as a Committee, to do the best we can to foresee and guard against possible causes of accidents ; and this cannot be done without a serious and continuing study of the science of flight. We gladly acknowledge the sympathetic and encouraging support which is given by the Air Ministry to all our proposals for fundamental research, however remote at first sight the investigations may appear to be from practical considerations.

Unfortunately, the ideal of being able to foresee all possible causes of accidents in the air is not easily attainable. Although progress in the science of aerodynamics has been rapid in recent years, accidents still occasionally occur which are difficult to understand and consequently to guard against. Our Accidents Sub-Committee has been busily engaged for two years in an endeavour to elucidate the cause of a series of accidents to Puss Moth machines. The Puss Moth is a well-known light aeroplane, which has been manufactured in considerable numbers and has given satisfactory service all over the world. It has good flying qualities and, as originally designed, fulfilled all the requirements of "airworthiness." Yet there have been eight cases of breakage of Puss Moths in the air, all resulting in loss of life. Only one of these accidents occurred in England, when the machine was being flown in stormy weather, and, at the time of the accident, was hidden from the ground by a heavy cloud. Five of the remaining accidents occurred in bad weather, and two in good weather. In most cases one or both main planes came away in the air, and some parts of the wreckage could not be found.

When the reports of the early accidents came before our Committee, it seemed probable that the cause was due to a form of rudder flutter which had been known to occur in flight on some occasions without accident. An investigation carried out at the National Physical Laboratory confirmed that rudder or elevator flutter might, under certain conditions, cause a serious accident, and recommendations were made to alter the design so as to prevent any such occurrence in future. But the Sub-Committee were not satisfied that this was a sufficient answer to the problem before them; and subsequently a machine which had been modified to meet their recommendations broke up in the air.

There are certain features common to all the known accidents. The mode of breakage of the spars and the damage to the wing tips has been similar in all cases, and in spite of the negative results of the many investigations we have initiated we still think it possible that all the accidents occurred in exactly the same way, and that further research will elucidate the primary cause. Experiments on a model with wings of the correct proportional elasticity are now in progress at the National Physical Laboratory, and when they are completed a full report will be issued giving an account of all the evidence that we have accumulated.

Effect of Bad Atmospheric Conditions.—The fact that the majority of the Puss Moth accidents, and also the Meopham accident, occurred in bad weather, has led us to attach great importance to the work of our Atmospheric Turbulence Sub-Committee. Everyone who has travelled by air knows that atmospheric conditions may cause the forces on an aeroplane to change suddenly by a large amount; but how suddenly and by how much is not known with accuracy. We do know that the present "factor of safety" is high enough to make the breakage of an aeroplane in bad weather a very rare occurrence; but we also know that the accelerations to which an aeroplane is subjected when flying in any weather increase greatly with the speed of the aeroplane. As speeds increase the margin of safety tends to decrease. It is therefore essential to collect accurate information about atmospheric turbulence, in a form that can be used as a satisfactory guide to designers.

Last year we briefly recorded some data which were obtained from recording accelerometers carried in flight. Special flights have been continued at the Royal Aircraft Establishment this year in all conditions of rough weather except the extreme conditions of thunderstorms and line squalls. Accelerometers have also been carried in the machines of Imperial Airways and of some Service Squadrons. The results so obtained have been correlated with the records of the frequency of horizontal gusts near the ground which have been observed at Worthy Down over a long series of years. The net result of all the observations goes to show that only during one flight in 10,000 in Western Europe is an aircraft likely to encounter atmospheric disturbances corresponding in effect to that which would be caused by flying into a sharp edged vertical gust which had an upward velocity of 30 ft. a second. This conclusion is valuable in that it gives a point of reference; but it does not go far enough. Aeroplanes as now designed should be amply strong enough to withstand such gusts; but we cannot deduce from the statistics now available what is the probability of an aeroplane encountering much more violent gusts. The chance of obtaining more decisive results from accelerometer records appears rather remote; so, although we hope to continue to collect such statistics, we shall also pursue other lines of inquiry. At present we are considering the design of instruments to be located on a mast or tower, with the object of recording the nature of violent gusts more accurately than can be done with ordinary anemometers. Calculations are also being made to determine what kind of gusts are likely to impose dangerous forces on an aeroplane.

We have briefly considered the effects of thunderstorms and line squalls. It is probable that no practical aeroplane can be built to withstand the severest of atmospheric conditions. But severe thunderstorms and line squalls are easily recognisable a long distance away; a pilot can be given warning of their probable occurrence, and the centre of the disturbance can usually be avoided. The danger in practice is not therefore likely to be great. When flying near thunder clouds aeroplanes are liable to be struck by lightning, especially when trailing an aerial. The Director of the Meteorological Office has communicated to the Committee an interesting and important paper on the effects of lightning on aircraft, which will shortly be published by the Meteorological Office as a Professional Note. It is interesting that no instance is known of any fatality occurring as a result of an aeroplane being struck by lightning, while damage to structure is usually comparatively slight. It seems therefore that lightning, however alarming it may appear, does not constitute a serious danger to aeroplanes.

Reports have reached us that in the United States acceleration much more severe than any we have observed are often encountered over mountainous country, but that there is no record of any accident directly attributable to failure of the structure in bad weather. Our present state of knowledge of the effect of severe atmospheric disturbances can therefore be briefly summed up as follows. It is extremely unlikely that an aeroplane will encounter weather bad enough to break it, if it is built to the present factors of safety. We hope that the further work on which we are engaged will enable us to give a precise form to this statement. In the meantime the commonsense rules of safety in flight are similar to those of safety at sea ; namely, avoid the centre of the storm when possible, and reduce speed when violent bumps are encountered.

Spinning.—The Free Spinning Tunnel at the Royal Aircraft Establishment has proved of great value for research and for the routine testing of models of new types of aeroplanes. Thanks largely to the success of this work, the investigation of spinning no longer has the urgent importance that it had a few years ago. It is not, however, possible to say that spinning is now free from danger nor that the phenomena are understood so thoroughly that it is always possible to avoid dangerous characteristics in design. Cases have been known of normal spins turning suddenly into flat spins, out of which it is difficult to recover. Recent full-scale and model work has also revealed cases where the power of recovery is slight, even though the incidence in the spins has not exceeded 50°. Those features in design which aid recovery from any spin are for the most part the same as those which oppose the development of a flat spin. A rudder placed either below or in front of the tailplane may be regarded as essential if rapid recovery from any type of spin is to be guaranteed.

The problem of designing an aeroplane to be safe in spins is inevitably dependent upon the function which it is intended to perform. If the sole condition were that the aeroplane should be capable of normal flight manoeuvres there is little doubt that an aeroplane could now be designed which would recover very rapidly from any spin it could be made to execute, nor would it be necessary to depart greatly from current practice so far as general appearance were concerned. It is now established that a body extending a distance equal to the semi-span behind the centre of gravity will dominate the effects of any normal wing arrangement, provided that a suitable cross section and profile are employed. It is, however, more than probable that an aeroplane built to a definite specification so as to avoid all possibilities of risk in spinning, would prove inferior in other respects to one in which the question of spinning had been left to chance, and in the latter case the spinning characteristics *might* be equally satisfactory. The practical problem facing the designer is to effect a compromise between those factors which are conducive to high performance and convenient operation, and those which improve spinning properties; and it is satisfactory that the technique of experiment in the Free Spinning Tunnel has now been developed so as to help him considerably in the solution of his problem.

Flutter and Buffeting.—In our report for 1929–30, we stated that the causes and methods of prevention of wing flutter were understood, and that, from a purely practical standpoint, there did not seem any need to pursue the theory further. This work was followed by a research on tail flutter, and here, again, it has been found possible to indicate a number of preventive measures whose efficacy has been proved in practice. The general theory and technique developed in these researches is being applied, as need arises, to the treatment of particular practical cases. At the moment the most urgent problem is to eliminate flutter in servo-control systems, whose use is certain to increase as aeroplanes grow in size. Research on this subject has been proceeding during most of the year under review, but it is too early to draw up any recommendations for practical preventive measures. The problem is one of great complexity as so many variables and degrees of freedom have to be taken into account in any analysis which is to be regarded as reasonably complete.

Airscrew flutter is also receiving attention, but progress has been considerably delayed by the needs of more urgent work.

The causes of buffeting have been established and methods have been indicated for reducing its severity. The conclusions will have to be verified by full-scale experiments before they can be finally accepted.

Safety on Landing and Taking Off.—The increase in the wing loading and efficiency of aeroplanes tends to increase the difficulty of landing and taking off, and for this and other reasons we have given a good deal of consideration to the question of improving the stability and control of aeroplanes at low speeds. We referred last year to the method developed by Professor Jones and Flight-Lieut. Haslam for obtaining a picture of the air flow over a wing by watching the behaviour of tufts of wool attached to the surface (*see* Fig. 2). This method has been applied further during the year and has given much useful information on the flow of air over stalled wings. In wind tunnel experiments fine silk threads about ¼ in. long, were used instead of wool tufts to explore turbulence near the surface of the wing. It has been shown that discontinuities in the air

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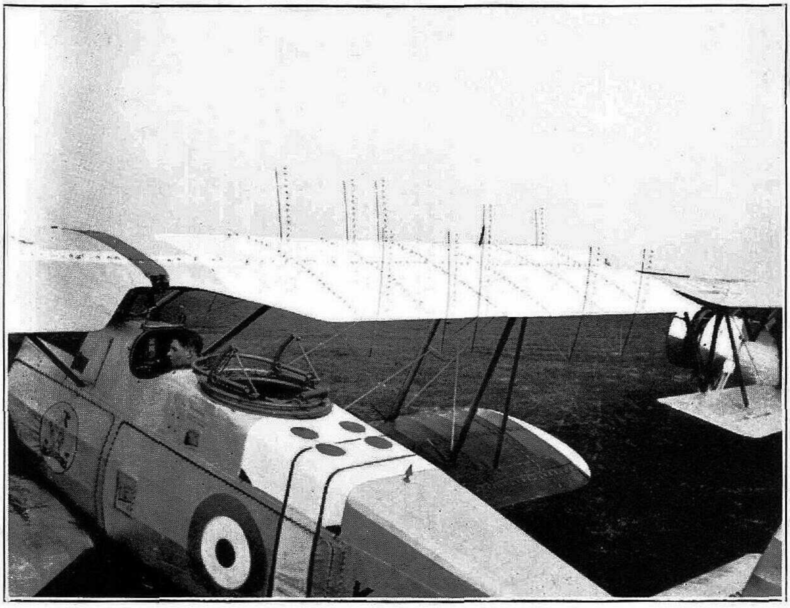

FIG. 2.—Aeroplane fitted with wool tufts to investigate the flow of air over the wings.

flow start in definite areas of the wing surface, and gradually spread over the whole surface as the incidence is increased. These local discontinuities are not shown by the ordinary methods of wind tunnel research; it is important to explore them thoroughly, since they undoubtedly have a great effect on the control of aeroplanes near the stall. Full-scale experiments have generally confirmed the results of the model experiments.

It seems clear that modern aeroplanes of the conventional type will be easier and safer to land in restricted spaces if some device can be used to increase drag, and possibly lift as well, at slow speeds. A good deal of attention has been paid to this problem abroad, especially in America, where a device known as the Zap flap has been developed. Tests on the properties of the Zap flap have been made in the National Physical Laboratory Compressed Air Tunnel, and the results agree generally with those of the American experiments. We have recommended that full-scale experiments should be carried out with this and other similar devices, and arrangements have already been made for a full series of tests at Farnborough.

In our last report we referred to an observation made by the Royal Air Force in Africa that in certain circumstances the rate of climb of a heavily loaded aeroplane was abnormally low up to a height of two or three hundred feet, above which its normal rate of climb was recovered. It was suggested that the rapid fall of temperature with height that is sometimes observed in Africa, might cause an instability in the atmosphere sufficient to have a marked effect on the performance of the aeroplane; but investigation did not confirm this theory. Recent calculations suggest that an aeroplane can take-off at a speed lower than the stalling speed, and that a long time is then required for the aeroplane to reach its best climbing speed if only a small reserve power is available for climbing. The rate of climb may be very slow until the best climbing speed is reached. It appears probable that this provides an adequate explanation of the so-called "dead layer of air," but we hope to have the views of experienced pilots before accepting the explanation as final.

The Autogiro.—The autogiro is an unconventional type of aeroplane, which has remarkably good landing and take-off characteristics. We referred briefly last year to Señor de la Cierva's most recent design, in which the fixed wing has been suppressed and the whole control secured by action on the rotor shaft. Señor de la Cierva attended one of our meetings and gave us an interesting account of his work. It is evident that the new type is a great advance on previous designs, and that from the point of view of safety in flight it presents some remarkable features. It is possible not only to land but also to take-off in a very small space. Its minimum flying speed is about half that of a conventional type of aeroplane. It is quite stable, and easily controllable under normal flying conditions. It may not be so efficient a weight-carrier as a machine of the conventional type, but for many purposes its comparative lack of efficiency in this respect may be more than compensated by the safety of its operation. We are now examining the theory of the autogiro in more detail, in order to find out whether there are any unusual conditions of flight when it may become unstable and dangerous. We have also recommended that model experiments should be made at the National Physical Laboratory to determine accurately the profile drag of the rotor blades.

We have also considered a number of proposals for the construction of cyclogiros or paddle wheel aeroplanes of the Moineau, Platt and Rohrbach types. We have made no detailed analysis of these proposals, but we see no *a priori* reason to disbelieve the claims that such machines can give adequate lift and thrust, can permit of safe landing in the event of power unit failure, and can be made stable and controllable at any forward speed. It seems to us probable that the difficulties in the way of producing practical machines of these types are difficulties of construction rather than of aerodynamics.

ENGINES

In previous reports we have referred to the development of single sleeve valved water-cooled cylinders by Messrs. Ricardo and Company. This work led to the conclusion that the replacement of the conventional poppet valves by a single sleeve valve in each cylinder would increase the efficiency of aircraft petrol engines; but the practical difficulties of producing a satisfactory air-cooled sleeve valved engine appeared to be great. During the year the Bristol Aeroplane Company Ltd. has nevertheless been successful in building a reliable air-cooled sleeve valved radial engine, the performance of which has confirmed the results of the researches with single cylinders. We were particularly interested to learn that the construction of engines of this type was likely to be cheaper than that of poppet valve radial engines, owing to the smaller number of parts required. The illustration in Figs. 3 (*a*) and (*b*) shows the number of parts of a poppet valved and sleeve valved cylinder of a radial engine.

The sleeve valved engine is peculiarly suitable for high supercharging, and now that the chief constructional difficulties have been overcome we look forward to its use on an extended scale.

Mr. Ricardo has continued his experiments on compression-ignition engines of the sleeve valve type. A two-stroke single cylinder unit has satisfactorily completed a 50-hour endurance test, and there is now some prospect of its development as an aircraft engine. Experiments have been made with single cylinder units supercharged up to $3\frac{1}{2}$ atmospheres intake pressure; these will be continued and extended in order to provide data of use to designers.

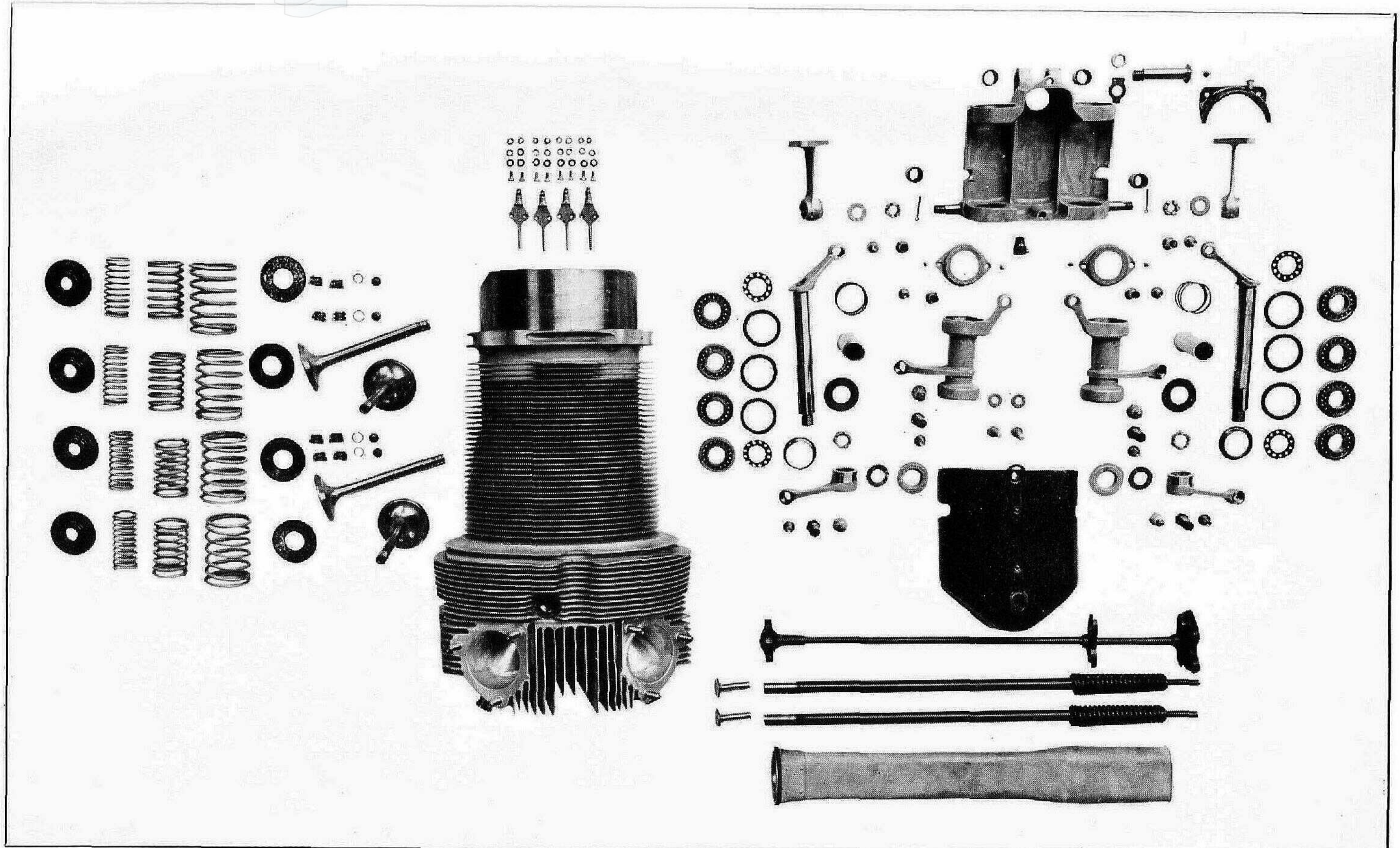

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FIG. 3a.—The parts of a poppet valved cylinder of a radial engine.

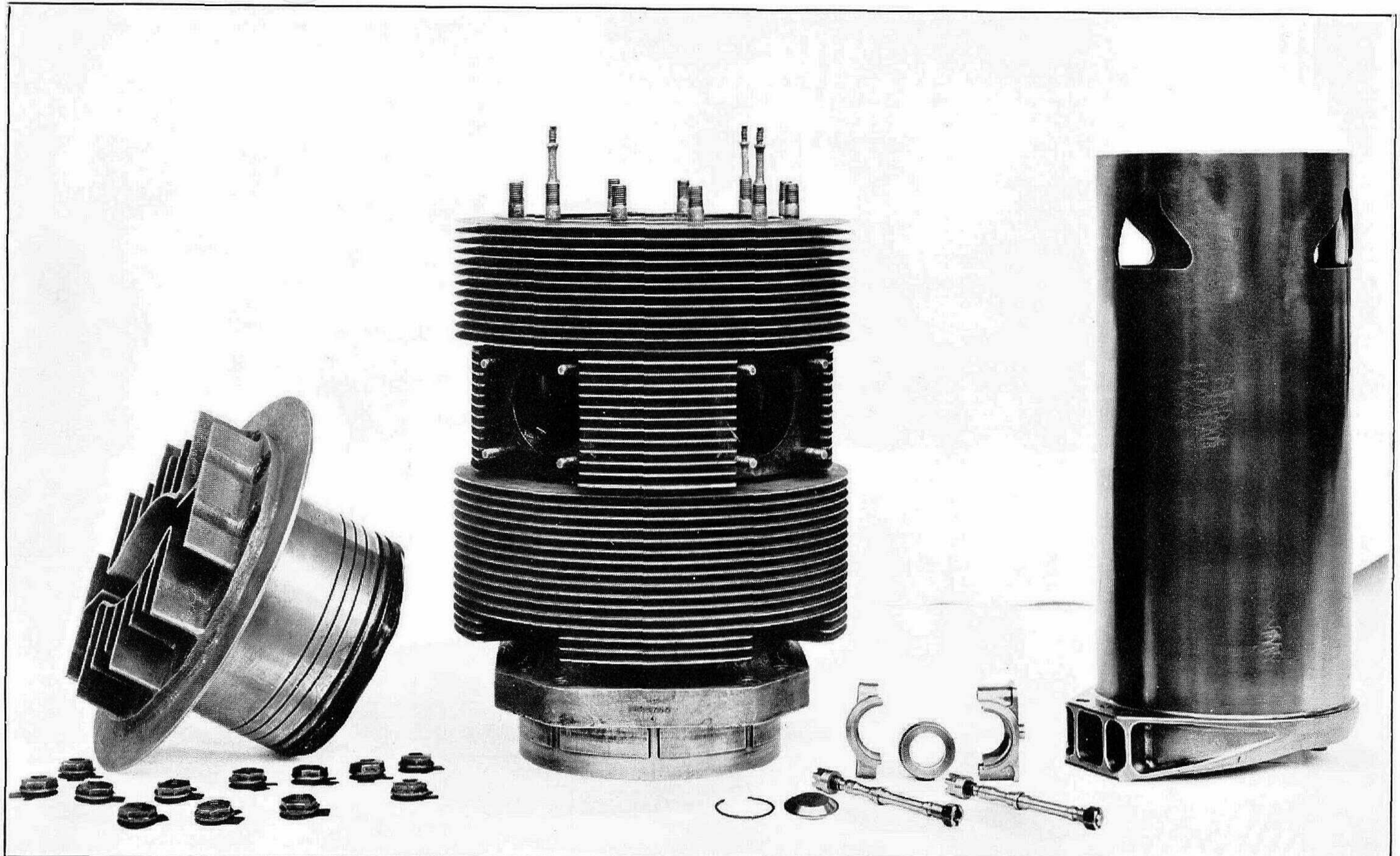

FIG. 3b.—The parts of a sleeve valved cylinder of a radial engine.

Consideration has been given to proposals for replacing carburetters in petrol engines by injection pumps. It is claimed that better fuel distribution would thereby be secured, and consequently lower fuel consumption. It is also claimed that the use of fuel pumps would do away with all difficulties of ice formation in carburetters. Experiments carried out at Farnborough indicate that a properly designed carburetter is likely to give just as good results as a system of injection pumps so far as fuel consumption and full throttle performance are concerned, and that ice formation in carburetters may be prevented by the use of comparatively simple devices. In view, however, of the importance attached by some designers to the development of injection pumps, further experiments on lines suggested by them are in progress.

Lubrication.—We have discussed the programme of work on lubrication with representatives of operating and manufacturing companies. It appears that there is considerable scepticism as to the value of the Air Ministry specification for lubricating oils ; although the difficulty of providing an improved specification is fully realised. It is claimed by some experienced designers that better lubrication can be obtained with oils which would be rejected under the Air Ministry specification, and also that oils which fall within the specification differ greatly in their properties. We are taking steps to have these criticisms properly examined, and it would be a great help to us if samples of oils believed to have specially good or specially bad properties were sent in for examination.

Special attention has been given during the year to the prevention of excessive oxidation of oils, and to the formation of gum on cylinders and piston rings. Experiments at the Royal Aircraft Establishment have indicated the possibility of delaying the formation of gum by the addition of inhibitors to the oil. We have recommended that the efficacy of such additions should be determined by full-scale experiments over a considerable period of time.

We propose to pay more attention during the coming year to the prevention of the formation of sludge in lubricating oils, as this appears to be giving difficulties in modern engines, particularly when supercharged.

General Research.—A full account of the work of Sub-Committees is given as usual in the Technical Supplement. We should like to draw attention here to some of the more fundamental aspects of this work to which reference has not already been made.

It is well known that the behaviour of aircraft in flight cannot always be predicted accurately from experiments in wind tunnels ; and it is of great importance to get closer agreement between model and full-scale results. The lack of agreement is due partly to the existence of micro-turbulence in the air of the tunnel. This micro-turbulence is, of course, quite distinct in nature from the large-scale atmospheric turbulence to which we have referred previously in discussing the effect of gusts on aeroplanes. In free normal flight it is likely that, although the air is seldom, if ever, free from turbulence, the forces on the aeroplane are not substantially affected by the degree of turbulence that exists when the weather is calm. It is very difficult to construct a large wind tunnel that is free from micro-turbulence, so that it is desirable to be able to measure accurately the amount that exists.

In all wind tunnels considerable variations in velocity can be detected by a hot wire and seem to be of a random character. Both the free air flow and a regular eddy system behind a grid of slats placed in an air stream have been explored in this manner. In each the law of variation appears to be the same and follows what is known as the "law of normal errors". The same result has been obtained by the use of hot particles of air created by spark discharges and viewed by a special optical method. These investigations have clearly demonstrated an important experimental fact which is independent of any theory and which justifies a statistical treatment of turbulence.

Two methods for measuring turbulence in wind tunnels have been developed. In one of these methods local eddies are measured by observing the movement of small particles with an ultramicroscope; in the other by observing the changes of temperature of a thin hot wire. The results from the two methods are not in complete concordance and further investigations are being made.

Satisfactory progress has been made with the memoir on fluid motion and the theory of the boundary layer, and we hope it will be published before our next report is issued.

An interesting research on combustion in petrol engines has been conducted under the direction of Mr. A. C. Egerton at Oxford University. By the use of a specially designed sampling valve it has been possible to analyse the cylinder gases at various stages of the combustion, and so to obtain more accurate details of the process of combustion than has been possible heretofore. It has been shown how the nature of combustion changes when knocking occurs, or when inhibitors are added to suppress knocking altogether. A paper embodying the results of this work has been offered to the Royal Society.

General researches on materials have continued as in previous years. The influence of atmospheric conditions upon the fatigue strength of a number of materials has been investigated by tests in air and in vacuum. Fatigue under systems of combined stresses has also been investigated. This work is difficult, and we are a long way from learning what are the exact conditions which cause materials to break under fatigue.

Some research on impact testing has been carried out under the direction of Professor Southwell at Oxford University. The results of this work have been published elsewhere.

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RELATIONS WITH OTHER BODIES

As in previous years, we have held meetings with representatives of the Society of British Aircraft Constructors. We wish to express our indebtedness to the firms and their chief designers for the valuable assistance they have given upon general matters and upon a number of special problems that have been discussed with them during the year.

We have been in touch with the Aeronautical Departments of the Governments of Canada and Australia.

We have again had the pleasure of welcoming Dr. J. S. Ames, the Chairman of the National Advisory Committee for Aeronautics, U.S.A.

Contact with other workers in aeronautical science all over the world is attempted and publications and visits are exchanged when possible.

Signed on behalf of the Committee

H. T. TIZARD

Chairman.