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AERONAUTICS

# TECHNICAL REPORT
OF THE
# AERONAUTICAL RESEARCH COMMITTEE

## *for the Year 1937*

VOL. I

Aerodynamics General, Performance, Airscrews, Flutter and Spinning



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* This R. & M. is a collection of abstracts of papers published in full in outside journals.

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*December* 1937

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# AERONAUTICAL RESEARCH COMMITTEE

## *Report for the Year* 1937

*January*, 1938

The Right Hon. the Viscount Swinton of Masham, G.B.E., M.C.,
Secretary of State for Air.

My Lord,

We, the Aeronautical Research Committee, beg leave to submit our report for the year 1937.

During the past year much of our time has been spent in the consideration of problems of stability and control, cooling of engines, and reduction of drag of wings. We propose to describe briefly the nature of this and other work with which we have been concerned. Further details are given in the appendices to our report.

*Wing Drag.*—For some years the drag of aeroplanes has been steadily diminishing as designers have discovered improved methods of avoiding features which tend to produce large eddies. This trend has now gone so far that further progress on these lines is becoming increasingly difficult, and attention has been turned towards the resistance due to skin friction. The energy wasted from this cause is dissipated through the agency of much smaller eddies than those referred to above, but at the same time these small eddies account for a large part of the total wastage of energy with which the total drag is associated.

The most convenient way of estimating the drag due to skin friction is to make experiments on wing surfaces. The study of wing drag is being carried out both on models in the laboratory and on the full scale in flight by exploring the wake of air which is set in motion by the drag of the wing passing through it. This exploration, called a pitot traverse, has been described in a previous report. It has now been used to measure the effect on wing drag of rows of rivets of several types and in various positions on the wing.

When all obstacles to smooth flow (such as rivets) have been removed, the wind stream close to the wing is found to be free from small eddies over the forward portion but eddying over the rear of the wing. The position of the point of transition where the change from smooth to eddying flow occurs has an important bearing on wing drag. The further back the transition point can be induced to go the less, in general, is the drag of the wing. For this reason attention is being concentrated on the factors which affect transition. Simple methods have been developed for finding the transition point, on a wing in flight and in the laboratory. The location of the transition point, used in conjunction with a pitot traverse, is proving a powerful method in research designed to reduce wing drag.

It has long been known that the turbulence in a wind tunnel may have a pronounced effect on the drag and on the maximum lift of a model. For this reason and also for its intrinsic scientific interest turbulence in wind tunnels and in the atmosphere is now being studied in greater detail than in the past. Until recently only the magnitude of the fluctuations in wind velocity were seriously studied: methods have now been developed for measuring the other elements which define the eddies. We can now measure their size and frequency and find whether they are longer than they are broad or vice versa. Such questions have an important bearing on the relation between models tested in a wind tunnel and full scale aeroplanes in flight.

*Engine Cooling.*—The constant effort to reduce aeroplane drag has resulted in the attainment of much higher speeds for a given expenditure of power, and has caused increasing attention to be focussed upon the amount of power wasted in cooling the engine. In fact this amount appeared at one time likely to determine the limit of possible speed. Cowlings were therefore introduced with air-cooled engines with the object of limiting the velocity of the air past the engine cylinders, the cowling being designed to provide adequate cooling on the climb. With this arrangement, when the speed exceeded the climbing speed the engine was overcooled and power was wasted. With liquid-cooled engines the case was better, since by retracting the radiator as the speed increased a saving in the drag was made possible although the power expended on cooling still increased. This increase was due to the higher air velocity past the radiator, it being more economical to cool by large surfaces over which air passes at comparatively low speeds than by small surfaces cooled by a high velocity air stream.

With these principles in mind, and guided by the general theory of air flow and heat transfer, many experiments have been made on the best way of slowing up the air before it reaches the cooling surface. Both the air-cooled engine and the radiator of the liquid-cooled engine have been enclosed in a passage or duct formed by a suitably shaped cowling. By varying the exit area of this duct it has been found possible to control the cooling flow and so to maintain the power absorbed in overcoming drag at a nearly constant value at all speeds. Moreover there is a further possibility in this scheme, since the addition of the heat from the engine to the air provides a source of energy, part of which is converted into useful work at the duct exit and thereby furnishes a thrust which balances some of the cooling drag. As the speed of aircraft increases it should eventually be possible for this useful work recoverable from the cooling air to be sufficient to eliminate the cooling drag entirely, or even to provide a positive thrust.

In practice non-essential losses are associated with every design of cooling system, and the problem now is to reduce these losses. The liquid-cooled engine presents the less difficult problem, because the cooling surfaces can be put in any convenient position, thus simplifying duct design. With attention to detail many of the special difficulties of the air-cooled engine installation can be overcome, and if engines could be completely buried in the wing it should be possible to reduce the losses in either the air- or liquid-cooled arrangements to almost negligible proportions.

The results of this work have been successfully embodied in recent civil and military aeroplanes.

*Stability and Control.*—The use of much higher wing loadings has been an important factor in the achievement of the higher speeds of recent designs of aircraft. Different arrangements of wing flaps to reduce the high landing speed associated with high wing loading have been tested, and various methods of approach and landing have been studied.

Since the limit to the further increase of wing loading is largely fixed by the possibility of bringing the aircraft down on to the ground at the highest speed consistent with a reasonable measure of safety, the qualities of control and stability necessary to achieve this are a matter of the first importance. A number of firms have, through the Society of British Aircraft Constructors, contributed information of great value in attacking this difficult and subtle problem.

Before this work on stability and control on broader lines had been started, a questionnaire on the longitudinal stability characteristics of monoplanes which was circulated to the Industry in 1936 met with an encouraging and informative response, and an analysis of the replies received points to certain broad conclusions which are now being considered. On the average it was found that the centre of gravity on the modern type of monoplane had to be well forward of the position found satisfactory in older types of aircraft. In these older types the sizes and positions of the wing and tail primarily determined the longitudinal stability, but on the newer highly loaded monoplanes the relatively large well-streamlined body and engine nacelles are responsible for part of the destabilising effect which has been observed, and it is believed that slipstream accounts for some of the discrepancies observed between estimates and full scale results.

As speeds increase, wings, particularly of the unbraced monoplane type, become liable to "flutter". As its name implies, fluttering is a rapid and dangerous vibration of the structure usually leading to partial or total collapse. One among several methods which can be adopted to prevent wing flutter is a modification of the aileron control system such that, while the pilot is free to move the ailerons in the ordinary way, the ailerons are locked against any movement by the air forces on them. This "irreversible" system, fitted to a "Fury", as mentioned in last year's report, has now been tested under blind flying conditions and we consider that aerodynamically the control is entirely successful. The outstanding difficulty has been the mechanical one of providing a satisfactory irreversible gear, and the problem has been put to a firm with experience in the design of hydraulically operated mechanisms.

An item of urgency remaining from last year is the development of a device to replace conventional ailerons as a means of lateral control. Ailerons, quite apart from their well-known shortcomings near the stall, are giving rise to difficulties which become increasingly severe as speeds rise. These difficulties include loss of control due to wing twist, the very close balance needed under modern conditions, and the possibility of flutter. Some while ago the advent of full span high-lift flaps directed attention to the solution of this problem: now, with the success achieved by the partial span flap, the need for a device replacing ailerons springs from other sources.

Tests on a "Moth" fitted with a new type of control known as a "spoiler" have produced encouraging results. In this type of control the use of any form of trailing edge flap is avoided, and in order to roll the aircraft a small shutter operated by the control stick is caused to project from the upper surface of one wing tip near the leading edge; this "spoils" the air flow, causes a loss of lift at one wing tip, and produces the required rolling. We consider that the troubles experienced with lag in operation can be overcome, and we recommend that further development of this device be undertaken.

*Other Matters.*—In addition to the problems dealt with above, we have considered during the year a number of matters to which brief reference only will be made.

High speed flight is introducing new problems, involving examination of the effects of compressibility of the air, of which only the fringe has been touched and for which new apparatus has been and is being provided.

The take-off of heavily loaded aeroplanes has become a problem of great importance. We have examined it from many aspects, including the design of airscrews, the effect of proximity of the ground, and artificial aids for shortening the length of run. Some compromises in the design of airscrews are necessary, and the blade section which is more efficient at low speeds of advance does not reach maximum efficiency at the top flying speed.

The theory of fluid motion as applied to aeronautics has been further developed, particularly as applied to wings, and an important section of the work of the Fluid Motion Panel has been the preparation of the Memoir on " Modern Developments of Fluid Dynamics " under the editorship of Dr. Goldstein.

We have mentioned above the consideration of the use of irreversible controls which may help greatly in the elimination of flutter. Flutter usually occurs at some definite critical speed which should be greater than the highest speed attained by the aircraft in flight. We have made estimates of critical flutter speeds over a range of variables covering modern practice and have measured in the laboratory the forces on an oscillating aerofoil. The results of this work are being used by the Airworthiness Department of the Air Ministry.

A number of measurements have been made in connection with the strength of flying boat hulls and with the strength and stiffness of stressed skin structures : both theoretical and experimental work have provided information of value to the designer.

The properties of certain alloys have been studied and their welding properties investigated. In relation to engine development consideration has been paid to air intercooling problems arising from the increase in the compression ratio of superchargers. An instrument has been devised which simplifies the measurement of the intensity of detonation.

The general properties of materials have been mainly discussed in the past by the Elasticity and Fatigue or by the Alloys Sub-Committee. The position regarding researches on materials is however undergoing a change, and much new knowledge on atomic structure, particularly of metals, has been accumulated in recent years. New problems are coming forward for solution, and some of these have been discussed at two meetings to which a number of persons not normally connected with the Committee have been invited.

*Work at Universities.*—Professor Jones is continuing his work at Cambridge University on the location of the transition point and allied problems. Professor Taylor is pursuing his study of turbulent flow and has aided the Committee in discussions on the strength of materials. Dr. Goldstein has communicated various papers to the Fluid Motion Panel. Dr. Howarth continues to assist on work on fluid flow, largely in collaboration with Dr. Goldstein. Professor Hartree is solving with his differential analyser a particular problem of the boundary layer equation, and the Committee has assisted his work with a grant. Dr. Hume-Rothery of Oxford University has continued his study of the alloys of magnesium, also with the aid of a grant from the Committee. Miss Lyon, until her appointment to a post at the Royal Aircraft Establishment, collaborated with Dr. Duncan of University College, Hull, on the investigation of flutter.

Our attention has been drawn to the researches in meteorology which are undertaken with success at many foreign universities. Apart from that at London University there is no professorship of meteorology in this country and there is no school adequately equipped and maintained for meteorological research. We wish to express our view that greater provision should be made for this increasingly important subject.

*Aircraft Industry.*—We have maintained our close contact with the aircraft industry and have had a number of meetings with representatives of the Society of British Aircraft Constructors on special subjects. We have also held a meeting with representatives of the aircraft operating companies, who brought forward a variety of questions for discussion. Many of these were considered scarcely to fall within the province of the Committee, and we are glad to learn that a clearing house for information on questions affecting civil aviation has now been established through which contact with the operating companies on technical questions will be maintained. In future, therefore, instead of our yearly meeting with the operating companies, any problems of a research character put forward by them will be referred to the Aeronautical Research Committee through the department of the Director-General of Civil Aviation.

*Personnel.*—Mr. H. E. Wimperis, who was appointed Director of Scientific Research in 1925, retired during the year. We part from him with great regret and we take this opportunity of expressing our thanks to him for his invaluable co-operation over a period of 12 years, during which he has had the satisfaction of seeing the research organisation of the Air Ministry grow under his direction to its present state of activity and efficiency. The news that Your Lordship had appointed Mr. D. R. Pye as his successor and Mr. W. S. Farren as Deputy Director of Scientific Research was received by us with great satisfaction. We wish them all success in their important offices.

Signed on behalf of the Committee,

H. T. TIZARD,
Chairman.