

scholarships should be established. This might be supplemented by the payment of small salaries in respect of periods passed in the research establishments or in aircraft works.

Organisation of the Higher Education in Aeronautics.

16. The specialised or post-graduate training of the kind which has been described in the previous paragraphs should, in our view, be organised on an entirely different basis from the undergraduate training. The latter, as we have shown, can and should be provided in existing organisations of University rank in various parts of the country. Post-graduate training, however, to be complete, requires access to aerodromes and to research stations fitted with technical equipment, and it would be, we think, impracticable under present conditions to try to provide completely for this highly specialised training at more than one centre.

The financial saving through the avoidance of duplication of research and other facilities necessary to the higher grades of education is obvious. It is also relevant that whatever the future developments of air transport may be, the number of posts for which men of the higher standard of training are required will be limited; and that men possessing the combination of theoretical aptitude and practical ability needed to profit by the highest kind of professional training are not numerous. Before the War the total yearly number of honours graduates in engineering, including civil, mechanical, electrical engineering and naval architecture, from all the Universities in the United Kingdom was not high, and only a fraction of the future number are likely to devote themselves entirely to aeronautics.*

17. In connection, however, with the question both of undergraduate and post-graduate education, we would remark that the demands for the courses provided must depend considerably on the policy of the Government for the filling of such higher technical appointments as may be required by the Air Force or by the Air Ministry, or whatever Department becomes responsible for the regulation of civil aviation. If technical appointments are thrown open to competition among graduates (as is done, for example, with the medical branches of the Naval and Military Services) the demands for the training provided in the University courses will be greater than if the State itself trains youths selected at an early age.

18. The Zaharoff Professorship of Aviation supplies the nucleus of the single organisation which we think is desirable for the direction of higher education in aeronautics. This Professorship was established as the result of a benefaction to the British Government by Sir Basil Zaharoff, G.B.E., and it has been arranged between the parties concerned that it should be established as a Professorship of the University of London and held at the Imperial College.

In our opinion the Imperial College should become the central school for advanced study in aeronautical science, and we have, in the later sections of the report, described an organisation for teaching and research whereby this might be secured.

19. It is clear that it would exceed the powers or abilities of any single teacher to cover all or many of the various fields of knowledge which are comprised under the general term of aeronautics. The appointment of additional teachers and the organisation of the Department of Aeronautics should be effected with the fullest regard to the resources which the Imperial College already possesses for providing instruction in interdependent subjects such as physics, mathematics and engineering.

20. The teaching personnel of the actual Department of Aeronautics should, we think, comprise professors or lecturers qualified to provide advanced instruction as regards aeroplanes, seaplanes, airships, and kite-balloons in the following subjects: (1) aerodynamics, i.e., the laws of motion of bodies moving in the air, (2) aero-engines and methods of propulsion, (3) design, including structure and materials in so far as these could not be treated apart from the principle of design of aircraft in the engineering and other departments of the college, (4) meteorology, instruments and navigation.

21. We consider that it is of importance that the same staff should to a great extent deal with both education and research, including much of the research directly required by the Government as well as that directed more especially to the advancement of the theory of flight. The expense involved in aeronautical research and the limited number of men competent to undertake it both lead to this result, which is in our view in itself desirable. We discuss this question in greater detail in Sections 49-52 of our Report.

Research in Aeronautics

22. The establishments which will be required to provide the facilities for the different aspects of research in aeronautics fall under five divisions:— (1) Model research; (2) full scale research; (3) testing and experimental investigation; (4) special investigations connected with airships and kite-balloons; (5) navigation and meteorology.

Model Research

23. This includes model work in connection with aeroplanes, with seaplanes and with airships (rigid and non-rigid airships and kite-balloons). The model research work under these heads is at present carried on at the National Physical Laboratory and also to some extent at the Royal Aircraft Establishment.

The fact that under the arrangements we propose research work at the National Physical Laboratory and the Full Scale Research Establishments will be undertaken in co-operation with the Aeronautical Research Committee should remove any lack of touch which might exist between those responsible for model work and those conducting full scale investigation. The National Physical Laboratory also contains facilities for research in allied sciences.

Full Scale Research and Experimental Investigation.

24. This work comprises research undertaken to investigate general principles and laws, and is at present mainly represented by the experimental side of the Royal Aircraft Establishment. During the War full scale research on seaplanes was mainly conducted by the Technical Department of the Air Ministry at the Isle of Grain and at Felixstowe, that on airships by the Admiralty at Kingsnorth and Pulham, while kite-balloons were investigated at Roehampton.

The Royal Aircraft Establishment and the aerodrome attaching to it are Government property, and it appears to us that suitable provision might be made either there or possibly at some other aerodrome near London for the full scale work which is essential to our scheme. Adequate facilities for the scheme already exist at Farnborough along with other facilities for production work. We therefore recommend that such portions of the establishment

* Vide paragraph 24 of the Final Report of Special Committee No. 5 of the Civil Aerial Transport Committee:—"As outlined above, the specialised training of the aeronautical engineer would be a post-graduate course, and the question arises as to the nature of the institutions at which such courses should be organised. It has already been pointed out that, whatever the development of the industry may be, the number of posts suitable for men of the highest standard of training is necessarily limited, and it is equally obvious that men possessing the combination of theoretical aptitude and practical ability required to profit by such a training are not numerous. Before the War, the total yearly number of honours graduates in engineering, including civil, mechanical, electrical engineering, and naval architecture, etc., from all the universities in the United Kingdom averaged about 200.

as are required for our purpose should be made available for researches, under the supervision of the organisation described in the Report.

Under such an organisation the research work at the Royal Aircraft Establishment should, we suggest, come under the following heads:—

(a) Experimental work for the advancement of aeronautics generally. The results should have open scientific publication, and participation in the experimental work should be among the educational facilities available at the establishment; (b) specific experimental work undertaken at the request of a Government department. The publication of the results of the work would be a matter for the Government to decide; (c) certain specific experimental and testing work on payment for the industry.

The establishment at Farnborough could not, of course, meet completely the need for full scale research and experiment on seaplanes and on airships, much of which must continue to be carried out elsewhere. But while this is so, there are many problems common to all kinds of aircraft which could be dealt with at Farnborough.

Special Investigations connected with Airships and Kite-balloons

25. Full scale work on airships has been mainly carried on at Pulham Air Station, while kite-balloons have been dealt with at Roehampton, the model work, as in the case of aeroplanes and seaplanes, having been mainly done at the National Physical Laboratory. Here again arrangements must continue for full scale work to be carried on at some station possessing suitable facilities. Arrangements could, no doubt, be made for such investigations to go on under the supervision of the research organisation.

Navigation and Meteorology

26. The administration of the Meteorological Office has recently been placed under the Air Council, and we are glad to learn that the revision of the arrangements for the meteorological services which has now been carried through will be to the advantage of aviation, not only in respect of the collection and dissemination of meteorological information, but also in the furtherance of meteorological research.

The study of navigational problems, it may be remarked, has not been developed by the War to the same extent as some other aspects of air technology. The increasing range of air travel serves to emphasise the need for the fullest development of experiment in these directions, and the introduction of aerial transport on a civil basis will greatly enlarge the demand upon both practical and theoretical meteorology.

Testing and Experimental Investigation

27. This class of work, as apart from that referred to in Section 24, is at present represented by Martlesham Heath. It includes the determination of the performance of machines; tests of the efficiency of particular engines, and of minor modifications of machines and engines as affecting efficiency. This class of work may also include testing of typical machines to conformity with specification, as well as strength testing to destruction. A station of this character is required in view of the provisions of the Air Navigation Act.

Interests concerned in Research

28. We now turn to an enumeration of the different interests concerned in the conduct of aeronautical research—in varying degrees, but in all cases to a sufficient extent to require some voice in its control. They are (a) the State as responsible for the maintenance of the armed forces of the Crown by land, sea, and air; (b) the aircraft industry as constructors and as operators; (c) education—and in particular the organisations providing higher education; and (d) the State as the regulating authority for civil aerial transport.

Military Interests of the State

29. The scope of the State's responsibilities will be based on the future requirements of national defence, and it is probable that the aerial defence of the country will not be less important than naval and military defence of sea and land. Under present conditions, however, there is nothing to suggest any basis of expenditure on fighting aircraft either absolute or in proportion to expenditure on the Navy and Army.

30. We desire, however, to refer to one factor which seems to us of the first importance in the determination of the State's responsibilities as regards provision for research. In the pre-war Naval Estimates between one-third and one-half of the total vote was allocated to new construction, research and experimental work forming only a small incidental item. The larger naval units take a number of years to build. For that reason only a relatively small increase of effective construction can be brought about after a declaration of war; and supremacy, other things being equal, would be decided by the number and quality of the units available at the outbreak of hostilities. In the case of aircraft, however, the experience of the present war has been that a given type is becoming obsolete by the time that it is in general use. This applies essentially to the fighting scout machines, in a lesser degree to other types, and least of all to airships.

Regard must also be had to the high rate of wastage of aircraft under war conditions. There is, moreover, the liability of machines kept in store to become unfit for use, which makes it difficult (apart from financial considerations) to maintain a large peace reserve of machines.

The final supremacy in the air in any future war will thus depend not mainly on the number of units available at the outbreak of hostilities, but on the adequacy of the preparation made beforehand for the rapid construction of the newest and best types.

31. This preparation, so far as it might take the form of administrative arrangements for the maintenance of equipment for large emergency production, is not within the terms of our reference, but it is clear that such preparation must in any event imply the ordered availability of (a) general scientific knowledge accumulated by systematic research, (b) detailed information with regard to all available types, (c) a liberal construction (not necessarily by the State itself) of experimental machines.

It is relevant also to observe, in connection with the organisation both of research and education, that any emergency expansion of production which might be required by a future war must be directed by a body of technical experts who could not be improvised after the emergency had arisen.

The Aircraft Industry as Constructors and as Operators.

32. Economic and Imperial considerations alike emphasise the importance of securing that the aircraft industry of this country should be so organised as to maintain a supremacy against all competitors from other countries, and it is obvious that generous provision for scientific research is necessary for the efficiency of an industry so highly technical and scientific as that of aircraft construction.

It is, however, improbable that individual firms of designers or constructors could provide themselves with the research facilities which will be required. This is clear both from considerations of expense and of the insufficiency of men competent to undertake research work. The conduct of research on an individualistic basis, even if it were otherwise practicable, would involve a great deal of overlapping, and though it might enable individual firms to compete with each other, would not necessarily or even probably secure that their scientific resources would be organised in the best way to meet competition in international markets.

33. The formation of an Industrial Research Association, which is under consideration, implies a recognition of these facts. Such an organisation, which should embrace within its membership all the leading firms of aircraft