Ministry of Aircraft Production

A COLLEGE OF AERONAUTICS

Report of the Interdepartmental Committee on the Establishment of a School of Aeronautical Science

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Mr. R. G. R. Goldby, A.F.R.Ae.S., Ministry of Aircraft Production, Technical Secretary.

Terms of Reference

To prepare and submit to the Minister of Aircraft Production detailed proposals for the establishment of a School of Aeronautical Science within the general framework of the recommendations made by the Aeronautical Research Committee in their report of the 10th August, 1943, to the Minister.

* Note.—Air Commodore H. Gordon-Dean, A.F.C., Director of Technical Training, attended the later meetings of the Committee as an additional Air Ministry representative on technical questions.

† Note.—Sir Walter Moberly resigned on 9th February, 1944 (see paragraph 3).

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I. INTRODUCTION

1. We were appointed in October, 1943.

> " To prepare and submit to the Minister of Aircraft Production detailed proposals for the establishment of a School of Aeronautical Science within the general framework of the recommendations made by the Aeronautical Research Committee in their Report of the 10th August, 1943, to the Minister."

2. In a letter of the 7th October, sent to the Chairman on your behalf, the Permanent Secretary of the Ministry indicated certain matters with which we should deal specifically. In a further letter to the Chairman, dated 21st December, 1943, you were good enough to grant us some discretion in departing from the recommendations of the Aeronautical Research Committee if, on examination, we came to the conclusion that such departure was desirable.

3. On the 9th February, Sir Walter Moberly intimated his resignation from the Committee. By then the University Grants Committee had been reconstituted to include Sir Charles Darwin, another of our number, and it was felt to be unnecessary for that Committee also to be represented by a separate member, especially as it has already become probable that we would recommend that the College * should not be affiliated to any university.

Proceedings and Evidence

4. At an early stage we decided that it would be an advantage if representatives of the Dominions would attend some of our meetings in order that the needs of their students and their point of view should be given full weight at the stage when proposals were being formulated. Invitations were issued, therefore, and the following have taken part in our discussions and given us valuable help :

Canada : Air Vice-Marshal N. R. Anderson,
Wing Commander R. J. Brearley,
Dr. A. G. Shenstone.

Australia : Mr. H. E. Wimperis, C.B., C.B.E.

New Zealand : Mr. L. Poole,
Dr. I. E. Coop.

South Africa : Mr. E. K. Scallan,
Major A. H. Fish.

5. We appointed a Sub-Committee, consisting of the Chairman and Dr. Abbott of our number, Air Commodore H. Gordon-Dean, and two alternate members, Captain Jameson and Professor Duncan, which prepared for us a report on the subjects of instruction and the organisation required for teaching them.

6. In considering possible sites for the College we have been advised by the Air Ministry and we are grateful for the help of Air Vice-Marshal Pirie, C.B., C.B.E., M.C., D.F.C., Director General of Organisation, and the other officers concerned. In considering the lay-out of buildings, we have been advised by the Ministry of Works and we acknowledge the valuable assistance given to us, in preparing plans and estimates and in advising generally on building matters, by Sir Hugh Beaver, Mr. Brian H. Colquhoun and other officers of that Department.

* We use the term " College " throughout (see paragraph 106).

7. We are deeply indebted also to the following who prepared and discussed with us the detailed memoranda on the organisation and equipment of the several departments :

Aerodynamics (Appendix 4) Aircraft Structures, Engineering and Design (Appendix 5)	Dr. N. A. V. Piercy, M.Inst.C.E., F.R.Ae.S., M.I.Mech.E., M.Cons.E. and Dr. H. Roxbee-Cox, B.Sc., D.I.C., F.R.Ae.S., Ministry of Aircraft Production.
Engines and Systems of Propulsion (Appendix 6).	Mr. N. S. Muir, B.Sc., A.F.R.Ae.S., Ministry of Aircraft Production.
Aircraft Equipment (Appendix 7)	Mr. C. G. A. Woodford, A.M.I.E.E., A.F.R.Ae.S., Ministry of Aircraft Production.
Production and Maintenance (Appendix 8).	Mr. W. A. Sales, O.B.E., Ministry of Aircraft Production
Flight and Operations (Appendix 11)	Mr. P. W. S. Bulman, C.B.E., M.C., A.F.C., F.R.Ae.S., Hawker Aircraft Ltd.

In addition, Dr. Abbott, one of our number, and Mr. Goldby, the Technical Secretary, prepared the memoranda on the sections dealing with Administration and Materials respectively (Appendices 9 and 10).

8. We have obtained and taken into account much information on the comparable American institutions such as the Massachusetts Institute of Technology, and the Daniel Guggenheim School of Aeronautics of the California Institute of Technology, Pasadena. One of our alternate members, Mr. Farren, happened to visit the United States during our inquiry and informed us further on the American practice in regard to some matters of particular interest. We have obtained information regarding the facilities for the study of aeronautics in this country, in the universities, university colleges and technical colleges, and in the Service colleges. We also had the benefit of the views of a number of those responsible for training schools operated by leading firms in the aircraft industry.

9. The Society of British Aircraft Constructors and the Royal Aeronautical Society submitted to us memoranda on the general question of setting up a College of the sort recommended by the Aeronautical Research Committee. We obtained comments on the Aeronautical Research Committee's Report from nine experts on technical education in aeronautical and kindred subjects. We were furnished with the views, on several aspects of our inquiry, of certain American experts who, because of their eminence and number, might fairly be taken as authoritative representatives of American thought on aeronautics. A list of those who furnished written evidence is given in Appendix 1.

10. We have heard oral evidence from representatives of the Services, the aircraft industry, certain associated industries, the British Overseas Airways Corporation and experts on particular subjects. A list of all who assisted us in this respect is given in Appendix 2.

11. The Chairman, on our behalf, made a number of visits to obtain, at first-hand, knowledge of certain institutions and the views of individual experts. Our Sub-Committee, in order to study the requirements of the industry, paid instructive visits to three of Messrs. A. V. Roe & Co.'s factories and to a factory of Rolls Royce Ltd. Some of us, too, have inspected a number of the airfields that seem possible sites for the College.

12. We wish to record our indebtedness to our Secretary, Mr. N. W. Graham, who has ably summarised our lengthy discussions and prepared this Report with great care and thoroughness. We wish also to acknowledge the services of Mr. R. G. R. Goldby, who, as Technical Secretary, prepared for the Committee many technical documents and co-ordinated the preparation of the memoranda on the equipment of the Departments.

13. We have used to a considerable extent our discretion in interpreting our terms of reference, as regards " the general framework of the recommendations made by the Aeronautical Research Committee." The fact that we have made departures is not to be regarded as in any way a criticism of that Committee. Their report, which is summarised in Appendix 3, was prepared at relatively short notice and without the opportunity fully to survey the field. We have found it a good foundation on which to build.

14. We have held 16 meetings of our full Committee and now beg to present our Report.

II. SUMMARY OF RECOMMENDATIONS

15. (i) The primary purpose of the College should be to provide a high-grade engineering, technical and scientific training in aeronautics to fit students for leadership in the aircraft industry, civil aviation, the Services, education and research (paragraph 21).

(ii) The College should also provide shorter courses for specialists in particular subjects, refresher courses and a general "staff course" aimed at giving a broad knowledge of aeronautics. These courses, especially, should cater for students from industries associated with the aircraft industry as well as for those from that industry, the Services and the other fields referred to above (paragraphs 30–46).

(iii) The College should be planned on the basis of an entry of 50 students annually on a two-years' course and 200 students at any one time on shorter courses, i.e. a total of 300 students at any one time. It should be started, however, on a smaller scale (as to numbers of students, staff, equipment, etc.) and be built up rapidly (paragraphs 47–49).

(iv) The instruction should be at post-graduate level or its equivalent, research should be undertaken by staff and selected students, and attention should be paid to the technology as well as the science of aeronautics (paragraphs 51–59).

(v) The College should not be affiliated to any one university but should collaborate closely with the universities, technical colleges, research establishments and industry (paragraphs 61–65).

(vi) There should be five main subjects: (a) Aerodynamics, (b) Aircraft Structures, Engineering and Design, (c) Aircraft Equipment, (d) Engines and Systems of Propulsion, (e) Production, Administration and Maintenance, and there should be a department concerned with Flight and Operations, including full-scale experimental work and flight testing. Adequate provision should also be made for ancillary subjects (paragraphs 69–80).

(vii) The conditions of service of the tutorial staff should be comparable with those of university staffs. Some should hold permanent appointments, others appointments for three to five years (paragraphs 88–96).

(viii) The ultimate responsibility for the College should rest with the Minister of Education but the control should not be meticulous. The College should have a Governing Body of its own, representative of all the interests concerned (paragraphs 103–110).

(ix) The institution should be called "The College of Aeronautics" (paragraphs 106 and 107).

(x) The College should be situated close to its own airfield and within reasonable distance of London and the principal aeronautical research establishment. The most suitable permanent site is Aldermaston, Berkshire (paragraphs 112–114).

(xi) If it is impracticable otherwise to ensure an early start, the adaptation of existing buildings at an R.A.F. Station is recommended. The most suitable Station is Abingdon, Berkshire (paragraphs 115–118).

(xii) Lay-out plans for the permanent buildings and memoranda on the equipment of the Departments are submitted (paragraphs 119–127).

(xiii) The scale of the equipment lies between that appropriate to a university and that for a major research establishment (paragraph 128).

(xiv) The estimated capital cost of the permanent College is £2,610,000. The net annual expenditure to be met by the Exchequer is £360,000. The capital cost of the temporary scheme is £400,000 and the net annual expenditure £200,000 (paragraphs 130–142).

(xv) The establishment of the College is a matter of urgency (paragraph 145).

III. THE PURPOSE, SCOPE AND CHARACTER OF THE COLLEGE

16. **Summary:**

(i) Provision should be made for a higher general training in aeronautics for an entry of at least 50 two-year students annually (paragraphs 24–29).

(ii) There should also be, as an important feature of the College, shorter and specialised courses for a substantial number of students (paragraphs 30–38).

(iii) Students should be accepted from associated industries as well as the aircraft industry itself (paragraph 41).

(iv) There should be a " staff course " providing a general survey of aeronautics for those who do not possess wide technical knowledge (paragraphs 42–46).

(v) The initial planning should be on a basis of 300 students at any one time (paragraphs 47–49).

(vi) The instruction should as far as possible be at post-graduate level or its equivalent. (A University degree is not essential) (paragraphs 51–53).

(vii) Research should be undertaken by staff and selected students (paragraphs 54–58).

(viii) The College should be concerned with technology as well as science (paragraph 59).

(ix) It should not be affiliated to any one university but be closely associated with the universities and other higher institutions, and with the aircraft industry (paragraphs 61–65).

(x) The governing body should be free to modify this conception of the College in the light of experience and having regard to other educational developments (paragraphs 66 and 67).

17. We understand that the Government have accepted in principle that a College should be established to provide higher aeronautical education. We are not concerned, therefore, to demonstrate the need for this College, although our enquiries leave us in no doubt on the subject. It appears necessary, however, to discuss in some detail the scope and purpose of such an institution. This Chapter deals with these matters and also sets out our view of some general considerations governing its character.

Existing Provision for Aeronautical Education

18. It may be useful, by way of preface, to summarise the existing facilities for aeronautical education. For the post-graduate study of aeronautics, the main centre is the Imperial College of Science and Technology, where the instruction is mainly on aerodynamics and aero-engines ; there are also some facilities at Cambridge University and at Queen Mary College, London University. Instruction up to the graduate standard is available at Cambridge, London and Glasgow Universities, at the University Colleges of Hull and Southampton, and at some technical colleges, notably Loughborough College and the Northampton Polytechnic (London). A number of technical colleges provide part-time courses for the Higher National Certificate in Engineering. The total output of qualified students from all these institutions, before the present war, was small.

19. For the Royal Air Force, the School of Aeronautical Engineering, Henlow, provided in peace-time a two-years' course of approximately graduate standard. There was no such provision for the Royal Navy before the present war, but aeronautical subjects have since been introduced in the general engineering course at the Royal Naval College, Keyham.

20. In both Canada and Australia there are University chairs of Aeronautics or Aeronautical Engineering, but there are not, at present, any post-graduate facilities of the sort we have in mind. In South Africa there is a School of Aeronautics attached to the Witwatersrand Technical College but it is concerned mainly with the training of pilots and ground engineers.

Purpose of the College

21. We consider that the purpose of the College, defined originally in paragraph 3 of the Aeronautical Research Committee's Report, might be re-stated in the following terms. Its object should be to provide a high-grade engineering, technical and scientific training in aeronautics for selected students, to fit them for leadership in industry and civil aviation, in the Services (including their technical and scientific administration) and in education and research. Its primary function is therefore to provide efficient and up-to-date teaching over a comprehensive range of advanced subjects and the curricula should include post-graduate courses in subjects of fundamental importance to design, research and development, together with courses at an appropriate level in other subjects vital to design, manufacture and maintenance. Other important functions are: (*a*) the introduction of selected students to research methods and participation in research; and (*b*) the provision of shorter courses in special subjects connected with aeronautics.

Scope of the College

22. In considering the scope of the College, we were bound to have immediate regard to the purposes and numbers of the particular classes of students who might attend. While the College may attract students simply by the excellence of its teaching and facilities and while it should develop in response to requirements as they emerge, it should be designed, at the outset, mainly by reference to all the legitimate needs that are now evident or can be foreseen.

23. To ascertain and assess these needs has proved very difficult. We deal first with the potential demand for the two-years' course referred to by the Aeronautical Research Committee.

Estimate of Numbers of Students on Two-years' Course.

24. The size of the post-war Services and their methods of recruitment and training are unsettled. We have, however, been given tentative estimates by the Admiralty and the Air Ministry of the numbers of officers that they expect to be able to send annually to the College on such a course. We have been given by the Ministry of Aircraft Production an estimate of the needs of the State, in respect of its responsibility for aircraft production and the research establishments. We have also received evidence as to the number of students who might be absorbed in civil aviation, although here also the uncertainty makes forecasting hazardous.

25. The most important factor, however, is the needs of the aircraft industry. The Society of British Aircraft Constructors in their memorandum, pointed out that the extent to which the industry will be employed in post-war years is unknown, but, after consulting a number of airframe and aero-engine constructors, they estimated that the industry could supply, annually, some 50/60 students on a general two-years' course. This estimate relates, we understand, mainly to the airframe and aero-engine constructors and does not

include either the manufacturers concerned with aircraft accessories or aircraft materials or the associated industries with peculiar applications to aircraft such as the oil and the machine tool industries.

26. The Royal Aeronautical Society, taking into account all the needs, put the number of students entering on the two-years' course at 50 to 75 per annum.

27. These estimates are summarised in the following table:

TABLE I

Two-years' course	*Annual number of entrants*
Naval Air Arm	5
Royal Air Force	7
Government Departments and Research Establishments ..	10
Aircraft Industry (SBAC estimate)	50–60
	72–82

(Cf. Royal Aeronautical Society estimate, 50–75.)

28. It will be apparent that these estimates do not cover the whole field. We have not attempted to ascertain the needs of the universities and technical colleges for staff. These will depend on the extent to which such institutions develop undergraduate courses in aeronautical science and engineering but, in any event, they should recruit a number of teachers annually from the students in the College. Nor do the figures take account of students who are likely to come from the Dominions, India or the Colonies, although from our discussions with the representatives of the Dominions, we estimate that at least ten students annually might be expected from these sources. It is likely, too, that the College will attract foreign students, especially from smaller countries which cannot themselves provide such facilities.

29. Even without any addition in these respects, it may be assumed that provision is needed for a higher general training in aeronautics for at least 50 students annually. On the Aeronautical Research Committee's assumption that this course should extend over two years, which seems to us reasonable, this annual entry would give 100 students at any one time. We recommend, therefore, that such a course should be the primary element of the College.

Estimates of Numbers of Students on Shorter Courses

30. The demand for shorter courses is more difficult to gauge; the periods will vary, the field from which students may come is wider and the demand in a particular subject is more liable to increase in proportion to the speed of its development.

31. For the needs of the Services and the State we have been given estimates amounting to about 130 students per annum. As regards industry, the Society of British Aircraft Constructors were of the opinion that only a few firms would take advantage of refresher courses. They estimated that the industry might send some 10/15 students annually for the advanced study of selected subjects, the majority being drawn from students who had already completed the two-years' course. The Royal Aeronautical Society recommended that provision should be made for a total number of 150/200 shorter course students at any one time.

32. These estimates are set out in the following table:

TABLE II

Shorter courses	*Annual number of entrants* *
Naval Air Arm	18
Royal Air Force	50
Government Departments and Research Establishments	40
British Overseas Airways Corporation	12
Aircraft industry (specialist) (SBAC estimate)	10–15
	130–135

(*Cf.* Royal Aeronautical Society estimate of 150–200 students *at any one time.**)

33. There are other possible sources of supply. No account is taken of overseas students or the needs of teachers in universities and technical colleges. There is no provision for airline operators other than the British Overseas Airways Corporation. Even in the field that they do cover, it is inevitable that the estimates should be highly speculative and it would be easy to over-emphasise their significance. Although they serve to confirm that provision is also needed for more specialised training over a shorter period, we prefer to leave aside the particular estimates we have received and to attempt a more general appreciation by considering the several directions in which it has been suggested to us, in this respect, that the College might profitably develop.

Types of Shorter Courses

34. There should be courses in his own subject for the specialist. It should be easier, for example, for a section leader in a design office to advance his knowledge, in some directions, by taking a course at the College than by studying text books and scientific papers or learning by experience. It may be impossible, moreover, for the specialist, at his job, to acquire the knowledge he needs of an allied subject; the potential airframe designer might, therefore, come to the College to study the use of materials and the engine designer to acquaint himself with methods of production or the applications of fuel technology to aero-engines. He might require to learn a new and rapidly developing technique such as strain-gauging or the instrumentation of flight testing. And as long as aeronautical science is developing rapidly, it should be possible to provide attractive refresher courses to bring up to date men whose ordinary activity does not leave them opportunity to keep abreast of development.

35. The success of the College in this respect will depend very much on the ability of those responsible for prescribing the courses to perceive the immediate needs and on their responsiveness to the demand, and for refresher courses, it is essential that the staff who give them should be able to obtain a full knowledge of recent work in their particular fields of study. If these conditions are satisfied this side of the College should quickly establish itself. While it is impossible, in advance, to estimate the demand accurately and in detail, we feel sure that it will prove to be substantial.

* Many of these shorter courses will be less than a whole year in duration. The number of students taking them at *any one time*, therefore, is less than a given number of *annual entrants*, e.g. assuming a year of three terms, an entry of 150 students each year for courses that, on the average, lasted only two terms, would give an average of 100 students at any one time during the year. The variation in length of these courses makes it difficult to estimate numbers at any one time.

Importance of Provision for Shorter Courses

36. We are satisfied, therefore, that the ultimate objective cannot be attained by making provision only for the higher training, at length, of those of university graduate standard and some practical experience (among whom Service officers are included). The Aeronautical Research Committee did not exclude from this field technicians from the industry who had the necessary knowledge and they contemplated some provision by way of specialised and refresher courses for students from industry and elsewhere, according to needs. But we wish to record our view that these latter aspects are relatively more important than they may have appeared at first sight. To train a corps d'élite only, by means of the two-years' post-graduate course, would be to postpone the ultimate achievement; to wait until these graduates have been absorbed in industry and elsewhere in substantial numbers, and have become leaders able to control policy, would be to wait for something like twenty years. It is essential, in our opinion, not only to train the future staffs but to improve the knowledge and enrich the experience of the staffs that are already serving. It will always be necessary, moreover, to cater for the man who deserves, although perhaps in a limited field, the opportunity of the highest training, but whose approach to it is devious, deferred, or peculiar through circumstances that may be no fault of his own.

37. There should not be any impression that the College, to open its doors more widely and to be useful to this class of student, must sacrifice the level of its teaching. In aerodynamics, for example, the section-leader from the drawing office of an airframe manufacturer will be as exacting in his needs as the university graduate, even if the latter has already studied aeronautics to some extent; and in some respects, notably in aircraft equipment, it is the specialists who will set the pace. The College need not relax its standards to provide for these students and it may well have to elevate them. Nor is there any risk in associating with the freshness and enthusiasm of the recent graduates the maturity and practical outlook of those with some years' experience. The blend should be to the advantage of all.

38. We recommend, therefore, that in making provision for the higher teaching of the particular subjects, the College should cater for the specialist as well as the student who will take the more general course. These specialised and shorter courses should be an important element of the College.

Comprehensiveness of the College

39. The Aeronautical Research Committee rightly attached importance to the comprehensiveness of the College. It must enable its students to study the aircraft as a whole, and to appreciate its components in their mutual relationships as well as to enquire into their design and construction as individual parts. Even the specialists must have a grasp of aeronautics generally if they are to see their proper subjects in their true perspective. And each must learn to have regard to the problems of other specialists if he is not, by his own work, to aggravate their difficulties unduly. A central College can best apply this principle, both by giving the general students a knowledge of all the main branches of aeronautics and by allowing the specialists, in their curricula and, perhaps equally important, in their contacts outside laboratories and lecture rooms, to obtain some grasp of subjects other than their own.

40. We think that this principle can be extended in two directions in order to meet two needs that were not referred to by the Aeronautical Research Committee.

Students from Industries associated with the Aircraft Industry

41. In the first place, we have received evidence that this main advantage of a central College could be utilised by students whose interests lie on the fringe of or beyond the field of aeronautics in the ordinary sense. There are several industries, other than the aircraft industry proper, on which the demands of aeronautics appear to be sufficiently important and specialised to warrant members of their staffs attending the College. The materials industry, especially the light alloys section, the machine tool, the electrical and the oil industries, all have peculiar concerns with aircraft and their equipment. While it is doubtful whether any members of their staffs would require, or could afford the time to obtain the general knowledge of aeronautics afforded by the normal two-years' course, it seems likely that some of them would profit from courses in the production, equipment or power plant departments, according to their interest. Having studied the fundamentals of their subject elsewhere, they could obtain in the College a more detailed knowledge of its aeronautical applications and at the same time they might profitably study some allied and primarily aeronautical subject. They would benefit also from constant association over a period of months with their contemporaries whose interests were in aeronautics and with whom they would be collaborating afterwards. We have no hesitation in recommending that the College accept and cater for such students from the associated industries.

Students on a General "Staff Course"

42. The other extension that we recommend is more radical. In the Services and in the aircraft industry there are and may always be men in important executive positions whose fundamental training has not been primarily scientific or technical. They have no opportunity to obtain and scarcely need, the deep knowledge to be acquired by those who will spend two years in this College, as they are mainly concerned, in the Services, with policy and administration and, in industry, with commercial and managerial questions, rather than with the solution of problems that are fundamentally technical. The decisions that they take, however, although they are primarily matters of operational or commercial policy, administration, organisation or management, may well have serious repercussions on technical development. It is important that those who take them should be able to appreciate the technical consequences. What they require is some conception of the content of aeronautical science and engineering in the light of which they can properly assess their own particular problem. We have been informed that this broad knowledge is often lacking among those in senior positions, both in the Services and in industry, and that its continued absence will be a serious handicap to future development. We have considered, therefore, whether a College that exists primarily to provide advanced scientific and technical training, could also be utilised to remedy this deficiency.

43. We fully appreciate that the two types of training are fundamentally different, although there is no reason to suppose that the students in the second class would be in any way inferior, intellectually, to those in the first. But from a teaching point of view, the curriculum, the equipment, and to some extent, the method of teaching, for students who do not possess extensive technical knowledge and require no more than an outline of the subject, are different from those for students who have already a fundamental knowledge of the subject and are being carried a stage further. The curriculum for the former must be more general, the equipment simpler and the teaching, to a much greater extent, by way of demonstration.

44. The proposal really involves something like two Colleges under one roof. Nevertheless, we have decided to recommend its adoption for the

following reasons. We are convinced of the urgent need for facilities to provide a general survey of the problems of aeronautics for those who will be concerned with them otherwise than in a purely technical capacity. We know of no existing means by which this training can be obtained and we do not see how it could be provided readily and economically except in this College. We believe that the students concerned will gain by being able to obtain the knowledge of the subject that they need in an institution devoted to aeronautics and where they will have the opportunity of associating with others whose interests are primarily scientific and technical. It is not a negligible consideration that in studying with them they will learn to work with them. If the need is admitted for this " staff course " for members of the Services and the Industry, there would be no corresponding advantage in providing it elsewhere than at the College. Moreover, there is an economy in that some of the more general lectures given to the advanced students, for example in aviation law and history, will be suitable also for the others. Equally, the staff whose main duty is to instruct their advanced students should be able to impart some knowledge of the content and the place of their subject to those who will not be equipped to study it deeply or at length.

45. Francis Bacon observed, in the *Advancement of Learning*, that " every knowledge may be fitly said, beside the profundity . . . to have a longitude and a latitude ; accounting the latitude towards other sciences and the longitude towards action." A College that is intended to advance the science and practice of aeronautics should, in our view, have some regard to the latitude and longitude of the subject and should open its door to those, other than the " profound " students, whom they concern.

46. It is unnecessary for us to make recommendations in detail as to the contents of this "staff course." The means and the method are matters to be considered and decided by the governing body. We recommend that the need should be recognised and that it should be accepted in principle that it is one of the functions of the College to meet it.

Summary of Requirements and Estimated Numbers of Students

47. Provision should be made, therefore, for three main requirements :

(i) a general higher training in aeronautics ;
(ii) specialist and refresher courses in particular subjects ;
(iii) a more general " staff course."

48. For the two latter types of course, we think it unnecessary to attempt to determine the numbers of students. It is better to leave the College freedom to develop, provided it has the means to use it as circumstances require. However, for planning purposes, we have adopted an estimate of 200 students at any one time which, together with 100 students on the two-years' course (paragraph 29 above) gives an average student population of 300. (The Royal Aeronautical Society suggested to us the same figure, although they pointed out that in the early years numbers should be a secondary consideration : in this formative period the recruitment should be selective, since the quality of the early students would be of lasting importance in determining the status of the College.) We think that this figure of 300 is a reasonable basis on which to work. We hope that the College will attain this size fairly rapidly and will continue to grow beyond it.

49. It should be observed that all the above estimates are with reference to the long-term requirement, that is, what is required to maintain a body of experts that has already been established. We wish to emphasise, however, that there is another problem of remedying the existing deficiencies that derive

from the lack of provision of this kind in the past. This demand is an immediate one. Indeed, at the beginning there may be, in some fields, almost a spate of students; for example, although the Air Ministry put the long-term requirement for civil aviation at three students annually, they thought that in the first years the number might reach 20. While, therefore, the estimate in the previous paragraph is made on a basis of calculation that will not apply immediately and relates to needs that will emerge only gradually, we consider that it should be used from the outset as a guide in planning the College.

Characteristics of the College

50. In designing a College to meet these several requirements there are some more general considerations that must be kept in view.

High Level of Instruction

51. There is one consideration that is cardinal if the College is to be worthy of its purpose. As far as possible the instruction must be at a high level that can properly be described as post-graduate. (This does not, of course, mean that a University degree is necessary for admission.) If the College were to teach undergraduates as well, it would seriously prejudice the development of aeronautical studies in the universities and technical colleges. It is desirable rather to encourage this development: the wider the field from which the students are drawn, the better it will be for the College. There should be no question, therefore, of accepting ordinary undergraduate students. It is, of course, impracticable wholly to exclude elementary instruction. The students' knowledge of ancillary subjects need not be profound and, even in the study of the main subjects, introductory courses will be needed, at least for some time; some of the graduate students will not be graduates in aeronautics and the elements of certain subjects, notably aerodynamics, will not have been included in their basic training. This sort of instruction, however, is to be regarded as a necessity and not a virtue. As the study of aeronautics in the universities and technical colleges progresses, it should be possible to elevate the standard of instruction in the College.

52. There is, however, a danger in setting the standard too high and limiting the field of recruitment overmuch. It is only from amongst those students—a relatively substantial number—who are susceptible of higher training, that some will emerge occasionally, to prove of the very highest calibre. The genius of these few cannot always be discerned in advance; it is necessary to foster all those in whom it is likely to dwell. Its achievement will be ample justification, if this were needed, for the effort devoted to those others who prove capable only of a secondary rôle and support and assist the progress of aeronautics without themselves making any outstanding contribution. The College, therefore, should accept the more substantial number for what it is worth and for the sake of those whom it may include.

53. Nevertheless, there is no duty more important for those responsible for the College than to be fastidious in the prescription of curricula and the choice of students and staff and to aim at a progressively higher standard of teaching. If the currency of instruction were to be debased, the inferior students would very soon drive out the best. The quality of the students it produces will be the true criterion of the College's success.

The Place of Research

54. Secondly, the place of research in the College will influence its character and deserves some definition. The Aeronautical Research Committee regarded as an important function of the College the introduction of selected studens

to research methods and participation in research and they thought it desirable that some of the staff should engage in research, primarily to maintain their own freshness and vigour. We endorse both of these recommendations.

55. While the first duty of the staff must be to teach, participation in research is essential if they are to discharge this duty effectively. This need was recognised by the Committee on Education and Research in Aeronautics appointed after the last war. Their Report* stated that "it is of importance that the same staff should to a great extent deal with both education and research. . . . The expense involved in aeronautical research and the limited number of men competent to undertake it both lead to this result and it is in our view in itself desirable. . . . No School . . . can be successful . . . unless those engaged in teaching are also engaged in or directing scientific research or experimental design." We observe that the connection is recognised in practice in the comparable American institutions, and the case for it is summed up admirably in the prospectus of the Massachusetts Institute of Technology: "Experience has demonstrated that teaching of the highest type, especially in science and its application, thrives best in an atmosphere of steady progress in the understanding of the subject taught. He who is still a student, who is still himself learning, whether it be new relationships of the most fundamental scientific nature or sounder and more economical ways of applying scientific knowledge . . . can best guide those about to enter upon a professional career."

56. So far as the students are concerned, the function of the College should be to impress them with a proper appreciation of the value of research, to introduce them to its methods, and to allow them (to quote again the Massachusetts prospectus) "to participate in it as an integral part of their educational experience rather than for the sake of anything that they themselves may achieve." Any research that they undertake will be limited by the time available for it. Some of them, however, will be competent and should be encouraged to devote part of their time at the College to research, perhaps mainly as assistants to the staff, although we do not contemplate that they will spend the greater part of their time in pursuing such inquiries in a narrow field. One of the College's functions is to train research workers and the initiation of these students in "live" work will be an essential part of their training.

57. We think it wrong to allow the research work at the College to become a business undertaken for the sake of its own results, rather than for the incidental benefits it brings both the staff and students. Obviously, however, there is a great advantage in work that is not simply a laboratory exercise but has also the urgency and interest of serving an essential purpose. We think that this end can be helped by arranging for the College to undertake suitable investigations on behalf of the Services, the Government research establishments and industry, and to co-operate with the universities and technical colleges. Evidence has been given to us of the value of the association on these lines between the Engineer-in-Chief and the Director of Naval Construction in the Admiralty and the staff of the Royal Naval College, Greenwich. A similar relationship exists in the United States between the National Advisory Committee for Aeronautics and the technical staffs of certain universities; indeed, the Chairman of that Committee has expressed the opinion that the execution of projects of this kind is the best possible way of training research workers.

58. We recommend, therefore, that the place of research in the College should be important without being dominant, that the activity of the staff in this field should be controlled sufficiently to ensure that it serves the essential

* Cmd. 554, 1930.

purpose, although subject to this condition, they should be free to prosecute their inquiries in any promising direction that attracts them, and that they should regard it as one of their primary duties to give their students an understanding of the principles and methods of research and of its importance.

The Place of Technology

59. There is one other major consideration that has been put before us. Although the problems of production in aeronautical engineering are to some extent common to other branches of engineering, the Industry is peculiar in that a much lower factor of safety has to be accepted in the product, which entails special attention to methods of production, inspection and testing. It is, moreover, an advantage to recognise the mutual dependence of the scientist, the designer and the production engineer, by giving a place in the College to all of them. In the past, the production engineer has too often had a lower status than the others and it would be unfortunate if the relative importance of his subject in the College's curriculum were in any way to cause this false impression to persist. A similar gap seems to exist between research and production. Too little attention seems to have been given to the training of development engineers, who require a wide experience, creative imagination, and the ability to interpret, co-ordinate and adapt, if they are to shape the means offered by research to the ends of production. The future of aeronautics in this country cannot be assured without advancing the standard of development and production engineering and industrial administration as well as promoting research. It has been suggested to us in evidence that, at present, the deficiencies are even greater in the former respects than the last. However this may be, it is clear that the College would be inadequate if it provided for training in research and neglected the problems of developing rapidly and producing efficiently the usable article that research makes possible. The College should, therefore, be concerned with technology as well as science in the narrow sense.

Relationship to other Institutions and Industry

60. It remains to set the College, as we visualise it, in the perspective of its relations with other institutions and the industry it is intended to serve.

Status of the College

61. The Aeronautical Research Committee recommended that the College should be affiliated to one of the great universities but should retain a large measure of autonomy; we understand that in adopting this view they were of the opinion that the university connection would help to maintain the standards of the College and to secure proper conditions of service for the staff. On this question of status there was a divergence of view among the experts on technical education whom we consulted. The Royal Aeronautical Society expressed the view that the College should be separate from the universities.

62. In favour of affiliation it may be urged that to arrange otherwise is to deprive the students of the opportunity both to associate freely with those whose interests are in other fields of study and to enjoy all the social and cultural amenities of a university. It would be profitable, generally, to have ready access to a university faculty concerned with engineering as a whole and affiliation would perhaps be economical in the teaching of some subjects and in the use of laboratory facilities. In a university, too, it would be easier to build a tradition of academic freedom. These arguments are not conclusive. It might equally be contended, for example, that many of the College's students will already have enjoyed the benefits of the corporate university life for several years as undergraduates and that there is a disadvantage in associating

aeronautics too closely with the older forms of engineering. Moreover, if affiliation can be disregarded, it is possible to range more widely in choosing the best site for the College. To these considerations we may add that it seems to us that the sort of College we have in mind would not easily be fitted into any university as it now exists. It is a new venture and should have the advantage of a clear field. We do not wish to rule out the possibility that at a later stage some form of connection may be found desirable and practicable, but we recommend that the College should start as an independent institution.

Relations with the Universities, etc.

63. Independence, however, should not mean isolation or competition. With the universities, with any similar higher institutions of science and technology that may be established, and with the research establishments, the College's relations should be intimate and continuous. We do not believe that it need in any way duplicate their functions, hamper their development or infringe their responsibilities. The gaps in the existing provision to which we have referred cannot, in our opinion, be filled by the improvement of the facilities at the universities, nor are they within the province of the training schools operated by leading firms in the Industry; indeed, we have been assured that, in dealing with them, the College will not interfere with the work of the latter institutions. The College is at once supplementary and more comprehensive but should co-operate with all the other institutions teaching in and adjacent to its field. For example, we should hope that the Universities would be prepared to recognise for the purpose of higher degrees, research work done by their former students while at this College. In any event, there should be from time to time exchanges of staff and, for occasional lectures or short courses, the College should borrow freely experts from other institutions and, possibly, send its students to them.

Relations with Industry

64. With the Industry, contact should be equally close. We agree with the Aeronautical Research Committee that the students entering on the two-years' course should normally have had at least one year's practical experience of workshop methods and conditions. Some of their training at the College, especially in methods of production, will include visits to suitable industrial undertakings. Equally, some of the instruction at the College can best be given by visiting lecturers who are actively engaged in industry. We refer later to the possibility that the full-time staff may be engaged on a basis that will permit some interchange between the College and industry (paragraphs 90 and 93). It was pointed out to us in evidence that the training in technical educational establishments tends to be out of touch with the latest developments in industry. The recruitment of staff from industry on a reciprocal basis would help to guard against this danger and it should be supplemented by encouraging the staff to maintain close touch with their fellows in industry in order that they may keep abreast of current practice and be aware of the emerging needs.

65. The cultivation of healthy relationships with these outside interests is important if the College is to avoid—and it must avoid—any tendency to become isolated and introspective. It should be, in a way, a microcosm of the whole aeronautical world, a community, engaged in the exchange of experience and the commerce of ideas and registering the progress of knowledge. Its outlook should be forward, receptive and catholic; it should be a clearing-house and not a forcing-house. If we may quote a former President of the Board of Education: " Education cannot be carried on with success in airless

compartments but depends for its healthy growth upon fresh currents of thought and interest sweeping in from the active intellectual life of the world outside." *

The College an Experiment

66. It will be evident, then, that we have in mind a new kind of College. While the Aeronautical Research Committee's original conception is the basis, we have extended it in more than one important respect, notably by emphasising the importance of the shorter specialised courses and by including the general "staff course" discussed in paragraphs 42 to 46. As we have said, the latter step involves something like two Colleges under one roof and must be regarded, to some extent, as an experiment. We are satisfied, however, of the urgency of the additional needs that are recognised in our conclusions. They cannot be ignored and it seems that the only alternative to our proposal would be to meet them by providing a second institution.

67. Here is perhaps the place to observe that throughout we have viewed with some misgiving the risk that our recommendations might be treated as a plan to be followed implicitly by the governing body of the College when they come to establish it. We are convinced that the College should be planned on the lines we have laid down in this Chapter, although some modifications may be required if, as it is not unlikely, there come to fruition other major developments in engineering education now, we understand, being considered. The chapters that follow elaborate our conception, in terms of the subjects to be taught, the staff, the organisation, the buildings and equipment that will be needed. It is to the last two especially that our expressed concern applies. The somewhat detailed plans have been worked out by us, or at our request, in order to arrive at a reasonable understanding of the form, magnitude and cost of the project. We wish to emphasise that their value lies in their scale and comprehensiveness rather than in their details; the latter are intended to guide and not to bind the governing body of the College. In practice they will be faced with a somewhat different situation in that, starting from nothing, they will be building gradually and with the opportunity to modify their own or our intentions in the light of experience. They should, of course, be free to do so.

* H. A. L. Fisher, *History of Europe*.

IV. SUBJECTS OF INSTRUCTION

68. **Summary:**

(i) There should be five main subjects:

(*a*) Aerodynamics, (*b*) Aircraft Structures, Engineering and Design, (*c*) Aircraft Equipment, (*d*) Engines and Systems of Propulsion, (*e*) Production, Administration and Maintenance (paragraphs 69–76).

(ii) There should be a main Department concerned with Flight and Operations, including full-scale experimental work and flight testing (paragraph 77).

(iii) Some provision should be made for ancillary subjects (paragraphs 78–80).

(iv) The main types of courses fall into two groups but there should be some flexibility (paragraphs 81–83).

The Basic Subjects

69. It seems unnecessary for us to discuss in detail the basic subjects on which any aeronautical education must be founded: aerodynamics, aircraft structures, thermodynamics, airframe and engine design, but we may, perhaps, indicate briefly the form of the instruction that should be given. Those who have taken an undergraduate course at a University, especially if it includes aeronautics, and the equivalent students from elsewhere, will come to the College with an appreciable scientific equipment. They will, however, have had time only for the easier fundamentals, primary knowledge and the simplest experiments. The substance of the teaching at the College must be wider and more adequate and include the more difficult fundamentals, advanced experiments and design work, and, for selected students, some research training in the investigation of new problems and the application of theory to practice. Comprehensive lecture courses should be provided to expand knowledge quickly, to give a grasp of theory, to explain the inter-relation of matters within the subject and the connection with kindred subjects. Experimental technique should be taught, and quantitative experiments undertaken by the students themselves to illustrate the lectures. Training will be required in methods of calculation and design and in the preparation and presentation of reports. The students engaging in research should be given authoritative assistance, advice and encouragement.

70. We agree with the Aeronautical Research Committee that aerodynamics and engines and systems of propulsion should be main subjects. We consider that it is more convenient, and preserves a better balance, to associate aircraft design and engineering with aircraft structures, and to group part of the latter subject, including aircraft hydraulics, togther with aircraft instruments (one of the Committee's ancillary subjects) in a main subject that we call Aircraft Equipment.

71. The relative importance we assign to this last subject needs emphasis. It is clear that students on a two-years' course covering aeronautics generally, would not be able to spend a great deal of their time on aircraft equipment. On the other hand, this appears to be a field in which design and development have lagged. In so far as this is the fault of the aircraft designer, the aim should be to give him a general knowledge of the applications of the accessories, their possibilities and limitations. The main trouble, however, seems to be that the specialists immediately concerned have lacked a full appreciation of the problems of weight and space peculiar to aircraft. It should be, therefore, the principal function of this department to enable the technician whose training

and experience have been devoted to, say, general electrical or hydraulic engineering, to study the place of his equipment in aircraft and the special requirements that must be met. This instruction would normally be given by relatively short courses. We understand that the Services attach importance to the provision of such facilities.

72. Mathematics is an essential auxiliary in many subjects of aeronautics, and especially in the theories of structures, oscillations and aerodynamics. Moreover, mathematical weakness among students, even at the graduate level, is often a serious obstacle to the increase of their knowledge and understanding. Clearly, therefore, there must be some provision for mathematical instruction at the College. We recommend that a Senior Lecturer in Applied Mathematics be attached to the Department of Aircraft Structures, Engineering and Design and that he should have sufficient junior lecturers to assist him. This mathematical staff should be at the service of the College as a whole.

Production, Administration and Maintenance, a Fifth Main Subject

73. It follows from the views that we have expressed above as to the importance of technology (paragraph 59), that methods of production should also be treated as a main subject. We have received a considerable amount of evidence on, and have discussed at length ourselves, the extent to which it is practicable and expedient to give instruction in Production. There can be no substitute, in this field, for practical experience in industry, and some of the instruction that can be given must consist of visits to industry to make studies of current problems and the methods used to solve them. There is, however, no adequate provision for the advanced training of production engineers. There seems to be a real need to co-ordinate the experience obtainable in the firms and to provide a centre at which, for example, the benefits of different types of design could be discussed from the production point of view. There is no means of distilling the engineering experience of the industry as a whole or of studying its relationship to the machine-tool industry. There is room, therefore, for courses that would give a general knowledge over the whole field of production, teach the fundamental knowledge on the principles of the subject that is accumulating, and correlate at the College the knowledge previously obtained by the students at first hand in industry. Attention should be given to the problems of maintenance, to which the Service Departments attach great importance. It is desirable, too, that at some stage in his course, each student should make with his hands some article or component within his field of study. We recommend that a department should be set up in the College for these purposes.

74. In this Department provision should also be made for giving some training in industrial administration to those who are technicians. The subject is best appreciated by mature minds and after industrial experience, and its inclusion in the curricula is therefore appropriate. It is suggested that the investigation of specific administrative problems in industry should be a feature of the courses.

75. Whether more advanced training in administration should be provided in the College for those who are already primarily concerned with industrial administration depends partly on the needs of those referred to in paragraph 42 above, who will come mainly for technical studies, and partly on the provision made elsewhere for teaching in administration. We do not recommend that special provision should be made from the outset for advanced studies in administration, but neither do we seek to prohibit it; we prefer that the governing body should keep an open mind on the matter and consider satisfying any legitimate demands that may arise.

76. Production, Administration and Maintenance should become, then, the fifth main subject. A Chart is attached (Appendix 12) showing one possible method of grouping these main subjects, and their component parts, in five main Departments, together with a sixth Department on Flight and Operations.

Flight and Operations

77. Some comment may be made on those matters which, on the Chart, we group in the Department called Flight and Operations. Within this department there should be provision for

(i) full-scale experiments and their correlation with laboratory results,

(ii) instruction in flight testing,

(iii) the practical aspects of aircraft performance and maintenance.

We attach importance to (i). It will be a great advantage to students to be able to check, by actual flight, the work they have already done in the laboratories. This department should undertake the full-scale experimental work, involving flight, for all the others, and teach the rapidly developing technique of flight instrumentation. As regards (ii), it has been suggested to us that the small School for the training of Service pilots as test pilots, now established at the Aeroplane and Armament Experimental Establishment, Boscombe Down, might with advantage be transferred to the College at a later date. In this department, also, would fall the provision for flying instruction. The general opinion, which we endorse, is that the students attending the College should have the opportunity to learn to fly and that those who can already fly will require facilities to keep their hand in and to use flying as a means of transport. Whether this provision is made directly by the College or by means of a flying club, using the College's airfield and open to such students as wish to join, is a matter of detail.

Ancillary Subjects

78. It is obviously necessary also to provide some instruction in ancillary subjects such as those referred to by the Aeronautical Research Committee: navigation, meteorology, the special problems of civil aviation. The needs of students will vary and none of them will be able to devote very much time to such studies. Their object is to broaden the outlook of the students and, to some extent, they will provide relief from the heavier work; which of them should be included in a general two-years' course is a matter best left for those responsible for administering the curriculum.

79. The tendency in aeronautics towards a very high degree of specialisation makes it necessary to provide some means of giving the specialists-to-be who come to the College a proper appreciation of the relation of these other subjects to their own. Some of the possible subjects, such as labour management or economics, are not peculiar to aeronautics. On others the courses that are necessary might be given more conveniently outside the College; for example, that on Airline Operation by the house school we understand that the British Overseas Airways Corporation proposes to set up. As regards others still, such as Navigation, while it is true that their place in the College need only be secondary, there appears, nevertheless, to be no convenient provision elsewhere for teaching them. On the one hand, it may be more economical for the College to arrange for its students to be given extra-mural instruction in these subjects; on the other hand it must be recognised that in this expedient there is a risk of creating the unfortunate impression that these subjects are not of much importance there are also likely to be serious prac-

tical difficulties in travelling and the co-ordination of time-tables. The answer in each case should depend on the actual needs of the students and on how far suitable provision to meet them exists in other convenient institutions.

80. In any event, the intensive and specialised study of these subjects for their own sake, should be carried out elsewhere.

Main Types of Course

81. We need not catalogue lists of topics to be covered in the curricula. The scope of the Departments is further explained in the relevant Appendices. It may be useful, however, to describe what seem to us to be the main types of course.

82. The main types of course fall into two Groups :—

I. (*a*) A two-years' course to be taken by students of graduate or equivalent educational standard. Some would be graduates and have had not less than a year's industrial experience ; others would be drawn from those who, having started in the works and acquired their education by part-time study, up to the standard of the Higher National Certificate, gave promise of occupying positions of responsibility. The course would cover all the main subjects of instruction, with some provision for ancillary subjects, and would be designed to produce not the narrow specialist but the man with an all-round knowledge at a high level. Towards the end of his course, each student might undertake one or more approved investigations or similar studies, to be preserved in the College for reference, as a gauge of his proficiency and ability.

(*b*) Specialist courses to be taken by students of the same type as at (*a*) but providing advanced instruction in one or two subjects only ; ancillary subjects might also be included. These courses would vary in length from, say, three months to a year. The level of instruction would be at least as high as (*a*) ; the front would be narrower.

(*c*) Refresher courses varying in length according to the subject, for students already of considerable experience, who require to be brought up to date in the latest aeronautical developments. These courses, primarily for the Services, might also be used by others, e.g. teachers or lecturers, requiring specific information on a particular aeronautical development.

II. A general course in aeronautics for men already of some standing in the Services and Government Departments as well as in the Industry. The aim would be, in a course lasting perhaps six months, to provide a wider knowledge of the content of aeronautics than can be derived from every-day experience with its specialist tendency. Possibly in time the need for this provision will diminish as the number grows of those who have taken course (*a*) in Group I.

83. We consider, however, that it would be unwise to lay down now any hard and fast distinctions and divisions. Especially in the early years, there will be a need for flexibility in devising and adapting the curricula. Within the general framework we recommend that the governing body of the College should experiment and accommodate individual needs. They should bear in mind that to develop the qualities of leadership the students will need opportunities of self-expression. From this point of view, the limits of technical education are themselves narrow enough without any undue curtailment of the students' choice within them.

V. THE STAFF AND THEIR CONDITIONS OF SERVICE

84. **Summary :**

(i) The numbers of tutorial staff should be liberal to ensure adequate individual tuition (paragraphs 85–87).

(ii) A high level of ability will be required in the teaching staff (paragraphs 88 and 89).

(iii) Their conditions of service should be comparable with those of university staffs (paragraphs 91 and 92).

(iv) Some should hold permanent appointments, others short-term appointments for three to five years (paragraphs 93–95).

(v) The recruitment of staff of the right type will be difficult but quality should not be sacrified (paragraph 96).

85. Generally, we consider that the numbers of tutorial staff should be liberal to ensure adequate individual tuition and to afford appropriate opportunity to the staff to devote time to research. We think that a reasonable proportion of teachers to students in an institution of this kind would be one to five or six. In considering the staff required in the College we have assumed a total number of students at any one time of 300 : such an assumption is not always needed, as in some instances there is an irreducible minimum.

Numbers of Staff

86. As regards full-time staff, the proposals in the memoranda dealing with the several departments (Appendices 4 to 11) may be summarised as follows :

Aerodynamics

Head of Department.
2 Senior Lecturers.
1 Senior Experimental Assistant.
1 Experimental Assistant.
3 Junior Lecturers.

Aircraft Structures, Engineering and Design

Head of Department.
3 Senior Lecturers (1 to deal with Applied Mathematics).
1 Superintendent of Design Office.
1 Superintendent of Laboratory.
6 Junior Lecturer-Demonstrators.

Engines and Systems of Propulsion

Head of Department.
4 Senior Lecturers.
1 Superintendent of Laboratory.
6 Junior Lecturers.

Aircraft Equipment

Head of Department.
4 Senior Lecturers.
1 Superintendent of Laboratory.
4 Junior Lecturers.

Production, Administration and Maintenance

(*a*) Production and Maintenance.
Head of Department:
3 Senior Lecturers.
5 Junior Lecturers.

(*b*) Materials.
1 Chief Chemist-Metallurgist.
2 Senior Lecturers.
2 Junior Lecturers.
1 Radiographist.

(*c*) Administration.
1 Senior Lecturer.

Flight and Operations Department

1 Supervisor of Flight Experiments.
3 Senior Test Pilots.
3 Flight Test Technicians.
2 Junior Test Pilots.
3 Pilot Instructors.

These proposals give a total staff as follows :

Heads of Departments	5
Supervisor of Flight Experiments	1
Senior Lecturers	19
Junior Lecturers	26
Chief Chemist	1
Superintendents of Laboratories and Design Office	4
Experimental Assistants	2
Radiographist	1
Test Pilots	5
Flight Test Technicians	3
Pilot Instructors	3
	70

In addition, the proposals provide for a number of mechanics, draughtsmen, demonstrators, computers, electricians, storekeepers, etc., perhaps 80 in all.

87. Some of us think that these numbers are excessive but they may be taken as a guide to the ultimate requirements when the College is fully established and we have adopted them as a basis for estimating costs. The College, can, of course, be established with a considerably smaller number and the rate at which the nucleus is built up will be a matter for the governing body.

Attainments Required in Staff

88. The current discussion on education has emphasised the critical importance of the teacher's part, the method of his training and the conditions of service. These considerations apply with at least equal force to a College of such an advanced and specialised character.

89. The level of the instruction will demand teachers with interests that are wide as well as profound. They must be men who have the gift of imparting their knowledge ; they must have high mental ability and varied experience ; they must be receptive of new developments. It is impossible to fashion the shining instrument of precision that the finished article should be if the tools are crude to begin with or blunted by monotonous repetition. Practical engineers can be found who are fully acquainted with their particular subject and research workers skilled in their own field. Such specialists, however, may not be natural teachers, and at best will need time to learn the art. The main difficulty will be to find leaders who combine practical experience with scientific attainment, both in a wide field, and who are already themselves expert teachers able to supervise the others.

90. A spirit of collaboration between the staff and the aeronautical world outside is vital. While the permanent members will have to maintain closer contact with scientific and industrial developments than has been customary amongst teachers in universities and technical colleges in the past, this contact alone will not suffice and there should always be some members of the tutorial staff whose normal vocation lies in one or other of the industrial undertakings. Similar connection is desirable with the research establishments and the Services. Personal experience and associations expressed in an individual point of view will exercise a valuable influence on the form and content of the teaching.

Conditions of Service and Remuneration

91. For men of outstanding merit, there will be counter-attractions in industry, the universities and the research establishments. It may be some time, although we hope that the time will soon come, before a permanent appointment in the College is prized for its own sake. It is all the more necessary that the conditions of service should be comparable with those of universities and other similar institutions. In place of the more glittering prizes of industry, the College must be able to offer its teaching staff some measure of freedom to pursue independent inquiries and some leisure to cultivate wider interests, as well as the satisfaction to be found in teaching itself.

92. A difficulty not unknown in universities is that the few men of parts at the head have too little time for teaching. Whether due to compendious administrative duties, pre-occupation with personal research, or other cause, the result is sometimes to relegate the bulk of the teaching to those who have never had full opportunity to gain the necessary qualifications for the work. Heads of departments, therefore, should be, as far as possible, free of routine administration and equally responsible with the rest of the staff for teaching the students. An adequate share of the teaching work, together with their research work, will occupy most of their energies in term-time. Their other work, such as the writing of books and consultations, should be done mainly in times of vacation and for this reason vacations should be allowed liberally, although they need not be as long as those of universities. Such vacations would assist both staff and students in maintaining their contacts with industry.

93. It seems to us that the staff will fall into two classes. The heads of departments and some of the senior staff, at least, should hold permanent appointments, remunerated on a scale comparable with that for similar university appointments, and with similar provision for superannuation on retirement. We assume that the scale of remuneration for university appointments generally will be increased. Unless this assumption is realised it will be more difficult to attract to the College staff of the right calibre. To permit some interchange of staff between the College, on the one hand, and on the other industry, the universities, the research establishments and the Services, there should be some appointments for periods of, say, three to five years, renewal being exceptional. The remuneration for these appointments, so far as they are made from industry, should be on a higher scale than for the permanent staff; it need not be competitive with the remuneration in industry.

94. We believe that it would be of great value to the College if it were possible for the staff to act as consultants to industry in accordance with the American practice at similar institutions. There might, however, be some difficulty in permitting them, if they were State servants, to augment their income by private practice of this kind.

95. Some of the instruction can best be provided by visiting lecturers who would come to the College to deliver an address or a short series of lectures on

the subject on which they were peculiarly qualified to speak. We would expect these lecturers to be drawn from a very wide field and to be remunerated, where remuneration is appropriate, on a fee basis.

Quality and Quantity

96. It is, unfortunately, one of the consequences of the lack of such a College up till now that staff of the right quality will not easily be obtained. While it is unlikely in the early years that the full number will be needed, we foresee a considerable problem in obtaining the services of those who are. From the point of view of equating the supply with the demand, it may be aggravating the problem to reiterate the importance of high quality. Nevertheless, it is of cardinal importance and should not be sacrificed because of any temporary stringency. On the shoulders of the staff, especially in the early days, will rest most of the responsibility for setting the standards and establishing tradition. Their careful selection is perhaps more crucial than any single measure in the establishment of the College. Without teachers who are worthy of them, it would be useless to be discriminating in the admission of students. And without teachers with the skill and resource to use them to the full advantage, the buildings and equipment that we recommend below will only be dead instruments and passive tools.

VI. ORGANISATION AND GOVERNMENT OF THE COLLEGE

97. **Summary:**

(i) There should be a Board of Studies, a Board of Entrance and a Careers Advisory Committee (paragraphs 98–101).

(ii) Candidates for admission should be accepted on their merits, after interview. There should be no entrance examination (paragraph 100).

(iii) The Principal should be assisted by a Registrar and possibly an officer responsible for works administration (paragraph 102).

(iv) The ultimate responsibility for the College should rest with the Ministry of Education but the control should not be meticulous (paragraphs 103–105).

(v) It should be called "The College of Aeronautics" (paragraph 106).

(vi) The College should begin as a Company limited by guarantee if it is impracticable to obtain a Royal Charter at the outset (paragraph 107).

(vii) There should be a Governing Body, representative of the Universities, the Industry, the aeronautical profession, the Departments concerned, the Dominions and the staff, and including independent members. It should work through an executive committee (paragraphs 108–110).

98. The organisation of the several departments is a matter for the authorities of the College but, by way of illustration, the chart in Appendix 12 shows a possible lay-out in six main Departments. While such an organisation may secure the concentration of cognate subjects within one department, correlation between courses and co-operation between the departments providing them cannot be secured by organisation alone. Machinery must also be provided to regulate the admission of students and to relate their studies to their future work. We recommend, therefore, the institution of three special bodies for these purposes.

Board of Studies

99. There should be a Board of Studies, selected mainly from the senior teaching staff, which should be responsible for prescribing the types of course to be provided and the curriculum for each. It should have a general responsibility to correlate the instruction in the several departments.

Board of Entrance

100. There should also be a Board of Entrance to determine the standards for admission. We agree with the Aeronautical Research Committee that it would be inappropriate for this Board to proceed by way of special examination and we would expect that the normal method of selection would be to interview those candidates who, on the evidence of their applications, possessed the qualifications recognised as sufficient. The Board should be small and should have some members who do not belong to the staff. We do not think that it is practicable to prescribe in detail what the entrance qualifications should be for students either from industry or the Services. While the student from the university might be classified according to his degree qualification, the others could be judged only on their merits. The Services would, no doubt, nominate suitably qualified officers and we must leave it to the Board of Entrance to consider candidates from industry with due regard to the standards of the College and the ability of the individuals to attain them.

Careers Advisory Committee

101. In the third place, there should be a Careers Advisory Committee to guide students as to their professional prospects and to deal as necessary with students' appointments. The Committee should include outside interests as well as those of the College and obviously it is important that the aircraft industry should be represented.

Administration

102. The general administration of the College should be in the hands of a Principal. Especially in the formative years, much will depend on the way in which the duties of this post are conceived and discharged and the greatest care should be given to the appointments to it. The Principal, by his training, experience and competence, should be a man commanding the respect of the whole aeronautical community. It is doubtful whether, to any extent, he would be able to take part in the work of teaching and carry out research of his own, as the Aeronautical Research Committee recommended. In order that the Principal should be freed for the larger tasks, there should be a Registrar or Secretary in charge of the routine administration, secretarial and financial. It may be that the relative importance, in a College of this sort, of the buildings, plant and equipment justifies a similar officer responsible for all aspects of works administration.

Departmental Control

103. The higher government depends to a considerable degree on the method of financing the College. This question is discussed in Chapter VIII below. It is sufficient for this purpose to state the conclusions there reached, namely that the capital expenditure incurred in establishing and, from time to time, improving the College must be found mainly by the State and that the greater proportion of the recurrent expenditure must also come from public funds.

104. We assume, therefore, that the ultimate authority responsible for the College will be a Minister of the Crown. It appears to us that the appropriate Minister would be the Minister of Education. The purpose of the College is primarily educational and it should be regarded in this respect as comparable to other institutions for higher technical education that exist or may be set up.

105. The College's expenditure would, then, be borne on the Vote of the Ministry of Education. While the Minister must exercise some degree of control on this account, we venture to hope that the measure of this control will be restricted to the minimum that is compatible with his constitutional responsibility to Parliament for the expenditure. It seems to us that his normal functions might be limited to the appointment of members of the governing body, including the selection of those who are appointed individually and not nominated by organisations, the approval of major items of capital expenditure and a general supervision of policy. (The Minister would no doubt consult the Secretary of State for Scotland in making appointments to the governing body and otherwise as necessary.) The activities of a College of this kind are not in our view a desirable field for the exercise of any meticulous Departmental control.

Government of the College

106. We were asked to suggest a name for the College. We think that the name should be associated with aeronautics rather than with aeronautical science or aeronautical engineering. We suggest, therefore, that it be called: "The College of Aeronautics."

107. It is desirable that the College should be a corporate body. We hope that it will be possible to obtain for it at the outset a Royal Charter and the title of "Royal" (in which case it would become "The Royal College of Aeronautics"). If this were impracticable, it should begin as a company limited by guarantee.

108. The College will require a governing body of its own. As far as possible, this body should be independent. Its main functions should be to exercise a general oversight of the College's activities, to appoint the senior staff, to settle major questions of policy and to approve proposals involving capital expenditure. There are several interests to be included, some of which should be allowed to nominate representatives, while others can better be served by the selection of outstanding individuals. We recommend that the composition of the governing body should be as follows:

A Chairman selected by the responsible Minister.

2 members selected to represent the universities.

2 members nominated by the Society of British Aircraft Constructors to represent the aircraft industry.

2 members nominated by the Royal Aeronautical Society to represent the professional interest.

7 members nominated by the Departments concerned: the Admiralty, the Air Ministry, two (in respect of the Royal Air Force and the Department of Civil Aviation), the Ministry of Aircraft Production, the Education Departments, two, the Department of Scientific and Industrial Research.

Representatives of those Dominions who may associate themselves with the College.

2 members of the teaching staff.

3 independent members, who should be chosen for their personal worth; they need not necessarily have any active concern in aeronautics although one might be a former student of the College.

109. We recommend that the period of appointment to the Board should be, for the Chairman, five years and for the other members three years. The appointments should not be renewable consecutively but only after an interval of at least one year. To this arrangement we attach importance, as it is a means of ensuring the infusion of a fresh point of view. A proportion of the Board should retire annually, and for this purpose, a third of the initial appointments should be for four years and another third for five.

110. This Board, being concerned only with the major issues, would probably not find it necessary to meet more often than quarterly. A few of its number might meet perhaps monthly, with the Chairman, as an executive committee, to assist the Principal in disposing of matters of urgency or of more detail. The immediate responsibility, however, will rest on the Principal and on his staff. They will bear the burden of the day's work and they must be of such a calibre that they carry the confidence of those above and, in matters of detail, are encouraged to rely on their own judgment and discretion.

VII. THE LOCATION OF THE COLLEGE, ITS BUILDINGS AND EQUIPMENT

111. **Summary:**

(i) The College should be situated close to an airfield of its own (paragraph 112).

(ii) Other factors in determining the site are proximity to London and to the principal research establishment, local flying conditions and the amenities of the district (paragraph 113).

(iii) The most suitable site is Aldermaston (paragraph 114).

(iv) If it is impracticable otherwise to ensure an early start, the adaptation of existing buildings at an R.A.F. Station is recommended. The most suitable Station is Abingdon (paragraphs 115–118).

(v) A lay-out plan is submitted for the permanent buildings, providing for all the technical requirements, other teaching facilities, administrative offices, residential and recreational accommodation (paragraphs 119–121).

(vi) Memoranda are submitted as a guide to the equipment of each Department and an indication of the cost (paragraph 122–127).

(vii) The scale of the equipment lies between that appropriate to a university and that for a research establishment (paragraph 128).

The Importance of an Airfield

112. The Aeronautical Research Committee were strongly of the opinion that the College must be situated near its airfield, on the ground that continuous contact with flying was most desirable as a background for education in aeronautics. This view is undoubtedly correct. In our opinion an airfield is essential: without it not only would the opportunities for practical work in the air be lost but the whole atmosphere would be unreal. We recommend, therefore, that the College should be situated near an airfield and we believe that sufficient use can be made of the facilities both in experimental work and in flying practice and instruction to justify the College having an airfield of its own.

Other Considerations Governing the Site

113. We have approached the question of the location of the College from this point of view, considering it in terms of the suitable airfields that satisfy the other governing conditions and might be available. These other conditions seem to be:

(i) The airfield should have hard runways including one of not less than 2,000 yards, capable of extension.

(ii) The district should offer good flying conditions.

(iii) The College should be within easy travelling distance of London, say 50–60 miles, in order that the students may attend lectures and meetings of societies, etc.

(iv) The College should be within a reasonable distance, say 25 miles, of the principal aeronautical research establishment.

(v) The amenities of the district should be pleasant.

(vi) The site should be close to a town of some size offering housing accommodation for some of the staff and facilities for social life and recreation.

(vii) The site should be spacious to permit of expansion.

Proposed Sites

114. After considering the airfields within a 50–60 miles radius of London we consider that the College should be located in the vicinity of Aldermaston, Berks., or Dunsfold, Surrey, in that order of preference. We are informed that there are suitable sites at each within a mile or so of the airfield and between the lines of the runways, the ideal distance for accessibility and the best position, from the point of view of avoiding the noise of aircraft. We recommend that Aldermaston should be acquired, if possible, as the airfield and that the College be erected nearby.

Adaptation of Existing Buildings

115. We have considered the possibility of utilising some existing buildings as the permanent home for the College. Such buildings, to be useful, would have to be near a suitable airfield and would have to be educational in type; most of the expenditure will be on the laboratories, and we think it very improbable that any existing and suitable are likely to be available for the purpose. We have considered the airfields with permanent Service buildings. The Ministry of Works witnesses examined a typical case and reported that the saving in cost in a scheme of this kind compared with the development of a fresh site was about 11%. All the laboratories would have to be built and the adaptation of the other buildings would be very considerable; on the two together the effort would be little less than on a new College. The result would be a makeshift, unsatisfactory in lay-out and more costly to maintain. Moreover, if, as we assume, the Royal Air Force would require to replace the permanent buildings at some other station, the cost of this replacement must also be reckoned. We conclude, therefore, that the use of existing buildings as a permanent solution would be unsatisfactory, would gain no time, would involve as great or greater capital expenditure and higher recurring charges and, even so, be far less satisfactory. We are convinced that, from every point of view, the advantage lies in an untrammelled beginning, and we have drawn up plans on this basis.

116. If these arguments were not adversely affected by the time factor, we should have no hesitation in recommending that the College be set up in new buildings to be provided for the purpose. We regard the time factor, however, as of vital importance. The College is urgently needed and we hope that it will be set up as soon as possible after the end of the war in Europe. If, in these circumstances, it were found impracticable to commence new construction without serious delay then our preference for it must be reconsidered. We have recorded the evidence given to us that adaptation of existing premises would result in no ultimate saving of time and this is doubtless true for a scheme planned on the full scale. But it may well be that a much earlier start could be made by utilising the best existing premises that are available to establish the College in embryo, and that adaptation and extension could proceed *pari passu* with the recruitment of staff and students and the manufacture of the apparatus—all of which will take time. Although, therefore, the case for a new College, untrammelled by any existing provision, is overwhelming, we stress that the decisive factor is that of time; if new premises cannot for one reason or another be provided quickly we recommend consideration of the other but much less desirable alternative as a temporary solution.

117. Such an improvisation should be designed only to accommodate the College on a small scale and until such time as the proper buildings could be provided. Adaptable buildings would be required within reasonable proximity of a research establishment and some expenditure would be needed on temporary

laboratories. It is inherent in such a scheme that the expenditure on it must soon be written off, but we consider that it would be worth while, if this course were immediately more practicable than the new provision that is preferable on other grounds.

118. The most suitable site we can suggest from this point of view is the Royal Air Force station, Abingdon, Berks., and we understand that the Air Council would be prepared to make the station available temporarily for the purpose. It would be very difficult, and we have thought it unnecessary, to attempt any detailed examination of the adaptations required. We contemplate that the governing body would incur only the minimum expenditure necessary to build up a nucleus of the College. We believe that the practical experience gained during the first two or three years in this temporary home would be of great value in enabling them to determine what was required in the permanent buildings and equipment, and we should expect our recommendations on these heads to be improved upon by this experience.

The Lay-Out Plan

119. For the permanent buildings the Ministry of Works prepared for us the plan shown in Appendices 13 and 14. We thought it right to have this plan prepared both to give form to our conception of the College and to afford a practical basis for calculating costs. It takes account of the technical requirements of the several departments, referred to below, and was prepared in consultation with those responsible for the memoranda on them. (Appendices 4–11.) It makes what appears to us to be a reasonable provision for the general facilities, library, museum, lecture halls, administrative offices. It assumes, properly, that the students will be in residence at the College. In this connection, we regard as important the provision for the students of the facilities of recreation normally found in a university and we have taken full account of these in preparing our estimates of cost.

Features of the Plan

120. The following description of the plan is based on a memorandum submitted to us by the Ministry of Works.

121. The building falls into six sections which together form a flexible and economical plan, the sections being capable of extension without interruption.

(1) *The Hall* (A on plan) is capable of seating not less than 1,000 people. It is equipped with a stage and cloakroom facilities (A.1), and is connected to the main entrance hall (B) of the Administrative Block by a foyer (A.2). This is intended to be the principal entrance, a separate entrance being provided on the south wall for the use of students and their guests. The Dining Hall (M) is also connected to the foyer.

(2) *The Administrative Block* (B) contains the main entrance hall and rooms for the Board of Governors, the Principal, the senior staff and the administrative staff. The unit is planned on ground, first and second floor levels. The second floor consists of lecture rooms which, if need be, can be converted to offices later.

(3) *Lecture and Reference Section.* This section has access from both the Administrative and Laboratory blocks and contains the museum and library (C), one large lecture theatre to seat 350 students (D), and lecture rooms (E). The section is planned on ground and first floor levels. It could be extended by providing an additional storey and adding a second lecture theatre.

(4) *Laboratories.* This section is planned on ground, first and second floor levels. It has direct access to sections 3 and 5. Most of the laboratories are capable of easy extension either by additions at ground level or the provision of an additional storey. The section contains the following laboratories.

Aerodynamics (K).
Aircraft Structures, Engineering and Design (I).
Engines (H).
Aircraft Equipment (J).
Production (G).
Materials (F).

It is intended that the Flight section will be located at the airfield.

(5) *Students Assembly, Dining Hall and Recreation Buildings.* This section contains the following:

Students Assembly Hall (L).
Dining Hall (M).
Servery and Kitchen (N).
Lounge (O).
Swimming Pool (P).
Dressing Rooms (Q).
Squash Courts and Gymnasium (R. and S).
Recreation and Reading Rooms (T and U).
Main Boiler House (V).

(6) *Halls of Residence.* This accommodation is provided in separate blocks at ground and first floor level, conveniently adjoining the students' dining and recreation building.

Basis of the Memoranda on Equipment.

122. For several reasons we considered it necessary to examine in detail the question of equipment. Without some clear idea of the equipment required it would have been impossible to plan the buildings or to make a complete estimate of the cost. It would have been difficult, too, to consider adequately the form and content of the instruction to be given without reference to the equipment it requires. Finally, it seemed to us useful to afford some measure of guidance to those who will be responsible for establishing the College.

123. We wish to emphasise that these memoranda are to be regarded as a guide. The development of the science and technique will always create new needs and some items become unnecessary. The research equipment will to some extent depend on the particular lines of research that the staff are authorised to pursue. The lists in the memoranda, therefore, are neither absolute nor final. The College can start with less and it may well need more.

124. The memoranda were prepared by the individual experts to whom we have already acknowledged our debt (paragraph 7). Each of them was generally informed as to our conception of the scope and character of the College and they prepared their memoranda after full consultation with other experts in the research establishments and the Industry. They discussed their proposals fully with our sub-committee and made changes. They also discussed them with us, and we have modified them further, especially as regards the staff requirements.

Observations on the Memoranda, as regards Equipment

125. We wish to refer briefly to the salient features in each department.

(i) *Aerodynamics*. The equipment for this department must include a battery of small slow-speed wind tunnels on which the more general exercises can be carried out. The technique of the subject, however, is advancing rapidly and more elaborate and specialised equipment is needed for the higher branches of study, although, obviously, the largest and most expensive apparatus is more appropriate to a research establishment than to this College. A middle course has therefore been adopted, and the equipment put forward includes only one tunnel involving high capital cost. This item is regarded as highly desirable for teaching at the high level appropriate to the College. Special attention has been given to the desirability of relatively low running and maintenance costs.

(ii) *Aircraft Structures, Engineering and Design*. This department is concerned with the principal subjects of airframe design, and apart from one item, the equipment recommended is not elaborate. The exception is a slow-speed general purposes wind tunnel, sufficiently large to accommodate the fuselage of a small aeroplane, complete with tail unit and propeller. There is a strong case for the inclusion of such a piece of equipment separately in this department, and this will avoid interference with the Aerodynamics Department for the many structural and design experiments involving a large air stream. Other equipment includes various types of testing machine and provision is made for a suitable drawing office.

(iii) *Aircraft Equipment*. The apparatus consists of a multitude of small items appropriate to the manifold branches of the subject. The aim has been to make an up-to-date selection adequate for instruction and practical work on all the services that are essential to the operation of the modern aircraft, and its structural and flight testing. Special attention has been paid to aircraft Electrics, Electronics and Instrumentation.

(iv) *Engines and Systems of Propulsion*. This subject is so wide that a great deal of equipment is required to cover demonstration and practical work. In the reciprocating engine field much can be done with single cylinder units, and a battery of these is therefore recommended, supplemented by two large test beds for full-scale investigations and instruction. Gas Turbines are still in their infancy, and the equipment recommended as being adequate in the present state of the art is relatively simple and inexpensive. Provision has also been made for low temperature experiments, and for various test rigs to cover such items as supercharging, carburation, ducting, propellers, accessories and individual components. A special section is devoted to work on fuels and oils.

(v) *Production, Administration and Maintenance*. While this department will work in very close collaboration with industry, nevertheless, a certain amount of equipment will be required at the College itself. It is recommended that there should be a prototype machine shop, in which parts would actually be fabricated by students, a standards room and inspection department, and a sheet metal shop. Provision is made for a representative selection of machine tools and heat-treatment equipment.

(vi) *Materials.* This section, which for organisation purposes has been dealt with as part of the Production department, is ancillary also to the various design departments, and requires a comprehensive range of special and general-purpose equipment. The apparatus recommended, which covers the field from chemistry and metallography to plastics and crystallography, is not elaborate, but has been selected as the minimum necessary for adequate up-to-date teaching of all these important subjects.

(vii) *Flight and Operations.* The principal function of this department is to provide facilities for practical full-scale experiments and their correlation with laboratory results. The equipment therefore comprises a number of suitable aircraft of various types, which can be used as flying laboratories, and a maintenance workshop. The preparation of aircraft for such work usually involves considerable ground work and a comparatively large fleet is therefore necessary to ensure continuity of demonstration.

126. Subject to these comments we have accepted and recommend these proposals as a reasonable guide to the scope and requirements of the several departments when fully established.

Museum and Library

127. It will be observed that the plans provide for a museum and a library. The former we expect will be built up gradually; its provision is mainly a question of the necessary space. The library will involve a substantial annual expenditure on the purchase of books and journals. A first-class library, however, is essential in a College of this sort, and we attach importance to adequate provision both for its initial establishment and the constant additions that will be necessary.

The Scale of the Equipment

128. The cost of these proposals is dealt with in some detail in the following chapter. It is considerable, but this is a College concerned with a science that depends increasingly on elaborate technique for which new and highly specialised apparatus is always being devised. We feel that it is impossible to set up such a College without heavy initial expenditure and also a reasonable provision for annual replacement and addition. It is very important, in our opinion, that the College should have adequate funds for the latter purpose. The College will not be a research establishment, but its needs go beyond those of a university. The memoranda are compiled on this basis and they do make some provision for research. The expenditure is not comparable with that involved in creating a modern research establishment, but, even so, it should perhaps be judged from the point of view that the College will train many of the future research workers; without due expenditure on its equipment, there can be no full return for the expenditure on research establishments.

VIII. THE FINANCE OF THE COLLEGE

129. **Summary :**

(i) Estimates are given of the capital expenditure, the recurrent expenditure and the annual income (paragraphs 133, 134 and 140).

(ii) Some allowance should be made for equipment provided from surplus Government stocks or on loan from manufacturers (paragraph 132).

(iii) An endowment fund should be raised if possible (paragraph 139).

(iv) The estimated charges for the capital expenditure are £2,610,000. The net recurrent annual expenditure will be £360,000. Most of this expenditure will fall on the Exchequer (paragraph 141).

(v) A temporary scheme would involve a capital expenditure of £400,000 and an annual expenditure of £200,000 (paragraphs 142 and 143).

Capital Cost

130. The cost of the new buildings described in the previous chapter is estimated by the Ministry of Works at £1,380,000. This estimate includes the actual building work, lighting, heating, roads and sewers, water supply. Provision is made for costs resulting from the Essential Works Order, the Uniformity Agreement, fees and contingencies : this provision amounts to 25% of the whole cost. No provision is made for bringing service mains to the site. For this a reasonable addition based on the Aldermaston site would be £20,000. The estimates are based on current costs.

131. The cost of equipping the several departments are as follows :

Aerodynamics Department	£260,000
Aircraft Structures, Engineering and Design Department	195,000
Engine Department	392,000
Aircraft Equipment Department	66,000
Production, Administration and Maintenance Department (including Materials Section)	200,000
Flight and Operations Department (including cost of hangars)	100,000
Total, say	£1,210,000

132. These estimates make no allowance for some items being obtainable from plant surplus at the end of hostilities or for manufacturers being prepared to provide examples of newly developed equipment on loan. From both sources and from gifts we believe that it will be possible to obtain a substantial amount of the equipment required.

133. The capital cost of the College would be, therefore, as follows :

Buildings	£1,380,000
Essential services	20,000
Equipment	1,210,000
Total	£2,610,000

Recurrent Costs

134. The annual expenditure is more difficult to gauge. A tentative budget would be :

Salaries and wages, including superannuation	£80,000
Other running expenses, including heat, lighting, power and maintenance	80,000
Depreciation and replacement of equipment	100,000
Special expenditure on experimental work in aerodynamics and engine departments	50,000
Expenditure on flight and operations department ..	70,000
	£380,000

Maintenance Charges and Fees

135. We recommend that the students should be charged the actual cost of their maintenance. We hope that local education authorities throughout the country will be prepared to provide scholarships tenable at the College and no doubt some, at least, of the students from industry will be maintained by their employers. In any event we consider that, in the interest of the students, the maintenance charge should be a fixed rate inclusive of all necessary items.

136. It would be impracticable to charge fees at a rate proportional to the actual cost of tuition, on any basis of calculation. After reviewing the scale of tuition fees in comparable institutions we recommend that the fee per year should be £75, with proportionate rates for shorter courses.

137. We recommend that students from the Services be accepted at the same nominal rate of fees as the others. But to the extent that the College offers facilities that would otherwise have to be provided by the Service Departments themselves, it would be reasonable that these Departments should, in addition, make annual fixed grants towards its expenditure.

Other Sources of Income

138. It is reasonable to suppose that the College will obtain some revenue from consultation fees, from charges for laboratory work, etc., but we prefer to exclude these from the calculation.

139. Account should also be taken of the interest on any endowment fund that may be raised. We hope that the Industry and private benefactors will be able to establish and build up such a fund. Although it is unlikely that, for a long time, the College's independent income will attain the proportion normal in the incomes of universities, the value of such resources exceeds their actual measure. However remote is the control exercised by the responsible Department of State, it remains true that an income from endowment will give the governors of the College a scope and sense of independence that must otherwise be lacking. One purpose it might well serve would be to provide a scholarship fund from which the governing body could afford assistance to students who needed it. We can only commend this object to the Industry and all others who are interested in the future of higher aeronautical education.

140. Omitting these uncertain elements, we estimate the annual income from tuition fees, at £20,000.

Expenditure to be Met from Votes

141. Our proposals, therefore, involve the following commitments that can be met only from the Exchequer :

Initial capital expenditure	£2,610,000
Annual grant towards recurring expenditure	360,000

Cost of Temporary Scheme

142. If the R.A.F. Station, Abingdon, or a similar station were utilised temporarily, some expenditure would be required to renovate and adapt the existing quarters, to provide additional services, e.g. electricity, and to adapt hangars to house equipment. Abingdon, fortunately, has hangars that could be used for this purpose. We do not contemplate that all the wind tunnels or test equipment would be provided there or that the College would grow beyond 150 students, i.e. half the size on which the new buildings should be planned. On this basis, we believe that the expenditure on adaptations would be about £150,000. The expenditure on new equipment would be about £300,000 ; the rest could, we believe, be found from surplus Government stock. The annual running cost might be about £200,000.

143. Much of the equipment at the temporary site would be moved, in time, to the permanent buildings of the College. The transfer, apart from expenditure in moving the equipment, would involve writing off some of the adaptation and providing essential services at the temporary site. While it is impossible to estimate the cost accurately, it seems to us that the expedient of using a temporary site first would increase the total ultimate cost by £150,000.

IX. CONCLUSION

144. In submitting these recommendations, there are some general observations that we should like to make.

The Need for the College

145. As we observed at the outset of this Report, we were not charged with examining the case for such a College. We have taken it for granted. Nevertheless, we wish, first of all, to record our sense of its urgency. Although, in our deliberations we have had inevitable differences of opinion, none of us questions the need for the College. Now that Air-Power has taken its place with Sea-Power, the sustained and comprehensive development of the science and practice of aeronautics is vital to the defence of this country. Our Service witnesses have set great store by the College as a means to this end. We believe that the College is equally necessary to the aircraft industry, although there has been, on the part of some of our witnesses from it, some tendency to depreciate the value of a higher scientific training and the utility of such an institution to the practising specialist. It seems to us that the Industry, in some part, may be judging from past experience and under-estimating both the future significance of research and the increasing limitations of a policy of empiricism. We believe that progress will now depend less on the genius and resource of individuals and more on the organised investigation and experimentation of trained workers working in teams and using large-scale equipment. If it is so, then the College is essential to the future of the Industry. It should be one of its aims to provide men capable of designing and producing aircraft that will find users all over the world because of their efficient design and economy in operation. For reasons of geography, the future of aeronautics may be even more significant for the Dominions, India and the Colonies than for the United Kingdom. We have sought to consult their interests in preparing our proposals and we share the hope, already expressed, that the College may become " a great Imperial venture." *

Improvement of Aeronautical Education Generally

146. In the second place, although we are not concerned with aeronautical education generally, we feel bound to point out that a structure such as we have proposed must be securely based. Attention should also be given to the facilities for aeronautical education in the technical colleges and the universities. Otherwise the flow of suitable students to the College will be dried up at the source. The College cannot flourish as it should unless there is a general improvement in aeronautical education.

Freedom and Enterprise

147. Lastly, there is one serious danger in drawing up such comprehensive proposals at the present stage. To be successful, any institution of this kind must grow organically. It cannot be created whole according to a prescription. One of the distinguished Americans with whose views we were furnished suggested that " the plan for the complete curriculum should be drawn from the beginning. Execution of the plan should be gradual, starting with the establishment of sound courses of study with adequate instruction (both quality and quantity) in the most vital fields. With a complete plan to work to, the addition of more fields of study as the School develops will be accomplished without confusion and duplication of effort." We agree that from the outset it is necessary to have some conception of the whole, but we would prefer to regard the proposals we make as a general guide rather than a plan to be adhered to in every detail. The College should be built up gradually from a relatively

* By Lord Cherwell, Parl. Debates, House of Lords, Vol. 128, col. 476 ,13th July, 1943.

modest beginning to the scale that we recommend. Although this policy might mean that initially the facilities cannot cope with the demand, intense competition for admission is a healthy sign; it will assist in the formative years in establishing the proper standards of excellence.

148. It follows that the College should be established with sufficient space and resources to enable it to develop naturally in response to increasing and even novel demands. Nor is liberty important to it only in the physical sense. The Aeronautical Research Committee asked that it should be conducted "in an atmosphere of freedom and enterprise." Those whom this College will train, and indeed those who train them, will spend most of their useful lives as pioneers on the frontiers and marches of aeronautical knowledge; in science or art, they will lead its advance into the unknown. The frontiersman is characteristically bold and energetic, restless and resourceful in adapting what he finds new. These are the qualities that will be needed and, if it is to breed them, the College must be allowed to develop, in all its activities, the atmosphere of freedom and enterprise that is natural in a frontier community. How this liberty is to be reconciled with the control inseparable from financial dependence on State subvention is perhaps the most vital problem of all for those who establish it and govern its destiny.

(Signed)
NORMAN W. GRAHAM, Secretary.
R. G. R. GOLDBY, Technical Secretary.

(Signed)
A. H. ROY FEDDEN, Chairman.
J. A. BARLOW.
M. S. SLATTERY, Commodore R.N.
W. P. HILDRED.
R. S. SORLEY, Air Marshal.
J. E. STEPHENSON.
W. ABBOTT.
C. G. DARWIN.
W. J. DUNCAN.*

19th July, 1944.

* Sir Melvill Jones was abroad when the report was completed and Professor Duncan signed it in his absence.

APPENDIX 1

List of Persons and Organisations Submitting Written Evidence

Society of British Aircraft Constructors.

Royal Aeronautical Society.

Sir Henry T. Tizard, K.C.B., C.B., A.F.C., F.R.S., F.R.Ae.S.

Professor J. F. Baker, O.B.E., M.A., D.Sc., Cambridge University.

Professor C. E. Inglis, O.B.E., F.R.S., Cambridge University.

Dr. H. Schofield, M.B.E., B.Sc., Hons (Lond)., A.M.Inst. C.E., M.I.Mech.E., D.I.C., F.Inst.P., Principal, Loughborough College.

Dr. A. P. M. Fleming, C.B.E., M.Sc., Metropolitan-Vickers Electrical Co.

Dr. N. A. V. Piercy, M.Inst.C.E., F.R.Ae.S., M.I.Mech.E., M.Cons.E.

Wing Commander T. R. Cave-Browne-Cave, C.B.E., F.R.Ae.S., Professor of Engineering, University College, Southampton.

Professor R. V. Southwell, M.A., F.R.S., LL.D., F.R.Ae.S., Imperial College of Science and Technology.

Mr. S. C. Laws, M.A., M.Sc., Northampton Polytechnic Institute.

Dr. J. C. Hunsaker, Professor of Aeronautical Engineering, Massachusetts Institute of Technology.

Professor Clark B. Millikan, Associate Professor of Aeronautics, Daniel Guggenheim School of Aeronautics, California Institute of Technology.

Dr. G. W. Lewis, National Advisory Committee for Aeronautics, U.S.A.

Mr. Lester D. Gardner, President, Institute of Aeronautical Sciences.

Mr. Arthur Nutt, Vice-President, Curtiss-Wright Aeronautical Corporation.

Mr. J. C. Zeder, Chief Engineer, Chrysler Corporation.

Mr. Grover Loening, Consultant on Aircraft, War Production Board, U.S.A.

Mr. T. P. Wright, Deputy Director of Aircraft Production, War Production Board, U.S.A.

APPENDIX 2

List of Persons and Organisations Submitting Oral Evidence

Royal Aeronautical Society (Mr. A. Gouge, B.Sc., F.R.Ae.S., M.I.Mech.E., President, Dr. H. Roxbee Cox, B.Sc., D.I.C., F.R.Ae.S., and Captain J. Laurence Pritchard, F.R.S., Hon. F.R.Ae.S., Secretary).

Sir Frederick Handley-Page, C.B.E., F.R.Ae.S., Handley Page Ltd.

Mr. R. K. Pierson, C.B.E., B.Sc., F.R.Ae.S., Vickers-Armstrongs Ltd.

Mr. C. C. Walker, A.M.I.C.E., F.R.Ae.S., de Havilland Aircraft Co. Ltd.

Mr. F. Whitehead, M.I.P.E., M.I.A.E-, Bristol Aeroplane Co. Ltd.

Mr. S. P. Woodley, M.B.E., Vickers-Armstrongs Ltd.

Mr. T. C. L. Westbrook, de Havilland Aircraft Co. Ltd.

British Overseas Airways Corporation (Lord Knollys, K.C.M.G., M.B.E., D.F.C. and Mr. A. C. Campbell Orde, C.B.E.).

Air Vice-Marshal R. O. Jones, C.B., A.F.C., Deputy Controller of Research and Development, Ministry of Aircraft Production.

Mr. E. T. Jones, O.B.E., M.Eng., F.R.Ae.S., Aeroplane and Armament Experimental Establishment, Ministry of Aircraft Production.

Mr. J. Summers, Chief Test Pilot, Vickers-Armstrongs Ltd.

Captain C. Uwins, O.B.E., A.F.R.Ae.S., Chief Test Pilot, Bristol Aeroplane Co. Ltd.

Intava Ltd. (Mr. A. R. Ogston, F.I.P., and members of the Technical Committee).

Mr. W. G. A. Perring, F.R.Ae.S., Royal Aircraft Establishment, Ministry of Aircraft Production.

Rear Admiral A. E. Hall, C.B., C.B.E., A.R.C.S., Director, Education Department, Admiralty.

Mr. W. Bennett, Handley Page Ltd.

Mr. W. H. Cooper, Short Brothers Ltd.

Mr. F. T. Hearle, F.R.Ae.S., M.I.P.E., de Havilland Aircraft Co. Ltd.

Mr. F. Holliday, B.Sc., A.F.R.Ae.S., Vickers-Armstrongs Ltd.

Mr. H. J. Newman, A.C.P., A.R.Ae.S., M.I.Ch.E., M.R.S.T., Bristol Aeroplane Co. Ltd.

Major J. D. Rennie, A.R.T.C. F.R.Ae.S., A.M.I.C.E., Blackburn Aircraft Ltd.

APPENDIX 3

Summary of the Recommendations in the A.R.C. Report

(i) On the assumptions that after the war the aeronautical industry would be very important and that there would be rapid development especially in design, demanding large numbers of scientific and technical staff of high quality, a central post-graduate school in aeronautical science and engineering should be established. The object of this higher training should be to fit the students for leadership, to give them up-to-date knowledge over a comprehensive range of scientific and technical subjects and to acquaint some of them with research and its methods.

(ii) The normal course of instruction should extend over two years, the first being general and the second more specialised. There should also be some provision for specialist and refresher courses for engineers and technicians from industry. The School should not teach at the undergraduate level.

(iii) The aim should be to recruit students from the whole British Commonwealth. They should be of University graduate standard though a university degree should not be essential. Selected engineer and other officers from the Services should be accepted and the selection system should be such that any trade lad or apprentice with the requisite ability may, in due course, enter the School. Students should normally have spent at least one year in industry.

(iv) The principal subjects of instruction should be four: aerodynamics in all its branches, aircraft structures, engines and systems of propulsion, aircraft design and construction. Some instruction should also be given in subsidiary subjects such as production methods, instruments, navigation, airport design and management; for this instruction existing facilities elsewhere should be fully utilised.

(v) The School should co-operate with the research institutions, borrowing lecturers from their staffs and sending its students on visits. The research work in the School itself should be primarily intended to maintain the freshness and vigour of its staff.

(vi) The School should be affiliated to one of the Universities and should exchange freely students and staff with the research departments and the post-graduate schools of the Universities.

(vii) The staff should consist of a Director or Principal, four professors, eight to ten senior lecturers, a supervisor of flight experiments, a registrar and appropriate juniors. They should have conditions of service attractive to men of the highest quality and should enjoy full academic freedom.

(viii) The School should be provided with equipment adequate in scale but not necessarily of very large size. It should have a well-equipped airfield and aircraft for instruction in flight and flight experimentation.

(ix) The School should be financed by the State. The students should all receive scholarships adequate for their maintenance.

APPENDIX 4

Memorandum on the Department of Aerodynamics

Introduction

Aerodynamics, owing to its basic nature, will be studied by nearly all students of the College, but many will either specialise in one or two branches or follow a simplified course. The division of the work of the Department between three Sections will ensure a high standard throughout. Alternative courses of a lower standard or more general character will be provided in each Section.

The leading Section of the Department will deal with the general theory of Aerodynamics, including model experiment and aerofoil design, together with relevant parts of Fluid Mechanics and Heat Transfer. The second Section is primarily intended for matters, such as flutter, depending on Aerodynamics and Elasticity, but may also cover stability and control. The third Section will specialise in airscrews, rotors and propulsion generally together with the more detailed treatment of aircraft performance.

In addition to formal lectures, which should be sufficiently numerous to allow of the discussion of important illustrative examples, supervision will be arranged for the students in groups of two or three.

All students will undertake practical work in the wind tunnels. Many will also carry out measurements in flight within the province of the Flight Department. The Aerodynamics Department has only to provide in the latter connection for correlating model and full scale experiment.

As regards the staff for the Department, a call has been made for three Senior Lecturers, one of whom will be the Head of the Department. Each will be in charge of one of the three proposed sections, and each could be expected to give a maximum of eight lectures per week. Three Junior Lecturers are also proposed, but they are not visualised as being required to give any lectures, except in an emergency ; they are intended to supervise the exercise classes and act as assistants to the Senior Lecturers and in the laboratories.

1.00. Summarised Requirements

1.1. Staff Required

Head of Department.
2 Senior Lecturers.
1 Senior Experimental Assistant
1 Experimental Assistant.
3 Junior Lecturers.
5 Demonstrators.
2 Computors.
1 Personal Assistant to Head.
1 Secretary-typist to Head.
1 Electrician and Mate.
1 Mechanic and Mate.

This full time staff would be supplemented as necessary by visiting specialists

1.2. Laboratory Accommodation

Estimated area required for the Department exclusive of lecture rooms, offices, etc., 40,000 sq. ft.

1.3. Subdivision of Department

Section I. General theory of aerodynamics, including model experiment and aerofoil design together with the relevant parts of fluid mechanics and heat transfer.

Section II. Such items as theory of dynamical stability, stabilising and control of aeroplanes, flutter, load factors.

Section III. Airscrews, rotors and propulsion generally together with the technical prediction and analysis of aircraft performance.

2.00. **Nature of Laboratory Equipment**

A conservative estimate of the number of students and the demands of time-table calls for at least 12 tunnels. The installation of 12 tunnels according substantially with the scheme proposed below is regarded as supplying a minimum equipment, compromises having already been effected. Space should be reserved for duplication of the smaller units in anticipation of increased numbers of students.

The educational policy observed in framing this scheme assumes that students will be admitted at suitable times to the Research Establishments for experience with large plant. Provision is made, however, for research to be carried out by more advanced students and the staff which should add materially to aeronautical knowledge and progress besides maintaining the vigour, contacts and reputation of the Department and the College.

3.00. **Scope of Experiments**

The experiments undertaken, varying with the standard and purpose of the students, will include the following :—

Exercises to foster aerodynamical instincts.
Illustrations of simple fundamentals and phenomena.
Applications of the theory of model experiment.
Instruction in more advanced wind tunnel technique.
Investigation of difficult fundamentals and phenomena.
Checking prediction and correlating results with flight data.
Development research. Original research.

4.00. **Equipment**

Part of this programme requires only small and slow wind tunnels, of which it is proposed to install :—

4.1. 5—Size 4′ × 5′ units.
Atmospheric pressure.
Contraction ratio 5.
Small Reynolds number.
125 ft./sec.
50 h.p.

They may be simply equipped, embody alternative layouts and balances, and possibly cater for different groups of experiments.

These tunnels will be supported by :—

4.2. 1—Size 5′ open jet unit.
Atmospheric pressure.
Contraction ratio 10.
Reynolds number 1 million on complete model.
250 ft./sec.
200 h.p.

4.3. **General Purposes Tunnel**

The need for a general purposes tunnel with a Reynolds number of 2 millions is unquestionable, but some difference of opinion has been expressed as to the form it should take. One view favours an open jet tunnel, at least 16 ft. in diameter, to permit of experiments on airscrews and rotors, flutter with larger-than-full size models, interference, control balancing and cooling; but, after careful consideration, it is recommended that this unit should be installed in the Aircraft Structures Department for experiments connected with the study of structures, and requiring an air stream. It is, therefore, not dealt with here. More economical views have led to the recommendation of the following General Purposes Tunnel for the Aerodynamics Department.

1—Size 13′ × 9′ unit enclosed working section.
Atmospheric pressure.
Contraction ratio 15.
Reynolds number 2 millions on a complete model.
240 ft./sec.
800 h.p.

4.4. Specialised Tunnels

Students should be in a position to experiment at subsonic and supersonic speeds and also on free spinning. General agreement also exists in favour of a low turbulence tunnel for 2-dimensional work. A suggestion by Mr. Perring of the R.A.E. to pressurise this unit, leading to a low turbulence variable density tunnel capable of a high Reynolds number on a complete model, has been adopted. Details of the specialised tunnels recommended for installation are as follows :—

4.41. 3—Size 2′ wide compressed air operated tunnels.
Height of section 8–18″.
Atmospheric pressure.
Speed 800–1,500 ft./sec.

These tunnels will be supplied from High Pressure Compressed Air Reservoirs of 500,000 cu. ft. capacity.

4.42. 1—12′ dia. spinning tunnel.
Atmospheric pressure.
Contraction ratio 3.
Small Reynolds number.
80 ft./sec.
50 h.p.

This unit should also incorporate some measure of vertical stability.

4.43. Variable Density Tunnel

Provision of a high Reynolds number is especially necessary to enable students to measure transitional and small full-scale coefficients, check predictions of scale effect and gain some idea of full-scale interference. Moreover, advanced students and staff will require fundamental data and guidance on stalling and associated phenomena, aerofoil theory, and other important research questions. Tests at high Reynolds numbers are also required for correlation with flight experiments. High Reynolds numbers are produced most economically regarding both capital and running costs by the compressed air method, of which all students should gain some experience.

The Reynolds number attained should not be less than 8 millions on a stalling model. Mr. Perring's suggestion of a 1,000 h.p. 8 ft. by 3 ft. tunnel pressurised to 10 atmospheres falls short, the Reynolds number reached for a complete model being $5\frac{1}{2}$ millions.

The apparatus recommended is :—

1—Size 8′ × 4′ race course type tunnel.
Possible pressurisation to 8 atmospheres.
Contraction ratio 30.
Reynolds number 8 millions on a complete model.
220 ft./sec.
2,000 h.p.

Cooling will be necessary in any case for the above and thus the tunnel can also be arranged to yield, at less than atmospheric pressure, speeds of 500–600 ft. per sec. for 2-dimensional and other experiments, for which the high speed tunnels of paragraph 4.41 are unsuitable.

The compressor plant for tunnels mentioned in paragraphs 4.41 and 4.43 will require to be of approximately 1,200 h.p.

4.5. Other Apparatus and Models

Although only main items of equipment have been listed, it is proposed, of course, to provide the laboratory with all ancillary apparatus and models required to realise the potentialities of its installations. Considerable expenditure will be necessary on an initial range of models, but the Department of Production, Administration and Maintenance will be relied upon for subsequent models, apparatus and replacements.

It is considered important to fit up a small laboratory for experiments on Fluid Mechanics as distinct from Aerodynamics, the advantage accruing to students completely outweighing the small outlay. The second Section of the Aerodynamics Department would ordinarily call for much special equipment, but it is proposed that this Section make use of that provided for airframe structures in the Department of Aircraft Structures, Engineering and Design. That some of the models should be of the elastic kind is implied above.

4.6. Schedule of Cost for Equipment Outlined Above

(i)	8′ × 4′ compressed air tunnel	£150,000
(ii)	13′ × 9′ tunnel	40,000
(iii)	5′ dia. open jet tunnel	6,000
(iv)	5—4′ × 5′ tunnels	9,000
(v)	12′ dia. spinning tunnel	5,000
(vi)	3 Specialised tunnels (paragraph 4.4) including compressor plant	25,000
(vii)	Other apparatus, models, calculating machines, etc.	25,000
	Total	£260,000

4.7. Buildings and Power

The floor area of this Department will cover approximately 40,000 sq. ft. exclusive of the following :—

Lecture rooms and drawing office accommodation.
Offices for staff and supervisions.
Space for duplicating the tunnels outlined above.

The total output h.p. will be approximately 4,500, including an air compressor plant of 1,200 h.p. All the tunnels will incorporate the Ward-Leonard, Kramer, or an alternative electrical system, and the total input h.p. may be provisionally estimated at about 5,000.

5.00. **Outline of Laboratory Accommodation**

		sq. ft.
(i)	Spinning tunnel	1,000
(ii)	Five small tunnels	5,625
(iii)	Small general purpose tunnel	3,000
(iv)	General purpose tunnel	14,400
(v)	Compressed air tunnel	4,400
(vi)	Compressor plant and reservoir	3,500
		31,925
	Working space	8,000
		39,925
	Total, say	40,000

6.00. **Teaching Staff**

The following suggests the staff required to carry out all the duties of the Department. It is assumed that the Head will undertake the lectures in one of the three Sections of the subject, for example the first. Occasional mechanical assistance, together with regular instrument and model making, will, it is assumed, be supplied by the Department of Production, Administration and Maintenance and the College maintenance section.

6.1. **A Professor or Head of Department**

6.11. 2 *Senior Lecturers* to take care of two of the main sections; the head being mainly preoccupied with the other one.

6.12. 1 *Senior Experimental Assistant* to co-ordinate the work of the laboratory as distinct from the lecture courses.

6.13. 3 *Junior Lecturers* for the design and calculations sections, to supervise the exercise classes and to assist in the laboratories.

6.14. 5 *Demonstrators and* 1 *Experimental Assistant* to work under the Senior Experimental Assistant in the laboratories and wind tunnels.

6.15. 2 *Computors* for the research section.

6.2. **Ancillary Staff**

In addition to the above there should be included :

(i) 1 Personal Assistant to Head.
(ii) 1 Secretary-typist to Head.
(iii) 1 Full time Electrician and Mate.
(iv) 1 Full time Mechanic and Mate.

N. A. V. Piercy.

APPENDIX 5

Memorandum on the Department of Aircraft Structures, Engineering and Design

Introduction

The Department of Aircraft Structures, Engineering and Design assembles in the scheme of a single department of the College the principal subjects of aircraft design.

It is felt that Aircraft Structures, so far as the College is concerned, is integral with, and inseparable from, airframe design. This does not derogate from the importance of the subject or preclude adequate arrangements being made for specialisation and research in its more general aspects.

Aircraft Structures should therefore form an important Section of the Department. It will cover theoretical Elasticity in relation to aeronautics, excluding flutter, which is dealt with in the Aerodynamics Department, and also provide a liberal course in Applied Mathematics suitable for the needs of all Departments.

The second and large Section will be the main preoccupation of the Head of the Department. Probably no single man would be conversant with the multifarious details of design problems arising in Service and Civil aviation, but the difficulty will be met by means of visiting lecturers on such matters as armament and radio.

The student will receive a unique training unobtainable in existing universities and colleges ; that is to say, in practical designing at the same time as in the experiments, calculations and tests essential thereto. The method aims at bridging the present gulf between the drafting and technical sides of design. A student can specialise in either Section, but in that case will again benefit by the reaction of one Section on the other.

1.00. **Summarised Requirements**

1.1. **Staff Required**

Head of Department.
3 Senior Lecturers.
Superintendent of Design Office.
Superintendent of Laboratory.
6 Junior Lecturer-Demonstrators.
1 Personal Assistant to Head.
1 Secretary-typist to Head.
2 Computors.
1 Storekeeper and Assistant.
2 Mechanics and Mates.
1 Electrician and Mate.

1.2. **Laboratory Accommodation**

The total floor area required by the Department is estimated to be in the region of 56,000 sq. ft. This is exclusive of lecture rooms and private rooms for the staff and supervisions, but includes the drawing office.

1.3. Estimated Cost and Special Equipment Required

(i)	Apparatus and machines in Structures Laboratory	£75,000
(ii)	Wind tunnel	90,000
(iii)	Design Office equipment	3,000
(iv)	Initial range of models and test pieces	2,000
(v)	Contingency for additional equipment to cover American technique	25,000
	Total ..	£195,000

1.4. Subdivision of Department

It is proposed that the Department be subdivided into the following :

(A) Aircraft Structures.
(B) Aircraft Engineering and Design.

2.00. Laboratory Arrangements

It is recommended that the two sections of the Department share a large laboratory of which occasional use will be required by the airframe section of the Aerodynamics Department.

More students are likely to attend this Department than any other, excepting the Aerodynamics Department, and the apparatus listed below may appear meagre. However, many tests and experiments will call for special rigs rather than permanent installations. The laboratory must be particularly spacious to accommodate complete aeroplanes and the main components of large aircraft under test.

It is assumed that the Government will keep the Department stocked with numerous specimens of up-to-date wings, spar systems, ribs, fuselages, tail units, undercarriages, turrets, engine mountings, control and operation gear, and the like, both for guidance of students in the Design Office and for tests of all kinds, frequently to destruction. To store this bulky material a hangar or other large building directly communicating with the laboratory will be needed.

3.00. Provision for Wind Tunnel Experiments

Wind tunnel experiments will be continually required for which the equipment of the Aerodynamics Department generally is unsuitable. These include practical cooling systems and ducts, with and without airscrew slipstreams ; full-scale control balancing ; operation of flaps ; turrets and undercarriage in the wind ; drag and interference of small details of construction ; autogyro and helicopter rotors ; etc. A large air stream rather than a high Reynolds number or low turbulence is demanded.

It is accordingly proposed to install in the present Department an open jet wind tunnel 16 ft. to 18 ft. in diameter, having a contraction radio of about 6, a speed of 150–200 m.p.h. and a power unit of 2,000–4,000 h.p. The jet will be sufficiently large to accommodate the fuselage of a small aeroplane complete with tail unit and airscrew. Study of engine installation at full power in the wind can also be carried out.

This tunnel will also be of use to the Aerodynamics Department for airscrew and flutter experiments, and should be shared to this extent. The enlargement of the general purposes tunnel of the Aerodynamics Department would not entirely meet the case ; apart from congestion, rather different types of tunnel are desirable.

4.00. **Design Office**

A feature of the present Department will be a commodious Design Office replete with every aid to drafting. The number of students using it at one time is provisionally estimated as 50. The office should be in charge of a superintendent of wide practical knowledge and experience who would be directed by the senior lecturers and assisted by the junior lecturers and demonstrators of both sections of the Department.

5.00. **Testing Machines**

The following testing machines are recommended to be installed. The list includes a certain number of duplications to meet the probable number of students.

Test frame for wings up to 60 ft. long.
Test frame for fuselages up to 45 ft. long.
2 Undercarriage drop testing machines (10 and 30 tons) with oscillographs.
A long test-bed for the study of non-circular torsion, together with soap bubble apparatus.
Various simplified testing frames and machines for the use of students following only a course of a general nature.
4 Fatigue testing machines (5, 10, 20 and 30 tons).
3 Vertical testing machines (5, 10 and 50 tons).
2 Long horizontal testing machines (20 and 100 tons).
4 Creep machines, with furnaces, etc.
Various instruments and apparatus in duplicate or triplicate, including strain and other gauges, oscillographs, aerographs, vibration exciters and pick-ups, calculating machines, large and small weighing machines and usual engineering laboratory equipment, including a travelling hoist capable of transporting complete fuselages, etc.
A small engineering shop for service jobs, equipped with 2 lathes, drills, gauges, etc.

6.00. **Schedule of Cost of Equipment**

(i) Apparatus and machines in Structures Laboratory	£75,000
(ii) Wind tunnel	90,000
(iii) Design Office equipment	3,000
(iv) Initial range of models and test pieces	2,000
(v) Contingency for additional apparatus which may be found desirable after studying American methods	25,000
Total ..	£195,000

7.00. **Outline of Laboratory Accommodation**

	sq. ft.
(i) Aircraft Structures Laboratory	15,000
(ii) Wind tunnel	29,000
(iii) Design Office	4,000
(iv) Specimen Store	7,000
(v) Small workshop	1,000
Total	56,000

8.00. **Teaching Staff**

The staff proposed for this Department is set out below. The word demonstrator is used to indicate a man of practical rather than theoretical qualifications; not a man of inferior standing.

8.1. *The Head of the Department* might take charge of the Aircraft Engineering and Design section and one of the Senior Lecturers might be in charge of the Aircraft Structures. They should both be first-rate men and will probably have to be drawn from the Industry.

8.2. 3 *Senior Lecturers* will be needed, one each for the two main sections and one to deal with Applied Mathematics.

8.3. An important man in the Department will be the *Superintendent of the Design Office* who should obviously be a really high-grade aeronautical engineer. He will have to have had many years' experience in the Industry.

8.4. *A Superintendent* will be required in the Structures Laboratory.

8.5. A total of six *Junior Lecturer-Demonstrators* will be needed to work under the senior people mentioned above.

The teaching staff required, therefore, for the Department of Aircraft Structures, Engineering and Design will be—

1 Head of Department.
3 Senior Lecturers.
1 Superintendent of Design Office.
1 Superintendent of Laboratory.

Various other staff will be required within the Department, including a Personal Assistant and Secretary to the Head, Computors, Storekeepers and Artisans.

N. A. V. PIERCY.

APPENDIX 6

Memorandum on the Department of Engines and Systems of Propulsion

Introduction

This memorandum assumes :

(*a*) that the total number of students of all categories attending the College at any one time will be 300.

(*b*) that a considerable measure of research work will be undertaken in addition to the academic and practical instruction. This is an important point, since it will decide the ultimate scale of the equipment, especially if the research work includes, for example, such items as superchargers or main engines using altitude test plant ; or full-scale propellers running on the appropriate test stands. The value of such massive equipment for purely instructional purposes is open to considerable doubt.

It aims at the highest possible level of quality and where the first cost tends, if at all, to seem prohibitive by present standards, then a process of balanced readjustment can be applied to the proposals to fit the needs of the case. In other words, it is deemed better to think big enough in the first instance and to begin small, but along the desired path, rather than to attempt the reverse which has proved to be unsatisfactory.

Range of Investigation

The procedure, therefore, has been to consider first the Power Plant curriculum on a post-graduate basis and then the kind and amount of equipment desirable to cover the curriculum plus some measure of basic research work to which some of the staff and advanced students will devote part of their time. An estimate of the cost of this equipment is given for the various laboratories based on known costs of similar apparatus or quotations for contemporary equipment now being ordered in various quarters.

Some observations are given on the use of facilities in Government Establishments to augment the functions of the Power Plant Department as regards theoretical and laboratory teaching, since this feature could have some considerable influence in reducing installational costs in the College.

An adequate staff of ancillary personnel will be required in the shape of skilled practical engineers to maintain the plant and be present during " running " experiments and carry out much of the constructional side of experimental work. They should be chosen carefully for their personality and technical and manual aptitude and ability to work in a scholastic atmosphere. A system of payment permitting annual increments over a predetermined scale should be applied and the standard of skill demanded, and the facilities provided, should be such as to attract the best possible type of engineer in this category. An adequately equipped workshop is, therefore, essential, and this should preferably be adjacent to, or part of, the main laboratory building.

The question of additional laboratory equipment to be added in future years is important and due notice must be taken of the trend of power plant engineering. Some observations on this aspect are also given.

1.00. Summarised Requirements

1.1. Minimum Staff Required

1 Professor or Head of Department.
4 Senior Lecturers.
6 Junior Lecturer Demonstrators.

1 Laboratory Manager.
30 Mechanics for laboratories, fitting shop and machine shop. 10 of these should be of superior type.
1 Storekeeper.
1 Technical Assistant to Head.
1 Personal Assistant to Head.

1.2. Laboratory Accommodation

The overall requirements on the scale laid down in this memorandum should not exceed 50,000 sq. ft., excluding a propeller test stand. If the scale of the equipment is considered excessive for the College's purpose, then appropriate reductions can be made in area required.

1.3. Allocation of Time for Studies

It is suggested that the power plant curriculum should be spread over the academic year and not concentrated into a few weeks, except for specialised or refresher courses which will, of necessity, be more concentrated as regards available time.

1.4. Estimated Cost of Special Equipment Required

(i)	Single cylinder beds	£63,000
(ii)	Main test beds	55,000
(iii)	Carburettor and fuel metering	15,000
(iv)	Accessory rigs and blower tunnel	25,000
(v)	Component test rigs	10,000
(vi)	Duct test rigs	5,000
(vii)	Supercharger test rig and refrigeration plant	30,000
(viii)	Radiator and oil cooler plant	14,000
(ix)	Propeller test stand	6,000
(x)	Propeller and vibration test rigs	3,000
(xi)	Large cold chamber	12,000
(xii)	Engine fitting shop	2,000
(xiii)	Turbine fitting shop	2,000
(xiv)	Machine shop (if separated from central facilities)	25,000
(xv)	Turbine test beds and laboratory (inclusive)	50,000
(xvi)	Fuel and oil laboratory	75,000
	Total	£392,000

1.5. Subdivision of Department

The work of the Department of Engines and Systems of Propulsion as catered for by the facilities outlined is subdivided approximately as follows :

1.51. Thermodynamics

(i) Combustion and heat cycles.
(ii) Fuels and oils.
(iii) Heat exchangers.

1.52. Power Unit Design

(i) Reciprocating engines—theory and design.
(ii) Gas turbines—theory and design.
(iii) Propulsive aerodynamics, propellers, jets, rockets.

2.00. Laboratories

These comprise appropriate rooms containing the plant and equipment on which the students will carry out the experiments and practical work related to the teaching syllabus. In addition to experimental plant it will be necessary to have a modern and well-equipped Drawing and Design Office for the Power Plant Department.

2.1. Drawing and Design Office for both reciprocating engine and gas turbine design might well be on the first floor of the Power Plant administrative building and should be of ample size, say 2,500 sq. ft., to accommodate 25 modern drawing boards and office equipment.

3.00. Outline of Work

The department's curriculum will cover, under the two main headings, items listed as follows :

3.1. Thermodynamics

Combustion and heat cycles.
Fuels and oils.
Heat exchangers.

3.2. Power Unit Design

Reciprocating engines—theory and design.
Gas turbines—theory and design.
Propulsive aerodynamics, propellers, jets, rockets.

The curriculum is outlined and the syllabus for the reciprocating engine is given in the Annexe, Item 9·00.

4.00. Power Plant Curriculum

4.1. Thermodynamics

Theoretical work dealing with fuels, combustion, heat exchangers and cycles of operation leading to practical application in—

4.2. Reciprocating Engines

Both 4-stroke and 2-stroke. The main points around which tutorial, design and practical work would be arranged, are given in the Annexe, Item 9·00.

4.3. Gas Turbines and Jet Propulsion

Theoretical work dealing with chemistry and aerodynamics of combustion and heat exchange, fluid flow in ducts and supersonic studies, design, mechanics of machines, stressing. Tutorial and practical work will be built up round these subjects and the grouping might be as follows :

Aerodynamics—blading, ducts, compressors, turbines.
Combustion—chemistry, fuels, burning characteristics, heat exchange.
Design—drawing office work, engineering, stressing.
Testing—bench work, test beds.
Performance—aircraft, engine combustion.

It is important to note that gas turbine development has introduced a special combination of sciences, namely, fluid flow and aerodynamics, in rotary machinery. The importance of these will become greater as knowledge expands.

A general syllabus would include :

Basic Subjects
Thermodynamics.
Aerodynamics and fluid flow.
Physics of gases in motion (heat transfer, convection, diffusion and mixing processes, etc.).
Materials (including elasticity and creep applied to light and heat-resisting alloys).

Stressing.
Vibration analysis.
Processes of combustion.
Mechanical drawing.
Manufacturing processes.
Applied mathematics.
Chemistry of fuels and propellants.

Design Courses (including laboratory experiments)
Review of aeroplane performance and design.
Turbine design.
Axial flow fan design.
Axial flow compressor design.
Centrifugal flow compressor design.
Gas turbine engine design.
Gas turbine engine performance.
Combustion chamber design.
General mechanical design.
Propeller design.
Review of reciprocating engine and gas generator design and performance.

Experimental Courses
Engine testing.
Instruments and their calibration.
Flight testing and performance reduction.
Combustion chamber testing.
Wind tunnel cascade tests.
Axial flow fan tests.
Bearing design and testing.
Vibration analysis.
Engine inspection.
Workshop practice.

In addition, each group of students would jointly design a power plant to suit a given aircraft and each student would be required to do a short thesis.

4.5. Power Plant Installations

Every feature of the reciprocating and gas turbine engine installation will be dealt with on a theoretical, design and practical basis. The important link with aircraft design leading to buried power plants will be taught and emphasised. The influence and solution of aircraft vibrational problems, as affected by the power plant, will also be dealt with.

4.6. Flight Test and Development

Here will be the practical realisation and demonstration under actual flying conditions, of the power plants dealt with in the earlier part of the course—flight development with full instrumentation of engines and accessories, vibrational analysis, performance reduction of test results.

4.7. Research Work

Theoretical and experimental items may be chosen, of a specific nature for solution by staff and advanced students. The items should preferably have some bearing on current problems, so that the Industry may use the solution as soon as possible. Some items of official work may be " contracted for " by the College, and the Industry may also use the facilities for certain pieces of research of a basic character. Enquiry among certain of the engine firms indicated a feeling that the application of basic results to the firm's own product was a matter that would not be amenable to collaboration in the

College, and the firms would continue largely to do their own development work. Such a feeling is, perhaps, natural in view of the financial aspect and the large measure of official subsidising that exists in the Industry on development work. No doubt it will take some time for this situation in regard to a new College to sort itself out, but it seems obvious, that unless the College assumes also the rôle of a research establishment, the kind of research and the availability of large equipment will be strictly limited.

5.00. Schedule of Equipment Requirements for Laboratories

5.1. Reciprocating Engine Laboratories

On a long view, the following indicates the type of equipment which would serve the purpose for a period of 15–20 years without becoming obsolete. It represents what might be attained within a few years of the start of the College —the size of the later installed plant being reviewed then to ensure that advantage is taken of the up-to-date trends. It is assumed also that a reasonable measure of research work will be undertaken—to justify the upkeep of the larger pieces of plant.

(i)	5—single cylinder test beds for powers up to 300 h.p. each. Two to be capable of artificial altitude conditions, one liquid cooled and one air cooled. Boost air pressure, temperature control, motoring and indicator gear required on all sets. Fully instrumented for performance tests, etc. £12,500 each say	£63,000
(ii)	2—main test beds, one air cooled and one liquid cooled for 5,000 B.H.P. single and contra propeller drives. Complete, less buildings, lighting, sound proofing, etc.	£55,000
(iii)	Carburettor and fuel metering laboratory: test rigs for pumps, carburettor fuel and air flow measurements, high speed rigs for slinger ring developments, instruments, gas turbine fuel metering	£15,000
(iv)	Accessory test rigs for starters, remote gear boxes, pumps, etc. As for auxiliary test shop at Gipsy Patch, Bristol, complete with cold starting chamber and 300 m.p.h. 350 h.p. blower tunnel	£25,000
(v)	Component test rigs for engine parts: con-rods, crankshafts, pistons, etc., under vibrating stresses. Similar to those seen at Chrysler Laboratory, Detroit, say 4 units	£10,000
(vi)	Duct test rig for induction system and installation ducting flow tests, blowers, motors and instruments..	£5,000
(vii)	Supercharger test rig 2,500 h.p. in two units similar to Bristol 1,200 h.p. scheme, complete with refrigeration and building	£30,000
(viii)	Radiator and oil cooler test plant for units suitable for 4,000 h.p. engines, complete with instrumentation and taking cold air from Item (vii)	£14,000
(ix)	Blower tunnel with open jet for studying installation problems on engine components such as cowlings, cylinder baffles, exhaust systems, flame damping, etc. on single cylinders and some multi-cylinder units 4′ 0″ diameter with speed of 300 m.p.h. is about the practical limit for the College. Can be eliminated if the full Item (iv) above is accepted, say	£5,000

(x) Propeller test stand : modern silenced hangar similar to latest Rotol type, 22′ diam. throat and to take air or liquid-cooled engines up to 3,000 h.p. *This costs £60,000 for a pair with cable suspension.*

A wing type to take up to 6,000 h.p. engines at 15,000 lb. thrust complete with torque and thrust measurements and instrumented as above. *Cost* £40,000.

A Boeing (U.S.A.) type open-air test stand comprising a wing and nacelle on a rail turntable and sound-proofed observation room for engines up to at least 2,500 h.p. Cost $15,000—say £6,000 now. This last unit could do all that is necessary at the College for power plant and propeller testing. It is, however, noisy.

Propeller and vibration test rigs as per Rotol Co's list—say 6 at £500 each, average cost £3,000

(xi) Large cold chamber 20′ × 20′, if required separately £12,000

(xii) Engine fitting shop with equipment for reciprocating engines £2,000

Ditto for gas turbines £2,000

(xiii) Machine shop for power plant dept., if separated from central facilities £25,000

5.2. **Gas Turbine and Jet Propulsion Laboratories**

(i) 2—main test beds, one to take up to 5,000 lb. thrust fully instrumented (ground level operation only) and one gas turbine engine driving a dynamometer (2,000 h.p.).

(ii) Combustion chamber and heat exchanger test rigs.

(iii) Fuel pump and nozzle rigs for metering systems additional to those in carburettor test laboratory, if desired.

(iv) Rotor balancing rig.

(v) Compressor test rig, 400 h.p. with typical centrifugal and axial superchargers for test.

(vi) Two low-speed axial flow fans and motors (30 h.p. each).

(vii) Fan delivering 50,000 cu. ft./min. at 6″ H_2O pressure for use with low-speed wind tunnel.

(viii) Sundry cascades to suit above.

(ix) Blower delivering 2 to 3 lb. air per sec. at 4 atm. abs. pressure together with motor and piping. This blower to supply air to wind tunnels, combustion chambers or to ducts.

(x) Two blowers delivering 1½ lb. air per sec. at 8″ Hg for sundry tests complete with motors.

(xi) Small shop for making wood and sheet-metal models.

(xii) Vibration equipment including pick-ups, amplifiers and cathode ray tube for studying disc and blade vibration.

(xiii) Tensile testing machine equipped for pulling specimens at high temperatures.

(xiv) Furnace for heat treatment.

(xv) Instrument laboratory together with calibrating equipment (in particular, instruments for gas temperature measurement).

(xvi) Bearing test rig for ball and plain journal and thrust bearings.

(xvii) Laboratory space and equipment for sundry tests on governors, fuel injectors, combustion (gaseous and liquid), gas analysis.

Estimated approximate cost of equipping Gas Turbine and Jet Propulsion Laboratories £50,000

5.3. **Fuel and Oil Laboratory**

The intention is not to teach fuel and oil technology from the production point of view, but to give, in some detail and at a fairly high level of theoretical teaching, to already trained technologists and engine specialists, knowledge of the use and development of fuels in actual engines and of the engineering technique employed in assessing and comparing the results. For this purpose a fuels and oils laboratory with samples of the essential engines and equipment for fuel testing and development will be required. A suitable layout of this equipment and its costs is given below.

(i)	1 Co-operative universal test engine	£4,000
(ii)	2 Bristol Hercules single cylinder units	5,000
(iii)	1 Rolls-Royce Merlin or Griffon single cylinder unit	3,000
(iv)	2 CFR 3-C. units	2,000
(v)	2 CFR/ASTM motor method units	1,000
(iv)	6 JAP single cylinder engines	500
(vii)	Dynamometer and/or water brake equipment for above	12,500
(viii)	Instrumentation, etc., for above	10,000
(ix)	Compressors for boost air, cooling air fans, motive power, etc., etc.	10,000
(x)	Laboratory inspection equipment	2,500
(xi)	Building and installation, sound proofing, machine shop facilities, etc.	25,000
		£75,500

5.4. **Total Estimated Cost**

The total estimated cost of the foregoing, taking the cheapest propeller stand (Boeings), is £392,000

6.00. **Outline of Laboratory Accommodation**

		sq. ft.
(i)	Single cylinder beds	4,100
(ii)	Main test beds..	2,500
(iii)	Carburettor and fuel metering	2,500
(iv)	Accessory rigs and blower tunnel	4,100
(v)	Component test rigs	1,000
(vi)	Duct test rigs	2,500
(vii)	Supercharger test rig and refrigeration plant ..	4,100
(viii)	Radiator and oil cooler plant	2,500
(ix)	Propeller and vibration test rigs	2,500
(x)	Large cold chamber	500
(xi)	Engine fitting shop	5,000
(xii)	Turbine fitting shop	5,000
(xiii)	Machine shop	5,000
(xiv)	Turbine test beds and laboratory (inclusive) ..	5,000
(xv)	Fuel and oil laboratory	3,000
		46,300
	Drawing office	2,500
		48,800

6.1. **Laboratory Accommodation**

The total floor area required to accommodate the equipment tabulated in this memorandum should not exceed 50,000 sq. ft., excluding a propeller test stand, the utility of which is rather controversial from the College aspect. A " Boeing " type as described would be more generally useful and is cheaper. It is an open-air piece of equipment and would need to be remote from the College on account of unsilenced noise.

7.00. **Additional Equipment to be Added in Future Years**

The situation here will clarify itself as time goes on.

It should be realised that the costs outlined above include all the ancillary equipment for the multitudinous tests and experiments that will be done and this equipment will need normal maintenance and replacement as years go on.

As regards the large expensive equipment it will suffice to say here that as the gas turbine power plant develops in the next 15 to 20 years, more and more of the new equipment might well be of this type and the limits of fuels and the reciprocating engines to use them may be more clearly marked.

Obsolescence of equipment fortunately sets in very slowly when instruction only is considered, but it is in the field of research where the equipment can so rapidly fall behind the practical developments. This, therefore, is a major problem in the allocation of the College's status in regard to the large research establishments.

8.00. **Teaching Staff and Classes**

8.1. **Classes**

In view of the nature of the power plant curriculum and the need for broad reading on the part of the students in addition to the normal course of lectures it is suggested that the curriculum should be spread over the academic year on normal University lines with appropriate allocation of time between lectures and practical work to be worked out later.

The probability of research work undertaken by the staff and selected students extending over a reasonable period, makes a concentration of the studies also inadvisable. Specialist and refresher courses may be more concentrated in time allowed.

8.2. **Teaching Staff**

It is thought that a minimum staff for the Department would be

- 1 Professor or Head of Department.
- 4 Senior Lecturers or Assistant Professors.
- 6 Junior Lecturer—Demonstrators.
- 1 Laboratory Manager.
- 30 Mechanics.
- 1 Technical Assistant to Head.
- 1 Personal Assistant to Head.
- 1 Storekeeper.

Experience may show these numbers to be inadequate and additional Senior Lecturers and Junior Lecturer-Demonstrators may have to be provided later.

It is important that the working groups of students should be kept small with as much individual teaching and guidance as possible.

8.21. **Ancillary Staff**

It is suggested that about ten keen, young engineers of the type visualised in the Introduction would not be too many to run the Department, and assist in the practical enlightenment of the students. About twenty others, not necessarily of the same calibre, would also be necessary for more general duties.

9.00. ANNEXE

9.1. Syllabus for Tutorial, Design and Practical Work relating to Reciprocating Engines, both 4-stroke and 2-stroke Cycles

9.11. General Characteristics

Types of engine : radial, V in-line, X, double V, inverted, air/liquid cooled, poppet or sleeve valve, pusher, tractor. Single or contra propellers ; long shaft drives ; coupled engines ; basic design, stressing, weight analysis, performance.

9.12 Mountings

Design, bulkheads, tubular, box girder, overhung mountings, integral with engine, vibration insulation, rubber, springs, damping, quick interchangeability, couplings.

9.13. Cowlings

Design, materials, thicknesses, aluminium, dural, magnesium, rigidity, reliability, working platforms, fasteners, general engineering, quality, future trends, enclosure of buried engines, ducting.

9.14 Air Cooling

Air-cooled cylinder fins : pitch, depth, use of copper and light alloys, methods of attachment to barrels. Baffles, ducts, forced draught, entry and exit shapes, controls, gills, shutters, hydraulic and electric servos.

9.15. Liquid Cooling

Cylinder construction, pipe systems, pumps, coolants, header tanks, pressure cooling, capacities, radiators, primary and secondary surfaces, construction, light alloy, brazing methods, "cycleweld," weights, mountings, vibration effects, pipe joints, pipe materials, relief valves. Automatic controls : electric, hydraulic, future trends. Forced draught, exhaust gas/air injectors, thrust recovery, aids to cold starting, coolant preheating.

9.16. Oil System

Coolers : construction, controls, mountings, relief valves. Pipe systems, scavenger pumps, drowned sumps, deaeration, filtration, pressure pumps, aids to cold starting, oil dilution, oil preheating.

9.17. Induction System and Fuel Metering

Intakes : construction, materials, position, ramming, sheltered wing entries, leading edge, boundary layer, hot and cold air, shutters, controls, anti-icing, ice-guards, internal freezing, air cleaners, momentum and/or filtration, aerodynamic characteristics. Carburettors : metering, continuous injection, timed cylinder injection, controls, boost and temperature characteristics, enrichment, maximum economy.

9.18. Supercharging

Blowers : centrifugal, axial, single and multi-stage, gears, speeds, controls, guide vanes, impellers, diffusers, efficiency, pressure ratios, temperature rise weights, bulk, materials, detail design, mountings, position in plant, charge coolers, air/air and air/water intercoolers, construction, matrices, brazing and welding methods. Turbo blowers : types, construction, installation.

9.19. Exhaust System

Materials, thickness, methods of fabrication, manifolds, ejectors, flame damping, exhaust thrust, drag, joints, mounting, cabin and wing heating, heat exchangers, CO contamination of cabin air, future trends.

9.20. **Reduction Gear**

Single or two-speed, spur, concentric, epicyclic, controls, power measurement by torquemeter, alloy-housing, bearings.

9.21. **Shaft Drives**

Types of shafts, lengths, couplings, gear-boxes, clutches, bearings, mounting structures, flexibility, flanges, splines, lubrication, weights.

9.22. **Accessories**

Auxiliary power units, pumps, compressors, controls. Starters: electric, cartridge, I.C. engines. Generators, remote gear-boxes.

9.23. **Ignition System**

Magnetos, harness, ceramic plugs, distributors, high frequency systems, insulation, future trends.

9.24. **Fuels and Oils**

Present position, octane values, dopes, composition, production rates, manufacture, new hydrocarbons, future trends.

9.25. **Propellers**

Design, construction, materials, single and contra, multi-blading, operation, hydraulic, electric, controls, governors, feathering, air brakes, ducted fans, wood, metal, future trends.

N. S. MUIR.

APPENDIX 7

Memorandum on the Aircraft Equipment Department *

Introduction

This memorandum assumes that the facilities in the Department should be capable of meeting the requirements with the necessary degree of flexibility for those students who would be taking the general two-years' engineering course, and with sufficient additional accommodation, equipment, etc., to cater for the needs of groups who would require to specialise in one or more sections of the work of the Department.

It is further considered that out of the time to be spent in the whole two-years' course, from 15% to 20% should be devoted by the general student to this Department. Such a proportion would appear to be both the maximum and minimum which should be so allotted, in view of the very great width of the entire curriculum on the one hand and the complexity of the work of this Department on the other.

The task has been approached by endeavouring to arrive at an estimate of the laboratory facilities required, with their special equipment, since the practical or demonstration side of this work necessarily forms a large proportion of the teaching of the underlying principles, and it is felt that this treatment is the readiest means of determining the basis of estimate on which the necessary facilities can be provided.

It should be noted that no provision is made herein for the teaching of the broader aspects of physics or other applied sciences in the various specialised directions related to the work of this Department. It will, however, be fully appreciated that both general and specialist students will have to have the necessary preparation in physics subjects. The teaching of the background on physics is outside the scope of the Department, which is regarded as offering instruction in the branches of this work as applied to aeronautical engineering. Should it be decided to include the teaching for the necessary physics in the curriculum of the College, an ancillary department for such purposes would be needed to cover all branches of applied science, leading to the specialised work in the several Departments of which the Aircraft Equipment Department is one.

The outlined scheme, which follows, has been discussed in a preliminary form with the R.A.E., Farnborough, various firms and the electrical department of one of the larger technical colleges in the London area and various modifications and additions in detail have been incorporated, arising out of these discussions.

1.00. Summarised Requirements

1.1. Staff Required

1 Head of Department or Professor.
4 Senior Lecturers.
4 Junior Lecturers.
8 Laboratory Demonstrators.
1 Laboratory Manager and Assistant.
2 Electrical Mechanics.
2 Instrument Mechanics.
2 Engineering Mechanics.
2 Storekeepers.

* In accepting this memorandum as an Appendix to their Report, the Committee wished to stress the importance of this Department in catering for students coming from the Aircraft Accessory Industry, as well as from the Aircraft Industry itself. They also wished to record the high value attached by the Service to this Department as a means of improving the design of aircraft equipment.

This full-time staff should be supplemented as necessary by specialists visiting or temporarily attached.

1.2. **Laboratory Accommodation**

	sq. ft.
Electrical and instrument section	22,000
Hydraulic and pneumatic section	6,000
Miscellaneous systems and equipment (de-icing, fire fighting, etc.)	5,000
Total ..	33,000

1.3. **Allocation of Time for Studies**

Laboratory work, one half-day period per week, spread over the full time of course for general students ; augmented as necessary for specialist courses.

1.4. **Tutorial Class Time**

Minimum six weeks' course in each year for general students ; augmented as necessary for specialist courses.

1.5. **Subdivision of Department**

The work of the Department is assumed to be subdivided approximately as follows :

(i) Aircraft electrical equipment.
(ii) Engine accessories and ignition.
(iii) Electronics.
(iv) Aircraft instruments.
(v) Special instrumentation for test flying.
(vi) Electrical strain gauging and vibration testing.
(vii) Hydraulics and pneumatics.
(viii) Miscellaneous equipment, including de-icing, fire fighting and ground trolleys.

2.00. **Laboratories**

Estimated 50 students per year for two-year courses and up to, say, 25% of the 200 students for short courses would require to use the laboratories, the former to the number of 100 on, say, one half day per week, and the others, say 50, for three or four half days per week. This indicates about 50 students using the laboratories at one time in parties, ideally of two each, or in some cases of three, so that about 20 experiments need to be catered for simultaneously. Of these some 12 to 15 would be in the electrical, electronic or instrument sections, and the remainder spread over hydraulics and pneumatics, and miscellaneous equipment sections.

2.1. **Scale of Equipment**

Each course should carry out 50 to 75 tests, so that the minimum initial equipment would have to cover say 200 tests, allowing for some selection in both general and special courses.

This equipment should be divided among :

(i) Aircraft electrical equipment.
(ii) Engine accessories and ignition.
(iii) Electronics.
(iv) Aircraft instruments.
(v) Special instrumentation for test flying.
(vi) Electrical strain gauging and vibration testing.
(vii) Hydraulics and pneumatics.
(viii) Miscellaneous equipment.

3.00. Schedules of Work and Special Equipment

To assess the special equipment required in the various laboratories, it will be considered in relation to the principal subjects to be taught under the several headings.

3.1. Aircraft Electrical Equipment

3.11. *Work to cover* design, performance, and characteristics of d.c. and a.c. motors and actuator assemblies ; performance and characteristics of aircraft accumulator at normal and low temperatures ; design and performance of switch gear, relays, etc., on d.c. and a.c. under high altitude and sea-going conditions ; principles of communication and aids to flying ; electrical installation systems for different classes of aircraft ; principles and practice of aircraft wiring ; principles of electric servo operation for undercarriage, flaps, tabs, etc. ; suppression of interference.

3.12. **Special Equipment Required will include :**

D.C. motors : range of types and sizes with associated gearing.
Actuators : range of types and sizes with self-contained motors, d.c. and a.c. as and when available.
A.C. motors of larger type for aircraft service, 0·5 to 10 h.p.
Generators : 1·5 kW., 3 kW. and 6 kW. at 29 volts d.c.
Alternators : range of standard sizes as (to be) adopted.
Blast cooling installation requirements for generators and alternators.
Aircraft component rigs for landing legs, flap and servo tabs.
Switchgear : range of cut-outs, voltage regulators, relays for d.c. and a.c., and suppressors.
Selsyns, including power and differential types.

3.2. Engine Accessories and Ignition

3.21. *Work to cover* design and performance of magnetos from small (e.g. Gipsy) engines to multi-cylinder types for high altitude ; screening ; research into improved systems of ignition ; research into performance of spark plugs with special reference to high altitude ; design and performance of electric starters ; design and performance of engine driven generators and alternators ; research on gas turbo alternators ; design and performance of electrical regulator equipment for turbo supercharger ; design and operation of electric single-lever engine controls.

3.22. **Special Equipment Required will include :**

Magnetos : 12 various types and makes.
Test frames, three with variable speed drives for mags.
Magneto and plug testing chamber to reproduce cylinder conditions combined with 75,000 ft. altitude conditions, with necessary equipment.
High voltage cathode ray oscillograph. Peak voltmeter.
Test rig for starter of plain cranking and differential inertia/cranking types.
Test rig for engine driven generator and alternator.
Test rig for turbo supercharger regulator.
Rig for development of electric engine controls.

3.3. Electronics

3.31. *Work to cover* principles of electronic operation and devices ; principles of communication and aids to flying ; special amplifiers for instrumentation ; integrating and differentiating circuits ; phasing of events and multi-channel recording; oscillographs, analysis of wave forms; transients; principles of measurement by electro-magnetic capacitance; piezo and resistance pick-ups; use of carrier frequencies for amplifying; power packs for electronic apparatus.

3.32. **Special Equipment Required will include:**

2 Valve voltmeters.
1 Audio frequency oscillator.
1 Very low frequency oscillator.
1 Valve test set.
2 Electrostatic voltmeter.
2 Strobotacs.
2 Drum cameras with timing circuits.
Electronic and radio: set of control equipment for turbo waste gate, and set of general purpose radio communication equipment, d.f. loop aerial and beam approach equipment with power units, representative electronic control equipment of industrial type for demonstration of principles. Radio altimeters, capacity and reflection types.
Initial stock of valves, C.R. tubes, resistors, capacitors and components.

3.4. **Aircraft Instruments**

3.41. *Work to cover* principles and operation of flight instruments (non-electrical types); characteristics of aircraft compasses; principles and operation of electrically operated cockpit instruments; layout of cockpit instruments and lighting; principles and operation of gyro instruments; principles and operation of automatic pilots.

3.42. **Special Equipment Required will include:**

Representative range of all commonly-used aircraft instruments in duplicate.
Vacuum pumps: three standard or suitable types.
Compasses: range of pilots and observers types, distant reading compass and remote indicating compasses.
Auto pilots: one set of each make of British and American equipment.
Cockpit sections of representative aircraft of 1, 2 and 4 engine types; three of each.

3.5. **Special Instrumentation for Test Flying**

3.51. *Work to cover* methods of measuring control forces, control surface displacement and loads, flight conditions, accelerations and movements in space; temperature and pressures in all parts of air, oil, fuel, exhaust and coolant systems, cylinder temperature; engine torque; propeller pitch; special thermo junctions; pressure heads, etc., for instrumentation purposes; methods of recording flight instrumentation data, photo recorders, recording potentiometers, small pressure recorders.

3.52. **Special Equipment Required will include:**

Control columns and rudder bars; four sets, various.
Empenage assembly for measurement of displacement and application of artificial loads.
Aileron assembly for similar use.
Force recorder: four sets various for stick and rudder.
4 Calibrated links for insertion in control cables. Sensitive position transmitters and indicators, 12 sets desyn (d.c.), 12 sets autosyn (a.c.).

10 Special gyro indicators, for rate of roll, pitch and angular velocity and displacement.
1 Trailing static head.
3 Mach number meters.
Photo recorders: four (two large and two small for 10 to 50 dials) with special recording cine cameras, mirrors and illumination. Recording potentiometer for multi-point temperature. Manometer recorders, with cine cameras, mirrors and illumination for 40 and 200 tubes. Thermo-couple and pitot tube apparatus, including calibration apparatus.

3.6. Electrical Strain Gauging and Vibration Testing

3.61. *Work to cover* use of strain gauges for measurement of stresses in specimen sections of bar and sheet, structures of spars, wings, tail units and for cut-outs; similar applications to propeller blades; measurement of torsional stresses in shafts and torque tubes; hinge moment measurements and assessment of loads on control surfaces.

Use of d.c. bridge arrangements for static testing with galvos and recorders for multi-point switching; use of carrier frequency amplifiers for recording steady or slowly varying strain.

Use of strain gauges, amplifiers and oscillograph to measure stresses in vibration; in structures, propeller blades, shafts and power plants, both on the ground and in flight.

Investigation of effects on strain gauges of temperature, humidity, etc., and methods of attachment, temperature compensation by use of dummy gauges; use of multiple gauges in compression and extension, and in rosette formation for special application.

Use of generator and reluctance type accelerometers for measurement of vibration, and low periodicity acceleration and displacement amplitudes with linear and carrier frequency amplifiers and multi-channel seismic type oscillograph, in ground tests and in flight; determination of flutter characteristics.

Use of cathode ray oscillograph to investigate high-speed transient vibration from gun blast; simultaneous use of strain gauges and accelerometer pick-ups with oscillograph for investigation of shock loads in landing, etc.

3.62. **Special Equipment Required will include:**

Static testing machines for bar samples.
Static testing machine for spar structures.
Static testing machine for wing sections.
4 High grade extensometers for calibrating.
6 50-pt. strain gauge switch units.
3 d.c. bridge units.
3 Sensitive light spot galvos.
2 Electronic bridge amplifiers.
1 12-element seismic type oscillograph
2 6-channel linear amplifiers with power units.
2 6-channel carrier frequency amplifiers with power unit.
6 Generator type accelerometer pick-ups.
6 Light movement reactance pick-ups.
6 Strong movement reactance pick-ups.
1 Portable (General Radio or similar) vibration meter.
1 Portable (General Radio or similar) sound analyser.
1 Calibrating table (horizontal and vertical) for pick-ups.
1 Tinsley pen recorder and amplifier.

1 Tinsley multipoint oscillograph recorder.
2 (Initial) flutter models of wing and tail units.
1,000 (initial stock) wire strain gauges.
50 (initial stock) condenser type strain gauges.
Motor vibrator with flex drive and applicator.
1 Vibrograph.

3.7. **Common Instruments and Equipment for Electrical and Instrument Laboratories**

Principal requirements will include :

12 Laboratory type sub-standard milli-voltmeters.
12 Laboratory type unipivot type milli-voltmeters for use with thermo junctions. Multiple ranges.
10 Laboratory calibrated thermo-junctions—various ranges.
3 N.C.S. sub-standard voltmeters multiple range.
6 Universal first grade A.V.O. meter test sets.
50 Shunts for millivoltmeters.
12 Moving coil d.c. ammeters and various shunts.
6 Rectifier type a.c. ammeters, first grade.
6 Multiple range current transformers for 250 and 400 c/s, and meters to suit.
12 Thermal type volt and ammeters.
4 Dynamometer wattmeters.
6 Dynamometer voltmeters
6 General purpose C.R. tube portable oscilloscopes.
6 Special purpose C.R. tube oscilloscopes, with time bases, bridge units, trigger units, etc.
3 Pull-through recording cameras for C.R.T.O's.
2 Dial-type Wheatstone bridges with galvo for measuring resistance.
6 Workshop-type potentiometers for thermo-couples.
1 High-grade a.c. bridge for measuring inductance and capacitance and frequency.
1 Signal generator and power amplifier (audio frequency).
1 A.C. standard potentiometer.
2 Decade standard variable condensers.
4 Decade high resistance boxes.
1 D.C. standard potentiometer.
10 Motors of $\frac{1}{4}$ h.p. to 15 h.p.
6 Hand tachometers.
6 Motor converter units for special supplies.
2 Small 500 v megohm testers, or meggers.
Chamber for altitude testing of equipment.
Dark-room equipment.

3.8. **Hydraulics**

3.81. *Work to cover* application of fluid mechanics to aircraft services ; design and performance of hydraulic pumps, jacks, accumulators and special valve devices ; comparison of low and high pressure systems ; temperature effects ; characteristics of oils and packing materials ; design and performance of shock absorbers and oleo legs.

3.82. **Special Equipment will include :**

Test bench for valve fittings.
Test bench for pressure gauges and calibration of instruments.
Test rigs for engine pumps.

Test rigs for large undercarriage legs with low and high pressures.
Test rigs for small undercarriages with provision for low temperature performance testing.
Test rigs for wing flaps with provision for artificial loading.
Test rigs for locking, indicating and remote control systems.
Low temperature viscosity apparatus.
Stock of assorted valves and fittings.
Range of 12 pumps in three or four size swith variable speed drives, including three motors of 2, 5 and 10 h.p.
Range of 12 jacks in six sizes.
Stock of assorted packing rings and jointing materials.
Stock of aircraft type oil pressure gauges of ranges 500, 1,000, 1,500 and 3,000 lb./sq. in. or as available.
12 High-grade gauges of similar ranges for reference.

3.9. Pneumatics

3.91. *Work to cover* principles of compressed air and vacuum actuation as applied to aircraft services ; operation of wheel brakes ; cannon firing, cabin pressure valves, air tube sealing ; emergency loading systems for hydraulics, etc.

3.92. **Special Equipment will include :**

Test bench for pneumatic fittings.
Test bench for calibrating instruments.
Two air compressors for 100 lb./sq. in. 1 h.p. and 3 h.p. motors.
Two air compressors for 300 lb./sq. in.
12 Aircraft type vacuum pumps of various makes and capacities.
Typical compressed air and vacuum systems complete for a large and a small aircraft with 200% spare fittings.
Stock of air pressure gauges of assorted single, triple and differential types.
12 High-grade air pressure and vacuum gauges for reference.
Assortment of compressed air bottles of aircraft and industrial types.

3.10. Miscellaneous Systems and Equipment

3.101. *Work to cover* principles and practice of de-icing (heat transfer by air, electrical and mechanical means, de-frosting action of liquids and pastes) ; fire fighting (Graviner, Lux, etc., systems) ; oxygen (storage, distribution, warning systems, precautions, protection of bottles) ; photographic (aircraft cameras for military and survey purposes, and applications to flight instrumentation), heating and ventilating (application of heat exchange equipment, regulating devices and design of systems) ; passenger equipment (provision of maximum comfort for minimum weight) ; ground equipment (trolleys for electric, compressed air, etc., services, passenger services) ; sound insulating methods and equipment.

3.102. **Special Equipment Required.**

The equipment for this section should be a museum of all current equipment laid out in systems where applicable and kept up to date by the addition of new items as introduced.

4.00. **Schedule of Costs of Equipment Requirements for Laboratories**

(i)	Special equipment for engine accessories and ignition	£3,000
(ii)	Special equipment for aircraft electrics	5,000
(iii)	Special equipment for electronics	3,000
(iv)	Special equiqment for aircraft instruments ..	6,000
(v)	Special equipment for instrumentation for test flying	5,000
(vi)	Specail equiqment for strain gauging and vibration	5,000
(vii)	Common equipment for electrical laboratories ..	5,000
(viii)	Special equipment or hydraulic and pneumatic section	5,000
(ix)	Special items of miscellaneous equipment	3,000
(x)	Equipment of laboratory workshops..	7,000
(xi)	Equipment for demonstration and lecture room ..	1,000
	Allow 25% for incidental items	12,000
	Allow 12% extra for special research equipment ..	6,000
	Total ..	£66,000

No amount is here included for the installations of fixed apparatus and plant, e.g. power supplies, accumulator charging, which should be covered in the cost of buildings, and their fittings.

5.00. **Outline of Laboratory Accommodation**

5.1. **Electrical and Instrument Block**

Separate rooms each, approx. :

		sq. ft.
(i)	Electrical equipment 50′ × 50′	2,500
(ii)	Engine accessories and ignition 25′ × 50′	1,250
(iii)	Electronics 25′ × 50′	1,250
(iv)	Layout space for electrical systems 25′ × 50′ ..	1,250
(v)	Aircraft instruments (incl. space for cockpit) 50′×50′	2,500
(vi)	Instrumentation for test flying 50′ × 50′	2,500
(vii)	Strain gauging and vibration 50′ × 50′	2,500
(viii)	Dark room (incl. photographic) 10′ × 50′	500
(ix)	Demonstration and small lecture room 25′ × 50′ ..	1,250
(x)	Cloakroom and lavatory accommodation 20′ × 50′..	1,000
(xi)	Accumulator and converter room 10′ × 50′ ..	500
(xii)	Equipment and special stores room 25′ × 50′ ..	1,250
(xiii)	Workshop and ready use stores 25′ × 50′ ..	1,250
(xiv)	Offices of laboratory manager and storekeeper 10′ × 50′	500
(xv)	Central corridor space 10′ × 200′	2,000
	Overall size of floor 200′ × (50′ + 10′ + 50′)	
	Total area	22,000

5.2. **Hydraulics, Pneumatics and Miscellaneous Equipment Block**

Separate rooms each, approx. :

		sq. ft.
(i)	Hydraulics 50′ × 75′	3,750
(ii)	Pneumatics 50′ × 25′	1,250
(iii)	Miscellaneous equipment 50′ × 75′	3,750
(iv)	Preparation and fitting shop 50′ × 25′	1,250
(v)	Central corridor space 10′ × 100′	1,000
	Overall size of floor 100′ × (50′ + 10′ + 50′)	
	Total area	11,000

5.3. **Layout of Laboratory Buildings, etc.**

Suggested layouts of the electrical and instrument block, and hydraulics, pneumatics and miscellaneous equipment block, are given. The roofs should be of " North light " type along each row of laboratories, with skylights along corridors. Artificial lighting should be by daylight fluorescent discharge tubes to a minimum of 60 foot-candles on the working plane (3 ft. above floor level).

6.00. **Teaching Staff and Classes**

6.1. **Classes**

6.11. **Laboratory Work**

The time required to be allotted to practical work as indicated in paragraph 2.00 is, one half day period per week for general students, and this time would need to be spread throughout the course to avoid undue congestion in the laboratories. The laboratory accommodation suggested above will provide a degree of flexibility in dealing with the varying requirements of general students and those specialising whether in electrical engineering, instrumentation or vibration, or other branches of aircraft equipment. There would be about 20 principal tests or experiments going on at all times, each with two or more students in partnership.

6.12. **Lectures**

As regards tutorial class time, it would be preferable for the time devoted to the various subdivisions to be taken over a consecutive period in the course rather than split up on a basis of so many hours per week. This would enable compact classes to run in rotation throughout the term of residence. Assuming not less than 35 weeks to the working calendar it is estimated that five weeks would be allowed for tutorial work in electrical engineering, instruments, instrumentation and vibration engineering for the general student and, of course, much longer for those intending to specialise in any of these branches. For specialist courses somewhat similar arrangements would hold with the periods extended as required. A week should be allowed for those who require to cover hydraulics and miscellaneous aircraft equipment.

Dividing the five weeks' general course between the electrical subjects covered, this would give two weeks for electrics, ignition and engine accessories (starters, generators, etc.), one week each for electronics and aircraft instruments, and one week for special instrumentation and vibration with strain gauging. This time must clearly be regarded as the minimum required for these subjects. For efficiency and convenience it would be preferable to break up the groups of students into classes of 10 to 15 so that there would be a steady flow through the tutorial staff. It will obviously be necessary for the Board of Studies to prepare carefully co-ordinated time-tables.

6.2. **Teaching Staff**

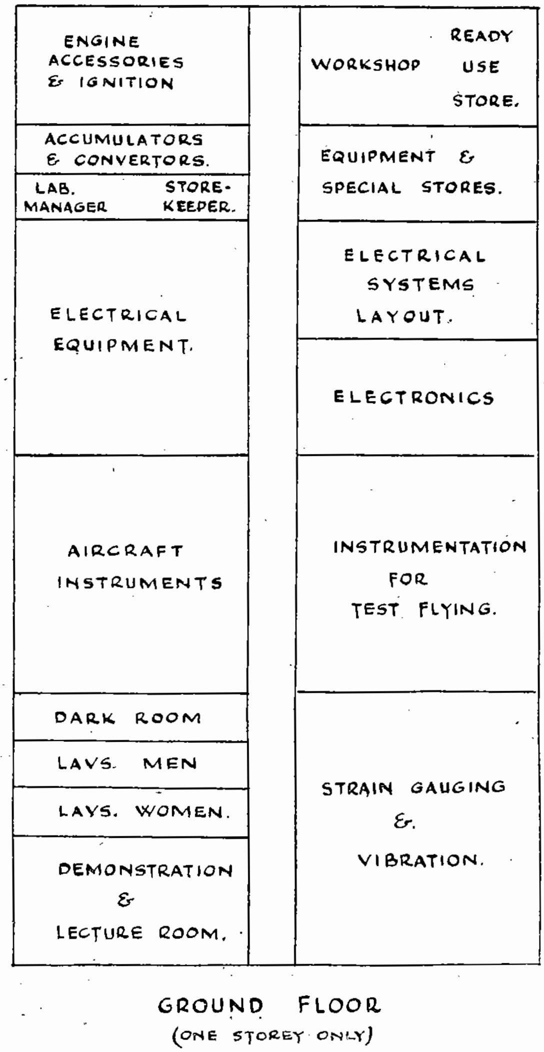
6.21. Full time Senior Lecturers will be required for :

(*a*) Electrical engineering.

(*b*) Instruments and instrumentation, preferably of engineering outlook.

(*c*) Strain gauging and vibration, preferably of physicist outlook.

(*d*) Non-electrical equipment (hydraulics, etc.).



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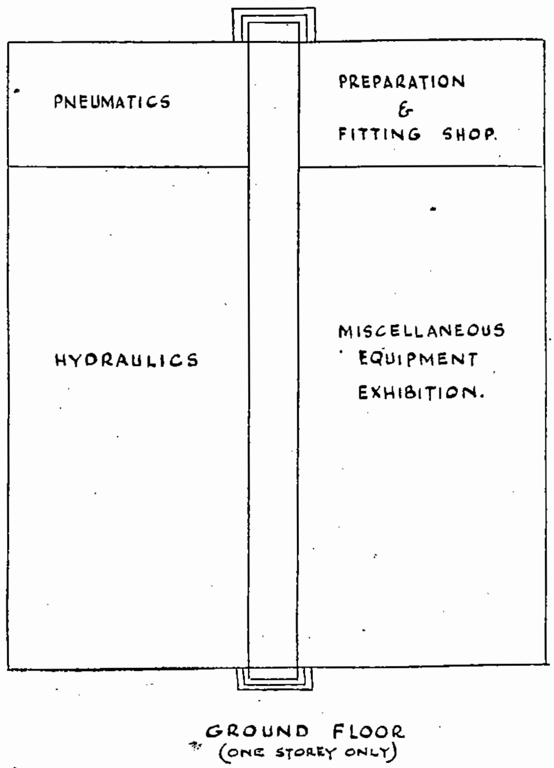
Suggested Plan for Layout of
Electrical and Instrument Laboratory Block.



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Suggested Plan for Layout of
Hydraulics, Pneumatics and Miscellaneous Equipment
Laboratory Block.

6.22. There should also be four **Junior Lecturers** for electronics, and for instrumentation and strain gauging, for ignition and engine accessories, and for miscellaneous equipment.

6.23. **A Professor or Head of the Department** will be needed, and in collecting the staff for the Department, a suitable balance should be aimed at between the outlooks of engineering practice and scientific development.

6.24. **Laboratory Demonstrators**

A total of eight will be required of good training and experience for:

(*a*) Aircraft electrical engineering.
(*b*) Aircraft instruments (applied physics).
(*c*) Strain gauging and vibration.
(*d*) Electronic applications in all branches.
(*e*) Special instrumentation of test flying.
(*f*) Engine accessories and ignition.
(*g*) Hydraulics.
(*h*) Miscellaneous equipment.

The teaching staff required, therefore, for the Aircraft Equipment Department will comprise:

1 Professor or Head of Department.
4 Senior Lecturers.
4 Junior Lecturers.
8 Laboratory Demonstrators.

These should be supplemented from time to time by specialists visiting or temporarily attached to deal with the needs of any particular special course or research which may be decided upon.

6.3. **Staff for Equipment and Maintenance**

In addition to the Laboratory Demonstrators referred to above, it will be necessary to provide for specialist maintenance and some construction work on instruments and equipment. This work will be outside the scope of the general maintenance of installations throughout the College. A minimum of two (one senior) skilled instrument mechanicians will be required with adequate knowledge of the physical properties of electrical and instrument materials, and two each general electrical and engineering mechanics. These together with two storekeepers should be under the charge of a Laboratory Manager and his assistant.

C. G. A. Woodford.

APPENDIX 8

DEPARTMENT OF PRODUCTION, ADMINISTRATION AND MAINTENANCE

Memorandum on the Production Section

Introduction

Whilst there appears to be some diversity in viewpoint on detail matters connected with the problem, all the people with whom I have consulted are agreed on the necessity for students being trained in shops actively engaged on aircraft production work. It is also generally agreed that there is a vital need for a co-ordinated training scheme for aircraft production engineers which will provide a wider scope than the system existing hitherto.

Whilst sound workshop training can be had in any good engineering works, aero-engine and airframe production engineers, to be of any real value to the Industry, must have received a course of training in *actual production in these branches*, where a number of the methods or processes employed are special to aircraft production. This applies to a smaller extent in the case of students specialising in certain subjects with the object of becoming departmental chiefs. Generally speaking the aircraft industry employs a far wider range of processes and methods than other fields of engineering.

Simple examples of the special methods or processes may be quoted as follows :

Heat Treatment and Methods of Hardening

Special quenching jigs, about which little is known outside the Industry, are often found to be necessary for successful hardening of light section highly stressed components, i.e. to prevent distortion.

Specially designed furnaces, etc., are often necessary and this involves close co-operation between the aircraft firms and suppliers of the equipment.

Nitrogen, cyanide and other hardening processes which may be in general use are essential to the aircraft industry.

Polishing

Although regarded in general engineering as of no consequence polishing and the removal of sharp corners and tool marks is of vital importance to highly stressed parts. (The use of Professor Coker's polarised light, stress determination method could well be employed by the design side of the College to illustrate this point and to provide general information on the serious influence of violent changes in section).

Special Drawn or Rolled Sections peculiar to Aircraft Structures

A wide range of special sections has already been developed either directly by the aircraft industry, or in collaboration with other firms, resulting in considerable improvements in design with attendant weight saving and enhanced aircraft performance.

Future aircraft designs will obviously be dependent on continued development of production methods in this field, and in consequence, potential production engineers and designers of the future must be trained to appreciate the further possibilities in this direction.

Photo Lofting and Mould Lofting

These methods, developed by the aircraft industry to provide for the quick and accurate production of a wide variety of shapes and profiles in sheet metal work, have effected a considerable saving in vital man-hours previously spent in the manufacture of templates and in pattern making.

The stretching press technique employed on large sheet metal parts, the rubber platen and zinc die developments in connection with presses employed on a wide range of the smaller sheet metal parts of fairly intricate design and for producing complicated bends in pipes of large diameter, and numerous other examples could be quoted, but the above simple cases will serve to show the need for prospective aircraft engineers being trained in shops where the full range of work essential to aircraft production is actually practised.

They will also serve to show the vital need for the provision of a co-ordinated training scheme as mentioned in the first paragraph, the state of development in technique varying fairly widely between the several factories engaged on aircraft production.

As an example of what may be expected in the way of future development of special production methods by the aircraft industry, one might mention the "Lost Wax Method" of casting intricate shaped parts to tolerances as close as ·0005 in. to finished size, eliminating almost completely present expensive machining operations on a wide range of parts. This process—virtually a resuscitation of an early Chinese method of casting, applied by modern science to meet the needs of a progressive industry—is now in course of development.

1.00. **Summarised Requirements**

1.1. **Staff Required**

1 Head of Section.
3 Senior Lecturers.
5 Junior Lecturers.

This full time staff should be supplemented as necessary by specialists visiting or temporarily attached.

1.2. **Workshop Accommodation**

Workshops on the scale outlined later would probably take up to 50,000 sq. ft. of floor area.

1.3. **Allocation of Time for Studies**

It is not possible to specify these requirements at the present stage, since the amount of work to be covered at the College will be entirely dependent on the degree of co-operation given by industry in providing initial instruction to students before entering the College, and also on the extent of the co-operation of accredited firms to which students might be attached for more advanced instruction.

1.4. **Estimated Cost of Equipment Required**

(i)	Machines and special equipment for prototype machine shop	£80,000
(ii)	Standard and special equipment for standards room	8,000
(iii)	Machines and special equipment for sheet metal shop	12,300
	Total ..	£100,300

1.5. Subdivision of Section

The practical work of the section as envisaged is divided among the following:

(i) Machine shop.
(ii) Standards room.
(iii) Sheet metal shop.

2.00. Range of Production Subjects to be Covered

It is generally agreed that the whole field of production, from "raw material" to "finished product" must—in the case of potential general managers, works managers and, we hope, managing directors of the future—be thoroughly covered. Students specialising in any particular field during their course at the College, would do well to study an allied subject, for example, inspection and quality control engineers should familiarise themselves with the standards of finish required by the design; particular attention being given to polishing, removal of sharp edges, close inspection for signs of local cracking or over-heating of ground surfaces, etc.

The courses to be taken would be in any event decided by the Careers Advisory Committee of the College when it was known what field of work the student was intended to cover subsequently in industry.

The whole field can be roughly outlined in sequence as follows:

Goods inward and despatch.
Raw material.
Stores sections.
(Raw material, rough stores, finished parts, etc.)
Purchase department.
Production planning and control.
Time study.
Wages and costs.
(Mechanised methods of checking, sorting and recording.)
Material control.
Jig and tool design.
Inspection or quality control.
Standards room.
Plating, polishing and processes.
Machine shop.
Heat treatment.
Tool room.
Sheet metal shop (including photo lofting, mould lofting, draw bench and section rolling, development of pressed parts in the flat, etc.).
Coppersmiths.
Welding (electric arc, spot and gas).
Main and sub-assembly (airframes, engines, etc.).
Engine test, strip and rebuild and preparation for despatch.
Packing methods, etc.
Plastics.
Light alloy foundry.
Stamping and forging.

From a review of the above it will be evident that whilst a number of the subjects quoted will be included in the Administration section, the majority would have to be taught and in fact practised to some extent—depending on the course being taken, i.e. specialisation or more general training—in factories or a college actually engaged on aircraft and/or engine, turbine or propeller production.

2.1. Extent to which Engineering Industry, Aircraft Industry and Proposed College of Aeronautics should Participate in Training

It appears to be generally agreed that if industry as a whole, but more particularly the aircraft industry, is prepared to *co-operate wholly* in the advanced training scheme envisaged, and is also prepared to adjust its own training schemes to cover a greater through-put of both potential, general and works managers, departmental managers and individuals specialising on certain subjects—the whole field in fact—then a very thorough system of training could be evolved to meet the future needs.

Such a scheme envisages willingness on the part of firms in the aircraft industry to accept for a course of training (general or specialised subjects) the cream of the students turned out by the engineering industry in general who wish to become experts in the field of aircraft production.

If such co-operation can be assured (and it is felt that *far more attention* would have to be given by departmental managers in the future to training than at present ; in fact the general manager should be made just as responsible for the output of trained men as he is for the hardware), then the proposed College, so far as production engineers are concerned, would probably confine its activities to co-ordination of training as a whole, plus a finishing course of three, six or twelve months (according to specialisation in one section or general training), in which the students would be lectured for example on :

(*a*) The merits of various designs both aircraft, engines and propellers from a production standpoint.

(*b*) Possibility of improving such designs from the production aspect.

(*c*) Advisability of developing new methods of production where such would eventually lead to much improved aircraft, engines or equipment ; co-operating with the design section in this course.

(*d*) The danger of over-emphasising the cheapening of production to the detriment of design development.

(*e*) Special processes and production methods not only evolved by the several aircraft or aero engine firms, but by those firms supplying to the Industry "bought out finished" equipment, part fabricated material, etc. "Hot die," "cold working" of tubes for example—a process recently developed by the tube industry—as an alternative to laborious machining of parts at present made from upset forgings. The checking of grain flow in such specimens to illustrate the advantages of the new methods. The metallurgical section of the College could be of direct assistance in the latter regard.

(*f*) Comparison of the costs of production.
- (i) When using standard machine tool plant.
- (ii) Special machine tools, with particular reference to quantities of parts to be manufactured. Co-operating with machine tool design and manufacturing firms and receiving lectures on this subject from the firm's experts ; also visits to their works.

A prototype machine shop, standards room and sheet metal shop should, however, be provided under this scheme so that the students, who will have already been fully trained to use the plant, could manufacture any essential small items of equipment they need to demonstrate, try out or prove any new methods or processes, and possibly to make parts under new methods evolved by themselves during the course. A list of the plant which it is recommended should be installed in these departments is given later in this memorandum. Further plant may be added at a later stage as necessary, provision for this having been made in the fl or area estimates.

3.00. Schedule of Equipment Requirements for Workshops

3.1. Prototype Machine Shop

1 Centre lathe.
1 Toolroom lathe.
1 Société Genevoise hydroptic jig borer.
1 Single spindle Keller profiling machine.
1 Cincinnati hydrotel milling machine.
1 No. 13 Browne & Sharp universal tool grinder.
1 Universal milling machine.
1 Pantograph form tool grinder (Wickman).
1 Tool and cutter grinder.
1 Horizontal spindle surface grinder.
1 Twist drill grinder.
1 Horizontal milling machine.
1 Vertical milling machine.
1 Matrix thread grinder.
1 Honing machine (Barnes).
2 Lapping machines (1 Norton and 1 Cincinnati Centreless).
1 Centreless internal grinder.
1 Centreless external grinder.
1 Diamond boring machine (single head—double-ended spindle).
1 Thread rolling machine (Steinle).
1 Diamond turning lathe (Boley type).
1 Universal grinder.
1 External super finishing machine.
1 Surface broaching machine.
1 Maag gear grinder.
1 Orcutt gear grinder.
1 Rivet internal grinder.
1 Rivet bench lathe.
1 4′ 6″ radial drill.
1 Toolmaker's microscope.
1 Heavy duty single spindle drill.
2 Highspeed sensitive drills.
1 Diamond lapping machine.
1 Horizontal borer.
1 Relieving lathe.
1 Surface and boring lathe.
1 Shaping machine.
1 Sawing machine.
2 Polishing spindles.
2 Flox spindle polishing machines.
1 Electric tool tipping machine.
1 Highspeed hardening furnace.
1 Cyanide hardening furnace.
1 Carburising furnace.
1 Air compressor.

3.2. Standards Room and Inspection Department

1 Pratt & Whitney universal measuring machine.
1 Bausch & Lomb projector.
1 Taylor Hobson profilometer.
2 Sets slip gauges.
3 Surface tables 6′ × 4′.
1 Screw pitch measuring machine, Pratt & Whitney.

1 Vickers diamond hardness tester.
1 Rockwell hardness tester.
1 Zeiss optical dividing head.
1 Zeiss optical comparator.
1 Electroflux testing machine.
1 Magnaflux testing machine.
Internal and external micrometer.
Verniers.
Height gauges.

It is assumed that all test piece checks on material, i.e. Izod, Tensile and Fatigue will be done by the Metallurgical Section of the College.

3.3. **Sheet Metal Shop**

1 Cecostamp 48″ × 36″.
1 6′ Guillotine.
1 Stretching press.
1 Rotary shearing machine.
1 Riveting machine.
1 Light alloy spot welder (condenser type).
1 Carbon arc welding plant.
1 Air riveter.
1 Spot welder (steel; 60 K.V.A. Metro-Vic.).
1 80 ton Lee & Crabtree mechanical press with air cushion.
3 Gas welding trolleys.
12 Benches with vices.
1 Portable grinder with flex spindle.
1 Zinc alloy furnace.
1 Large hydraulic press.

The items of plant listed above will be available to the College from Government-owned factories already established.

4.00. **Outline of Space Required for Workshops**

	sq. ft.
(i) Prototype machine shop	40,000
(ii) Standards room	900
(iii) Sheet metal shop	4,000
	44,900
Total estimated space required, say	50,000

5.00. **Teaching Staff**

5.1. **A Principal Lecturer or Head of Section** will be needed to co-ordinate the work of the Section. He would need to be a particularly good man with a sound background of aircraft design experience as well as the practical side; the latter involving a thorough knowledge of the manufacturing technique at present employed in the most up to date of our aircraft production shops. He should be capable of lecturing and directing his subordinates on the likely future development of production technique with particular reference to, and its influence on, design. He should also be familiar with the design of machine tools and the equipment employed on the wide range of aircraft processes.

5.2. Full time **Senior Lecturers,** having a similar background to that of the Principal Lecturer, but with particular reference to his own subject will be required for :

(i) Machine shop technique.
(ii) Standards and gauging.
(iii) Sheet metal work.

5.3. There should also be five **Junior Lecturers** or assistants to the Seniors. The teaching staff required therefore for the Production Section will be :—

1 Head of Department.
3 Senior Lecturers.
5 Junior Lecturers.

W. A. SALES.

APPENDIX 9

DEPARTMENT OF PRODUCTION, ADMINISTRATION AND MAINTENANCE

Memorandum on the Industrial Administration Section

1. Industrial Administration has been defined * as being concerned with six functions—forecasting, planning, organising, commanding, co-ordinating and controlling. Its fundamental principles are of general application and no one industry or group of industries has unique claims upon them, although each industry will furnish applications peculiar to itself. It is necessary to consider, therefore, whether it is proper for the subject to be dealt with in a college primarily intended for aeronautical science ; or whether, alternatively, it would be preferable to provide *ad hoc* instruction in other institutions for those concerned with administration in many industries (and not merely aircraft manufacture).

It is appropriate first to consider the needs of the various types likely to be selected to attend courses at the College ; and secondly, to review existing facilities for the teaching of the subjects included in Industrial Administration.

2. Those attending the aeronautics college may comprise groups at, and lying between, two extremes : at the one end there are those primarily interested in scientific research and requiring, in addition, some knowledge of industrial administration ; and, at the other end, those already concerned mainly with administration and requiring, in addition to further instruction in administration, perhaps some knowledge of a branch of technology, e.g. in science, engineering, or flight, by way of a refresher course.

Various ratios between Administration and Technology have been given † as being typical for the requirements of persons in an industrial organisation. Examples are as follows :

	Administration per cent.	*Technology per cent.*
Managing Director	90	10
General Manager	75	25
Works Manager	66	34
Chief Engineer	40	60
Director of Research	30	70
Sales Manager	55	45
Personnel Manager	60	40
Accountant and Treasurer	45	55
Secretary	55	45

Similar estimates may be given for the various less senior grades for whom the College may be a goal, and the following are suggested :

	Administration per cent.	*Technology per cent.*
Designer	50	50
D.O. Section Leader	40	60
Progress Planner	40	60
Production Executive	40	60
Inspection Executive	35	65
Foreman	35	65

For all these, some element of administration, as defined, enters into, or is required for the understanding of, their normal work.

* By the French Industrialist Henri Fayol.

† By Mr. E. S. Byng, Vice Chairman, Standard Telephones and Cables Ltd., in a Paper "Post Entry Training for Administration" given before the Institute of Public Administration, May, 1943.

(It may be worth mentioning that the Institution of Mechanical Engineers have a compulsory paper in their associate membership examination on Industrial Administration, usually taken at the post-graduate stage.)

3. As regards the educational facilities available (before the war) these may be summarised as under.

Several universities and colleges, e.g. Birmingham, Dundee, award degrees which involve some knowledge of modern industrial management ; others, e.g. Cambridge, include in degree courses a series of special lectures in Administration. The College of Technology, Manchester, has a Department of Industrial Administration. A large number of Technical Colleges, perhaps 80, provide part-time courses, usually evening, in preparation for Section C, Industrial Administration, of the A.M.I.Mech.E. examination, and other similar examinations. Some Technical Colleges provide full-time courses for the Diploma of the Institute of Industrial Administration.

The London School of Economics established in 1930 a Department of Business Administration. A one-year course at post-graduate level was arranged ; some of the students were graduates direct from the universities, others were men who had had about three years in a responsible industrial position and who were seconded by their employers. The Department has been closed down during the war.

4. The provision described in paragraph 3 is satisfactory up to a point : and it may be said that facilities now exist whereby a young man may systematically study the rudiments of administrative subjects.

But it is important to realise that practically all the systems of education existing before the war were designed to meet the requirements of men under the age of 30. The courses were appropriate for the younger men aspiring to intermediate, rather than to the higher positions. It was to fill the void at the higher level that the formation of a Staff College has been urged ; and with this in view an organisation was then outlined with the object of providing courses in higher administration for men between 28 and 35 years of age. These courses were designed to extend over five months, a great part of which time would be occupied with investigations, as distinct from teaching. The outstanding feature of the scheme lay in its highly selective entry proposals.

5. It is clear that if a National Administrative Staff College existed, or were likely to materialise, then the case for the teaching of advanced administrative subjects in the College of Aeronautics might be weakened. The advantages which seconded personnel would gain by rubbing shoulders with Administrators from other walks of life in such a Staff College, might outweigh the benefits accruing from immersion in the scientific and technical atmosphere of the Aeronautical College—unless the administrators had deficiencies of a technical character which it was imperative to remedy. Against this is the general experience that students drawn from a variety of industries are not very eager to investigate administrative illustrations connected with industries other than their own (and the distributive trades might well have a preponderating influence in any " omnibus " class).

However, the Staff College does not exist ; and there appears to be opposition to its establishment. If it does materialise, the necessarily strictly limited entry would mean that the quota for the aircraft industry as a whole might be of the order of two or three only. It seems desirable, therefore, that the Aeronautics College should provide high level courses in Administration for those who are primarily administrators in the aircraft industry, especially as a teaching organisation must be created anyway for the provision of courses in administration for those who are primarily technicians or scientists.

The possibility of sending students from the College to the London School of Economics for advanced teaching in Administration must be regarded as very undesirable. The College may be situated some distance from London, and much time would be wasted in travelling. It is true that the students would benefit by contact with other similarly minded students at the L.S. of E., but only if they had ample time at their disposal. Such an arrangement, however, would disrupt the organisation of the Aeronautics College and would interfere with the communal life of the students to an unacceptable degree. Service by visiting lecturers from the L.S. of E. would be quite another matter, and it is to be hoped that this would be arranged.

6. It would appear therefore that all the students in the College would follow studies in Administration to a greater or less degree. Those preparing primarily for research and development might spend no more than 10% of their time in the Administration Department and might not deal with the more advanced branches of the subject; those dealing with production and planning could well devote more time to administration and should go further in their studies; while those interested only in a secondary degree with science, or technology, or flight, would form the advanced group in administrative subjects, and they would be dealt with as if they were in a Staff College.

On this basis almost all grades of administration would have to be covered in the curricula; less advanced teaching for the science graduate relatively immature in administrative matters, rising to advanced teaching for the experienced industrialist selected to take a short refresher course. This latter class would naturally carry out, by way of research, investigations among firms in the Industry and would build up a body of knowledge of administrative affairs which would be of great value to the country. Such investigations appear to be regularly made by certain American schools.

7. The nucleus of the teaching staff for such a Department ought obviously to be provided by whole-time appointments; but in order to ensure that the services of the ablest industrial administrators are available for short periods to the advanced students, panels of visiting lecturers should also be formed. The exact composition of the staff is a matter for closer investigation when the numbers of students likely to be available are known more definitely. Assuming however that the College has some 100 long-course students, and a further 200 short-course students, it would appear that the Department could carry a full-time staff of three, one head of department and two lecturers, together with a strong team of visiting specialists. This staff might prove adequate if the Department had to cover, in addition to usual business administration courses, such subjects as the Economics and Laws of Air Transport (including Legal Control, Inspection and Licensing), the Organisation of Aerodromes, and so on.

W. ABBOTT.

APPENDIX 10

DEPARTMENT OF PRODUCTION, ADMINISTRATION AND MAINTENANCE

Memorandum on the Composition of the Materials Section

Introduction

The following memorandum makes a broad survey of the facilities which it would be necessary to provide within the proposed College for a comprehensive department dealing with all aspects of aircraft materials. The review has been made with the object of providing a department which will be capable of giving advanced instruction in all branches of the subject, together with the provision of facilities for a certain amount of research investigation, which could conveniently be combined with instruction in the use of apparatus and which is considered essential if the department is to be vigorous. It has been borne in mind that, although facilities are at present existing in universities and technical colleges for basic instruction, there are no courses at which students may study the higher branches or particular application to aircraft work.

At the same time it should be pointed out that the equipment provided for research purposes in the scheme set out here is of a very modest character, and in fact, if no research whatever were to be contemplated, it would still be desirable to provide the laboratories with the same scale of equipment for teaching and demonstration purposes alone. The research which might be carried out would be more of an investigational character than of a fundamental nature. For instance, the Section should not attempt to produce new materials: for work of this character, much more elaborate equipment would be required and more intensive and prolonged effort than could conveniently be provided in this organisation would be necessary.

The subject of materials is one intimately influencing the whole scope of the work of airframe and engine designers and of those whose task it is to fabricate the final product. In the past there has been far too much ignorance of materials and their properties and behaviour, and much effort has been wasted by both design and production staffs by reason of this. Only by a thorough knowledge of the whole field embraced by the term "Materials" can these people produce work of fundamental excellence and ensure that the most suitable material is selected and that it is employed and worked in the most economical way. For this reason alone it is felt to be essential that an adequate Materials Section should be incorporated in the proposed College and its curriculum worked out in accordance with the particular problems and influences of aeronautical engineering.

In the last 20 years it has been the peculiar requirements of aircraft and engine designers that have been responsible for almost all the development of high tensile steels and of high-strength light alloys. These developments are by no means approaching their limits, and as aircraft become larger, and engines more powerful, and as new methods of propulsion come into general use, new and vital problems will present themselves for solution. A deeper understanding of mutual problems by designers and producers in the future will do much to accelerate development. The aircraft industry can be said to dominate research on materials, and although in future much greater use of special materials is likely to be made by the motor car and other industries, which are now realising the importance of saving weight and volume of material, it will continue to do so. This, then, offers another important reason for the provision of a strong Materials Section.

A group of materials which has more recently become recognised as important for future aircraft work is "Plastics." Much preliminary work has already been done and quite extensive use of the many forms of material which the term embraces has already been made in aircraft. In the proposals provision has been made for comprehensive teaching and investigation under this heading.

It is visualised that all two-year students will spend a certain amount of time studying the general materials aspect, but, owing to the wide scope and complexity of the subject, it will be impossible for these men, unless they are intending to specialise on this side of the work, to study it in all its more abstruse branches. It is anticipated, however, that there will be a considerable demand both from users and producers for specialist courses in all branches. Such courses might conveniently be of any duration from three months to a year.

The information presented in this memorandum has been prepared following discussions with the Materials Departments of the R.A.E. and M.A.P., the National Physical Laboratory, Messrs. High Duty Alloys, The Bristol Aeroplane Co., and Messrs. B.X. Plastics, all of whom have been most helpful and collaborative. It may be proper to note that the scale of the provision has been endorsed by all those consulted as fulfilling a need which is not adequately catered for at present, and as doing so without extravagance.

1.00. Summarised Requirements

1.1. Staff Required

1 Chief Chemist—Metallurgist.
2 Senior Lecturers.
2 Junior Lecturers.
1 Radiographist.
4 Laboratory Assistants.
1 Mechanic Machinist and Mate.
2 Storekeepers.

This full-time staff should be supplemented as necessary by specialists visiting or temporarily attached.

1.2. Laboratory Accommodation

Laboratories on the scale outlined later would probably take up to 50,000 sq. ft. of floor area.

1.3. Allocation of Time for Studies

This is dependent on the type of course to be taken. Since the subject of Materials is one of fundamental importance to design and production alike, it is felt that the study time allocated to it must be comparable with that for the other major departments, and a figure of 10% is suggested as a minimum to cover the ground adequately, i.e. one half day per week throughout the whole course time, or approximately two months out of a two years' course. This proportion of study time would be increased for specialist courses as necessary.

1.4. Estimated Cost of Special Equipment Required

	Rough Cost
(*a*) Chemistry	£10,000
(*b*) Metallography	30,000
(*c*) Radiography and Crystallography	10,000
(*d*) Mechanical testing	15,000
(*e*) Foundry and heat treatment	18,000
(*f*) Plastics	5,000
(*g*) Physics and metrology	8,000
(*h*) General purpose equipment	2,500
Total	£98,500
Or in round figures	£100,000

1.5. Subdivision of Section

The work of the section as envisaged is subdivided into the following groups :

(A) Metallic (ferrous and non-ferrous).

(B) Non-metallic.

2.00. Equipment

Some of the equipment for the laboratories is common to both Metallic and Non-metallic work, and careful planning of a Syllabus Timetable would save duplication of these items. Only one each of the specialised pieces of apparatus has been called for in this report, the reason being, in some cases, that the item would be very costly and also difficult to obtain.

2.1. Scale of Equipment

The equipment called for later in this memorandum will be divided among the following laboratories :

(*a*) Chemistry laboratory.
(*b*) Metallography laboratory.
(*c*) Radiography and crystallography laboratory.
(*d*) Mechanical test laboratory.
(*e*) Foundry and heat treatment laboratory.
(*f*) Plastics laboratory.
(*g*) Physics and metrology laboratory.
(*h*) Large general purpose laboratory.

3.00. Schedules of Work and Special Equipment

To assess the special equipment required in the various laboratories it will be considered in relation to the principal subjects to be taught under the two main subdivisions.

3.1. Chemistry

3.11. It is not proposed that the section should teach chemistry comprehensively, but only to provide instruction at an appropriate level in such subjects as are allied to the study of Metallurgy, Plastics and Fuels and Oils.

3.12. Chemistry Laboratory

This should be particularly well equipped as it will be used by both group A and group B students.

Approximate cost £10,000

3.2. Metallography

3.21. *Work to cover* composition of metals, atomic structure, elements, ferrous and non-ferrous alloys, technology of materials production, spectography, photomicrography, microscopic examination, thermal analysis, pyrometry, plastic deformation, theory of fatigue and creep, corrosion, surface and inter-crystalline, protection of metals, anodising, plating, Parkerising, Sheradising, paints, varnishes, enamels, dopes.

3.22. Special Equipment Required will include

Bench microscopes, stereoscopic microscope, photographic equipment, automatic apparatus for thermal analysis, Spectrograph, Spekker absorptionmeter, apparatus for electrolytic separation of metals.

Introscope, profilograph, Magnaflux, Johnson Fell and supersonic crack detection machines.

Spray cabinet for corrosion tests, thermostatically controlled room, Ph.meters, high duty mains rectifier for plating, plating and pickling vats, degreasing plant, buffing machines, anodising baths, chromating baths, phosphate baths, shot blasting and metal spraying equipment.

Specific pieces of equipment in addition to above.

Hounsfield tensometer—1 ton capacity, Fisher press, Townson & Mercer desiccator, Paynes automatic potentiometer, Cambridge-Rosenhein plotting chronograph, Zeiss, Beck or Vickers photomicrographic apparatus, Chevenard photographic diletometer. (This machine is for measuring thermal expansion, critical points, etc., and is of French manufacture. Similar apparatus is made in the U.S.A., but is regarded as inferior.) Cambridge thermostatically controlled furnace for annealing micro-specimens. The laboratory should be subdivided at one end into a separate grinding room, complete with grinders, saws, etc.; etching room, including a large sink (fitted with taps and sprays) and hot plates; polishing room with automatic polishing wheels and air dryers.

Approximate cost £30,000

3.3. Radiography and Crystallography

3.31. *Work to cover* examination of failures, diagnosis, structural defects, fractures, surface quality, surface crack detection, internal cracks, stress.

X-ray and crystallographic analysis.

3.32. **Special Equipment Required will include**

1 Siemens-Schuckert X-ray unit 220 KV capacity for work on heavy sections of light alloys and steel.	Approximately	£1,500
1 Phillips-Macro X-ray unit 100 KV capacity	,,	750
1 Victor KX X-ray unit 140 KV capacity	,,	950

The Phillips and the Victor units are for use on light sections and magnesium. Of the two the Victor, being of slightly higher capacity, would appear to be the most useful. All the X-ray units mentioned above are fitted with fine focus tubes and are complete with switchgear, transformers and fully motored tube stands and tubes.

1 Metro-Vick crystallographic unit complete	Approximately	£1,000
Ancillary equipment:—		
1 Metro-Vick powder camera 9 cm. diameter		
1 Metro-Vick vacuum camera 19 cm. diameter	Together approximately	260
1 X-ray goniometer	,,	100
For single crystal analysis		
1 RCA electron microscope—complete ..	At least	2,000

All the X-ray equipment should be housed in a working chamber about 30′ × 30′, which must be either lead or Barium brick lined to a height of 7′, and preferably on the floor and ceiling also.

Ancillary equipment for this section:—

1 Phillips fluoroscopic screening table	Approximately	£200
3 Kodak Industrex viewing lanterns, these being fitted with screening blinds and foot-operated floodlight	Each	20
1 Victor Truvision stereoscope for viewing X-ray pictures	Approximately	120
1 Kodak thermostatic developing unit	,,	100
1 Film drying cabinet		30

This laboratory must be provided with comprehensive dark rooms and other general photographic equipment which could be used by all the other laboratories.

Approximate cost complete £10,000

3.4. Mechanical Testing

3.41. *Work to cover* tension, compression, bearing, torsion, bending impact, hardness, shearing, fatigue, creep.

3.42. Equipment Required

The majority of these items are standard equipment but are enumerated for reasons of clarity. Some of the equipment is of use to the non-metallic side only.

Avery-Rockwell and Vickers diamond hardness testing machines.
Avery 10-ton testing machine.
Avery 3/30 tons hydraulic testing machine.
Dennison 5/25 tons testing machine.
100 ton Buckton testing machine.
GEC electro-magnetic fatigue testing machine.
Haigh 1½ tons and 6 tons fatigue testing machines.
6 Wöhler bending fatigue test machines.
6 NPL-Dennison creep testing machines, fitted with 900° C. thermostatically controlled furnaces.
Hot and cold Brinell testing machine.
NPL combined stress fatigue machine.
Amsler 500 ton compression testing machine.
Shear testing machine.
Izod impact testing machine.
Avery impact tester up to 1 ft. lb. (plastics).
Hardness tester (plastics) (1 Hounsfield tensometer already called for. This can also be used for tensile, elongation, cross break and compression tests on plastics.)
Hardness tester for rubber. Schopper tensile tester, 30 kg. capacity.
Izod impact tester for laminates.
A battery of six creep machines is required because creep tests are often of long duration and no progress could be expected with less.

Approximate cost £15,000

3.5. Foundry and Heat Treatment Processes

3.51. *Work to cover* foundry processes, die casting, sand casting, centrifugal casting, powder metallurgy, sintering.

Heat treatment, annealing, hardening, tempering, case-hardening, nitriding, age hardening, carburising, salt bath procedure.

3.52. Special Equipment Required will include

General foundry equipment, seiving apparatus, automatic moulding machine, die casting machine, core oven, electric, gas and coke-fired melting furnaces, travelling crane, apparatus for lost wax casting process, presses, sintering furnace, optical pyrometers, evacuating equipment, mixing machine, ball mill.

Other items and specific pieces of apparatus necessary :

1 Ultra-low temperature refrigerator unit.
1 Standard control board.
1 Cambridge temperature controller and recorder.
1 Wild Barfield low temperature forced air circulation furnace.
1 Siemens low temperature forced air circulation furnace.
6–8 High temperature electric muffles.
Experimental rolls (various sizes).
1 Controlled-atmosphere furnace.
Salt baths, quenching tanks, pyrometers.

Approximate cost £18,000

3.6. Plastics and Synthetics

3.61. *Work to cover* organic chemistry, physical chemistry, viscometry, structural properties, rheology, acetates, resins, thermoplastics, thermo setting plastics, laminates, hardness, polymerisation, reaction rates ; synthetic and natural rubbers (including effects of fuels and oils), processes, applications ; glues and adhesives ; possible developments ; testing of mechanical properties.

3.62. Special Equipment Required will include

1 Schering Bridge for finding permitivity and power factors at low frequencies.
1 Hartshorn and Ward dielectric testing apparatus.
1 Volume resistivity apparatus.
1 Break-down voltage set.
1 Infra-red spectrometer.
1 Spectrophotometer.
Polarised light equipment for detection of strain in specimens.
1 Williams plastometer.
1 Injection moulding machine.
1 Impregnating plant.

Plus—

Die and die sinking equipment, power presses with heated platens, rolls, humidity chambers, mixing mills, special mechanical testing machines, vulcanising press, extruders, pelleting machine.

The equipment set out under this heading are items peculiar to Plastics Technology. The greater part of the work which is visualised can be undertaken in the Chemistry Laboratory and the Mechanical Testing Laboratory on equipment already called for. This laboratory, however, must be fully air-conditioned and maintained at a constant temperature.

Approximate cost £5,000

3.7. Physics and Metrology Laboratory

This laboratory will be used for checking calibration of gauges, permanence of dimensions, etc., and automatic temperature control is therefore necessary. Equipment required in addition to general physical laboratory items are :

Apparatus for determining thermal and electrical conductivity and thermal expansion.

Apparatus for checking calibration of thermo-couples.

Total approximate cost £8,000

3.8. **Large General Purpose Laboratory**

The equipment for the above will, no doubt, accumulate as the Department progresses, but it should, from the beginning, have a good number of metal-topped benches, vices, and other necessary etceteras. It is visualised that this laboratory will be used by all and sundry for odd work, making rigs and other small items for test purposes, demonstrations of welding, brazing and soldering in all their forms and the many miscellaneous things which the students and instructors will want to make and devise to help them in their work. It should be one of the largest laboratories of all, preferably about 5,000 sq. ft., and generally well laid out and planned. A good selection of ordinary engineers' hand tools should be maintained. It might be possible to combine this with the College General Maintenance Workshop, but in view of the low cost involved and the benefits of having it adjacent to the laboratories it is thought worth while to make separate provision.

Total cost approximately £2,500

3.9. **Miscellaneous**

3.91. *Work to cover—Joining Materials*: Welding, brazing, soldering; *Fabrics*: Fabric composition, fibres, weaving, strength.

3.92. No special equipment is required for the above items. Welding, brazing and soldering equipment will be provided in the general purpose laboratory; items for the testing of fabrics can be kept in the mechanical testing laboratory (3.42).

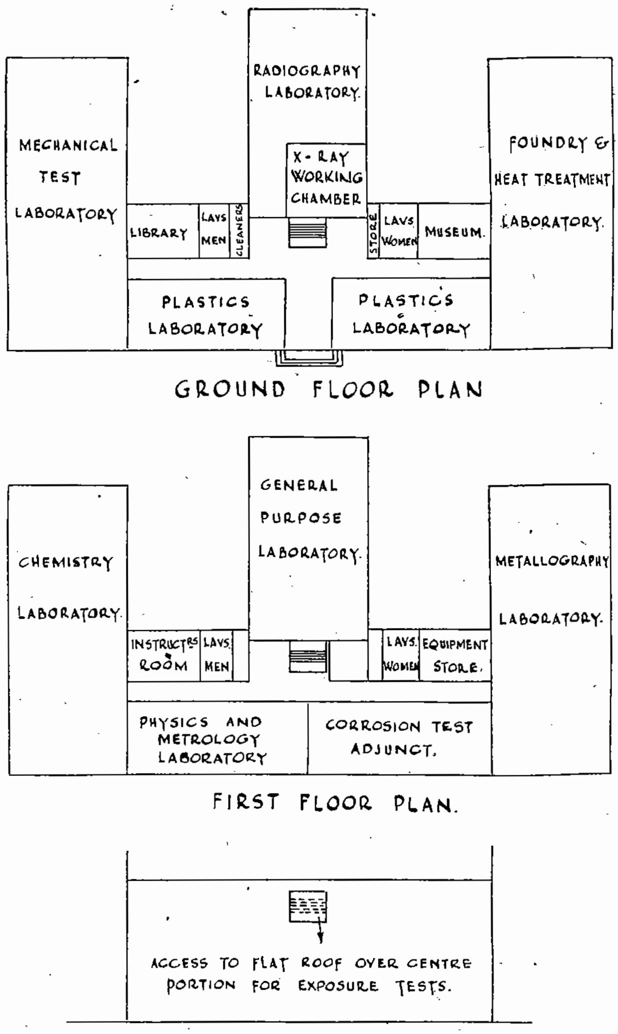
4.00. **Schedule of Laboratories and Costs**

		Rough cost
4.1.	(*a*) Chemistry laboratory	£10,000
	(*b*) Metallography laboratory	30,000
	(*c*) Radiography and crystallography laboratory	10,000
	(*d*) Mechanical test laboratory	15,000
	(*e*) Foundry and heat treatment laboratory	18,000
	(*f*) Plastics laboratory	5,000
	(*g*) Physics and metrology laboratory	8,000
	(*h*) Large general purpose laboratory	2,500
	Total	£98,500

4.2. Extras for shipment, fitting, wiring, etc., for all the equipment and apparatus visualised, might bring this figure to approximately £100,000

5.00. **Outline of Laboratory Accommodation**

		sq. ft.
(i)	Chemistry laboratory 50′ × 120′	6,000
(ii)	Metallography laboratory 50′ × 120′	6,000
(iii)	Radiography and crystallography laboratory 50′ × 90′	4,500
(iv)	Mechanical test laboratory 50′ × 120′	6,000
(v)	Foundry and heat treatment laboratory 50′ × 120′	6,000
(vi)	Plastics laboratory 30′ × 140′	4,200
(vii)	Physics and metrology laboratory 30′ × 80′	2,400
(viii)	Large general purpose laboratory 50′ × 90′	4,500
(ix)	Corrosion test room 30′ × 80′	2,400
(x)	Library 30′ × 20′	600
(xi)	Museum 30′ × 20′	600
(xii)	Allowance for lavatories, stores, etc.	2,000
		44,000
(xiii)	Allowance for classrooms or lecture rooms if these are desired to be adjacent to the laboratories	6,000
		50,000



Scale 1″ = 80′

Suggested Plan for Layout of Materials Laboratory Block.

.00. **Laboratory Building, Fittings, etc.**

The services for all laboratories should include :

High pressure water—60/80 lb. per sq. in.
High pressure a.c. electricity supply and a central d.c. conversion set.
High pressure steam to many points, particularly in plastics laboratory.
Gas.
Compressed air to frequent points in all laboratories.
Vacuum system, possibly augmented where desired by a Hyvac pump to give a really low figure.
Fume extraction system—particularly in the foundry and heat treatment laboratory.
Forced air ventilation—hot in winter and cool in summer. On no account should air be recirculated, but should be taken fresh from outside the building.

All services should preferably be contained in a trench system, no loose cables, wiring or piping being visible in the laboratories themselves.

The building would, of course, have to merge into the general architectural plan for the College as a whole, but as a guide, a block plan showing a suitable arrangement of the laboratories is included in this memorandum.

7.00. **Teaching Staff**

7.1. **A Professor or Head of the Section** will be required, and he should be an experienced physical chemist with a good knowledge of metallurgy or a good metallurgist with a knowledge of physical chemistry.

7.2. **Lecturers**

There should be two senior lecturers. The Section embraces a number of diverse types of laboratory, and it is considered that two junior lecturers will also be required.

7.3. **Laboratory Assistants**

A total of five will be required, including an experienced Radiographist, to handle the equipment of the various laboratories and help in the general enlightenment of the students. They should be men of wide practical experience and should have facilities for the study of the latest apparatus and practice in industry, research laboratories and elsewhere.

The teaching staff required, therefore, for the Materials Section, will comprise :

1 Chief Chemist—Metallurgist (Head of Section).
2 Senior Lecturers.
2 Junior Lecturers.
4 Laboratory Assistants.
1 Radiographist.

In addition to the above, one mechanic-machinist and a mate will be needed for general maintenance of equipment and two storekeepers to attend to the small items of equipment, small tools, etc.

R. G. R. Goldby.

APPENDIX 11

DEPARTMENT OF FLIGHT AND OPERATIONS

Memorandum on the Flight Section

1.00. Introduction

In laying down the framework of an organisation and the equipment for the section headed "Flight," the need for providing opportunities for the students to gain practical air experience of the latest practice in modern flight test technique has been kept to the fore. Provision has also been made for flight facilities required by the Departments of Aerodynamics, Aircraft Structures, Engineering and Design, Engine and Systems of Propulsion and Aircraft Equipment. It has been assumed that each of these Departments would require aircraft in which air tests of the appropriate apparatus could be carried out as a complement to the laboratory work. The constructional and installation work in connection with flight research would be apportioned between the laboratory of the section concerned, flight and central workshops.

Allowance has also been made for a certain amount of flying instruction and aircraft for transport of small and larger parties of students to and from outside manufacturing and research establishments.

2.00. Objects of Flight Section

By practical demonstration wherever possible in "flying laboratories" to enable students in all sections to become acquainted with modern aircraft, power plants and equipment.

To enable those already possessed of specialist technical knowledge to become familiar with practical applications in flight and so to bridge the gap between design and operation.

To provide examples of the most up-to-date methods of full-scale experiment and research, correlated wherever possible with laboratory work.

With a sound background of the fundamentals, a knowledge of modern test methods acquired by taking part in the practical work of the College, augmented by visits to Government Establishments, the student should be equipped to take part in design, development and research in the Industry or elsewhere.

3.00. Scope

Whilst the provision of full-scale test facilities to cover the ramification of each of the Departments of the College may be desirable, the following limitations are likely to apply :

(*a*) The availability of aircraft incorporating the latest developments.
(*b*) Limitations imposed by the time and cost of manufacturing special research parts and installations.
(*c*) The number of experiments which can successfully be demonstrated in the limited time available in either a "short course" of six months or a "long course" of two years or more.
(*d*) The desirability of avoiding the duplication of the larger, lengthy and more costly development and research work in progress at Government and other establishments.

Experience has shown that it is not satisfactory to attempt more than a strictly limited number of experiments on a given aircraft. The tendency to multiply aircraft and non-essential experiments and demonstration must be watched, otherwise the manufacturing or workshop facilities of the College may be overstrained.

A. Minimum Provision Considered Essential at the Outset

4.00. Basis of Requirements

On the assumption that about 12 principal experiments will be demonstrated by the following Departments of the College :

Aerodynamics,
Aircraft Structures, Engineering and Design,
Engines and Systems of Propulsion,
Aircraft Equipment,

and that demonstrations of the technique of test flying will necessarily be involved in such work, provision for 12 experimental aircraft, varying from single to four-engined types, is made.

In addition, the Flying Club and air transport needs of the College may be catered for by the provision of some 12 small aircraft, two small twin and one large twin-engined passenger aircraft.

5.00. Buildings

5.01. (*a*) For maintenance of flying school and transport aircraft .. 1 C. Type Hangar

(*b*) For maintenance of experimental aircraft, installation and calibration of test apparatus .. .. 3 C. Type Hangars

5.02. Hangar workshop for major experimental installations, say 50,000 sq. ft. .. .. 2 C. Type Hangars
This item may be included in a central engineering workshop to meet the general needs of the College.

5.03. Administrative buildings for
Flight Department,
Offices for Supervisor and Staff,
Design Office,
Technical Office,
Inspection Department,
Parachute Section,
Medical Section—Altitude Chamber,
Airport Layout—Model Room,
Operations Room,
Meteorological Laboratory,
Rescue equipment (demonstration),
Altitude Chamber,
Pilots' and Ground Crews' Offices,
Radio Station,
Stores—Test equipment,
Maintenance equipment .. 10,000 sq. ft.

6.00. Staff

1 Supervisor of Flight Experiments.
3 Senior Test Pilots.
(Lecturers included in College Staff).
3 Flight Test Technicians.
2 Junior Test Pilots.
3 Pilot Instructors.
1 Chief Engineer.
3 Designing Draughtsmen.
4 Maintenance Engineers.
4 Inspectors and Ground Engineers.
50 Mechanics (including Foremen).

7.00. Number of Aircraft Required

7.01. For school flying:

100 h.p. single-engine 2-seater	12 aircraft
600 h.p. twin-engine cabin	2 aircraft

7.02. For transport:

2,000 h.p. 20-seater cabin	1 aircraft

7.03. For flight experimentation:

600 h.p. 2-engine cabin	2 aircraft
2,000 h.p. single-seater	2 aircraft
2,000 h.p. twin-engine cabin	2 aircraft
5,000 h.p. multi-engine cabin	2 aircraft
3,000 lb. thrust single-jet	2 aircraft
6,000 lb. thrust twin-jet	2 aircraft

7.04. Total .. 27 aircraft

8.00. Estimate of Flying Hours per annum

8.01. School Flying:

12 Single-engined aircraft	at 150 hrs.	1,800 hrs.
2 Small twins	at 200 hrs.	400 hrs.
1 Transport 20-seater	at 200 hrs.	200 hrs.
		2,400 hrs.

8.02. Experimental Flying:

10 Medium (single and twin) aircraft	at 50 hrs. ..	500 hrs.
2 Multi-engine aircraft	at 100 hrs. ..	200 hrs.
		700 hrs

8.03. Total hours—

School	2,400
Experimental	700
	3,100 hrs.

B. Provision which it is Considered will Ultimately be Necessary

9.00. Basis of Requirements

Provision for approximately 30 experimental aircraft, varying from single to four-engined types, is made.

In addition, the Flying Club and air transport needs of the College may be catered for by the provision of some 20 small aircraft, six small twin and three large twin-engined passenger aircraft.

10.00. Buildings

10.01. (*a*) For maintenance of Flying School and transport aircraft — 3 C. Type Hangars

(*b*) For maintenance of experimental aircraft, installation and calibration of test apparatus .. .. 10 C. Type Hangars

Owing to the nature of the work a larger percentage of the aircraft will require to be housed as compared with wartime practice.

10.02. Hangar workshop for major experimental installations, say 10,000 sq. ft. .. .. 6 C. Type Hangars
This item may be included in a central engineering workshop to meet the general needs of the College.

10.03. Administrative buildings for
Flight Department,
Offices for Supervisor and Staff,
Design Office,
Technical Office,
Inspection Department,
Parachute Section,
Medical Section—Altitude Chamber,
Airport Layout—Model Room,
Operations Room,
Meteorological Laboratory,
Rescue equipment (demonstration),
Altitude Chamber,
Pilots' and Ground Crews' Offices,
Radio Station,
Stores—Test equipment,
Maintenance equipment .. 10,000 sq. ft.

11.00. **Staff**

1 Supervisor of Flight Experiments.
1 Chief Engineer.
6 Lecturer-Demonstrators.
10 Pilots—School and Transport.
10 Pilots—Flight Experimentation.
10 Aircrews, Navigators, Radio Operators.
5 Maintenance Engineers.
6 Draughtsmen.
10 Inspectors (Aircraft) and Ground Engineers.
100 Mechanics (including Foremen and Charge Hands).

Staff of main workshop (paragraph 10.02) is not included in above.

12.00. **Number of Aircraft Required**

12.01. For school flying :

100 h.p. single-engine 2-seater	10 aircraft
250 h.p. single-engine 2-seater	10 aircraft
600 h.p. twin-engine transport	6 aircraft
2,000 h.p. cabin 20-seater transport	3 aircraft
	29

12.02. For Flight Experimentation :

600 h.p. twin-engine cabin	5 aircraft
1,000 h.p. single-engine	5 aircraft
2,000 h.p. twin-engine cabin	10 aircraft
5,000 h.p. multi-engine cabin	4 aircraft
3,000 lb. thrust single-jet	2 aircraft
6,000 lb. thrust twin-jet	5 aircraft
	31

12.03. Total aircraft 60

13.00. **Estimate of Flying Hours per annum**

13.01. School Flying:

20 Single-engined aircraft	at 200 hrs.	4,000 hrs.
6 Small twins	at 200 hrs.	1,200 hrs.
3 Transport 20-seaters	at 200 hrs.	600 hrs.
		5,800 hrs.

13.02. Experimental Flying:

26 Medium (single and twin) aircraft	at 100 hrs. ..	2,600 hrs.
3 Multi-engine aircraft	at 150 hrs. ..	450 hrs.
		3,050 hrs.

13.03. Total hours, 5,800 School
3,050 Experimental

8,850 hrs.

P. W. S. Bulman.

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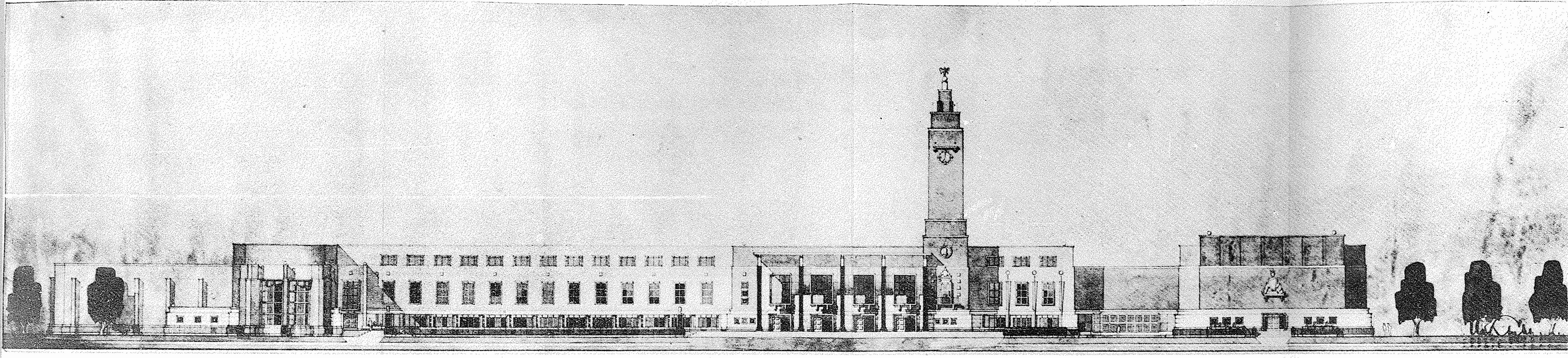
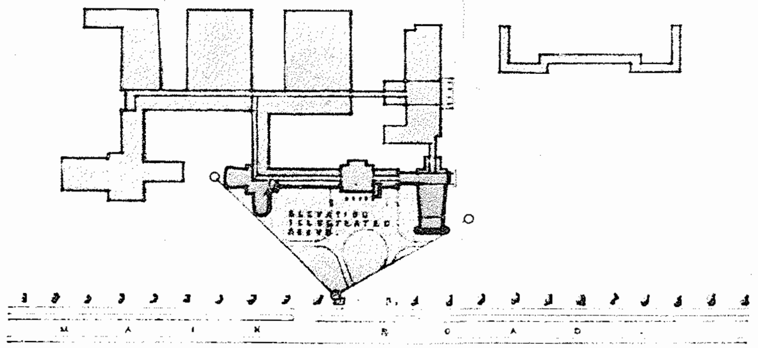


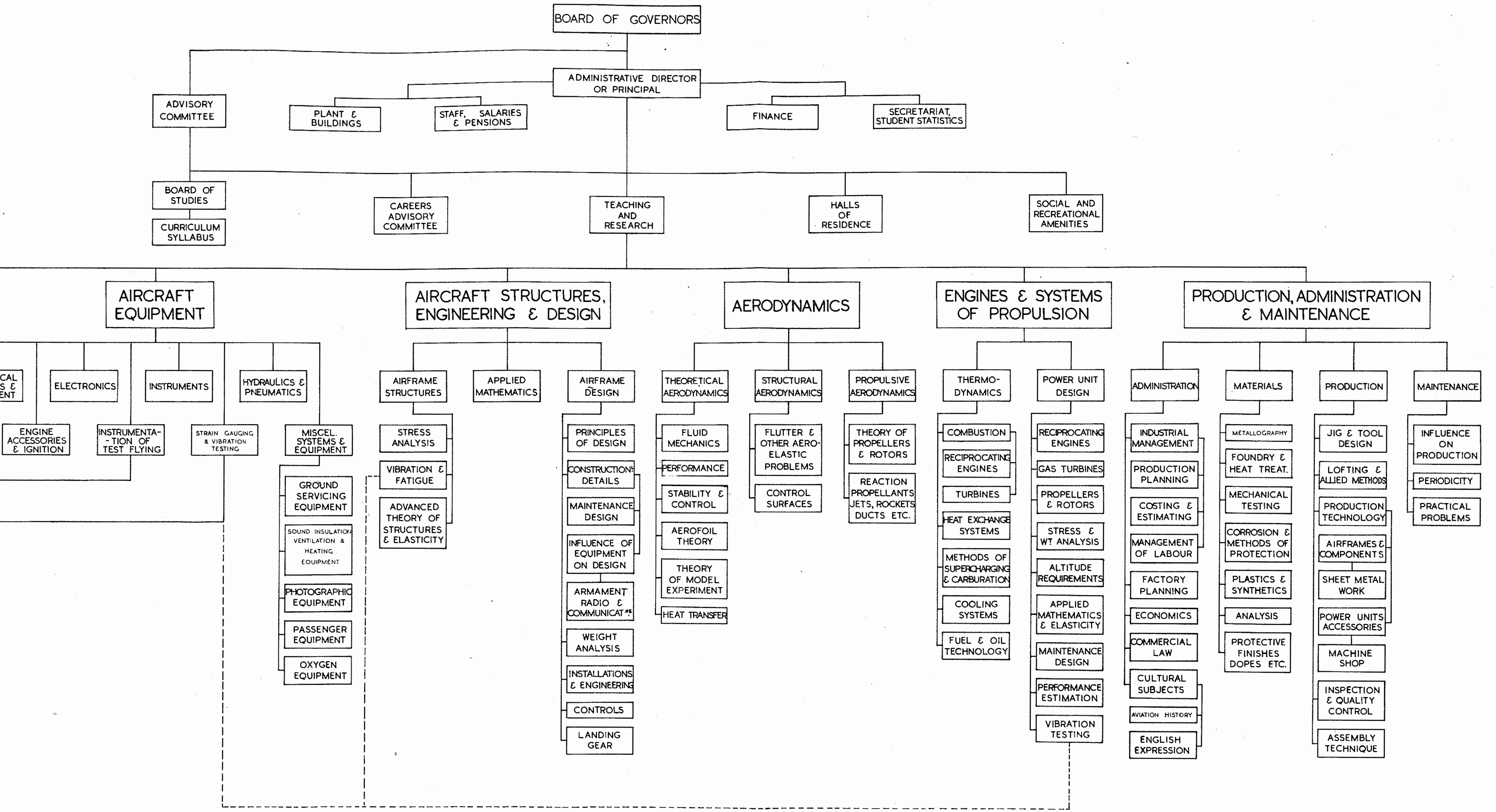


LAYOUT OF BUILDINGS.
SCALE 1/2500

DESIGN FOR AERONAUTICAL COLLEGE

PRELIMINARY SKETCH OF A SECTION OF THE PROPOSED GROUP OF BUILDINGS.
DRAWN TO A SCALE OF ONE INCH EQUALS SIXTEEN FEET

MINISTRY OF WORKS. DIRECTORATE of AIRCRAFT PRODUCTION FACTORIES. LONDON.


BOARD OF GOVERNORS
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ADVISORY COMMITTEE
PLANT & BUILDINGS
STAFF, SALARIES & PENSIONS
FINANCE
SECRETARIAT, STUDENT STATISTICS
BOARD OF STUDIES
CURRICULUM SYLLABUS
CAREERS ADVISORY COMMITTEE
TEACHING AND RESEARCH
HALLS OF RESIDENCE
SOCIAL AND RECREATIONAL AMENITIES
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AIRCRAFT STRUCTURES, ENGINEERING & DESIGN
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PRODUCTION, ADMINISTRATION & MAINTENANCE
CAL
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ELECTRONICS
INSTRUMENTS
HYDRAULICS & PNEUMATICS
ENGINE ACCESSORIES & IGNITION
INSTRUMENTA-TION OF TEST FLYING
STRAIN GAUGING & VIBRATION TESTING
MISCEL. SYSTEMS & EQUIPMENT
GROUND SERVICING EQUIPMENT
SOUND INSULATION VENTILATION & HEATING EQUIPMENT
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PASSENGER EQUIPMENT
OXYGEN EQUIPMENT
AIRFRAME STRUCTURES
APPLIED MATHEMATICS
AIRFRAME DESIGN
STRESS ANALYSIS
VIBRATION & FATIGUE
ADVANCED THEORY OF STRUCTURES & ELASTICITY
PRINCIPLES OF DESIGN
CONSTRUCTION DETAILS
MAINTENANCE DESIGN
INFLUENCE OF EQUIPMENT ON DESIGN
ARMAMENT RADIO & COMMUNICATNS
WEIGHT ANALYSIS
INSTALLATIONS & ENGINEERING
CONTROLS
LANDING GEAR
THEORETICAL AERODYNAMICS
STRUCTURAL AERODYNAMICS
PROPULSIVE AERODYNAMICS
FLUID MECHANICS
PERFORMANCE
STABILITY & CONTROL
AEROFOIL THEORY
THEORY OF MODEL EXPERIMENT
HEAT TRANSFER
FLUTTER & OTHER AERO-ELASTIC PROBLEMS
CONTROL SURFACES
THEORY OF PROPELLERS & ROTORS
REACTION PROPELLANTS JETS, ROCKETS DUCTS ETC.
THERMO-DYNAMICS
POWER UNIT DESIGN
COMBUSTION
RECIPROCATING ENGINES
TURBINES
HEAT EXCHANGE SYSTEMS
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GAS TURBINES
PROPELLERS & ROTORS
STRESS & WT ANALYSIS
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APPLIED MATHEMATICS & ELASTICITY
MAINTENANCE DESIGN
PERFORMANCE ESTIMATION
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AIRFRAMES & COMPONENTS
SHEET METAL WORK
POWER UNITS ACCESSORIES
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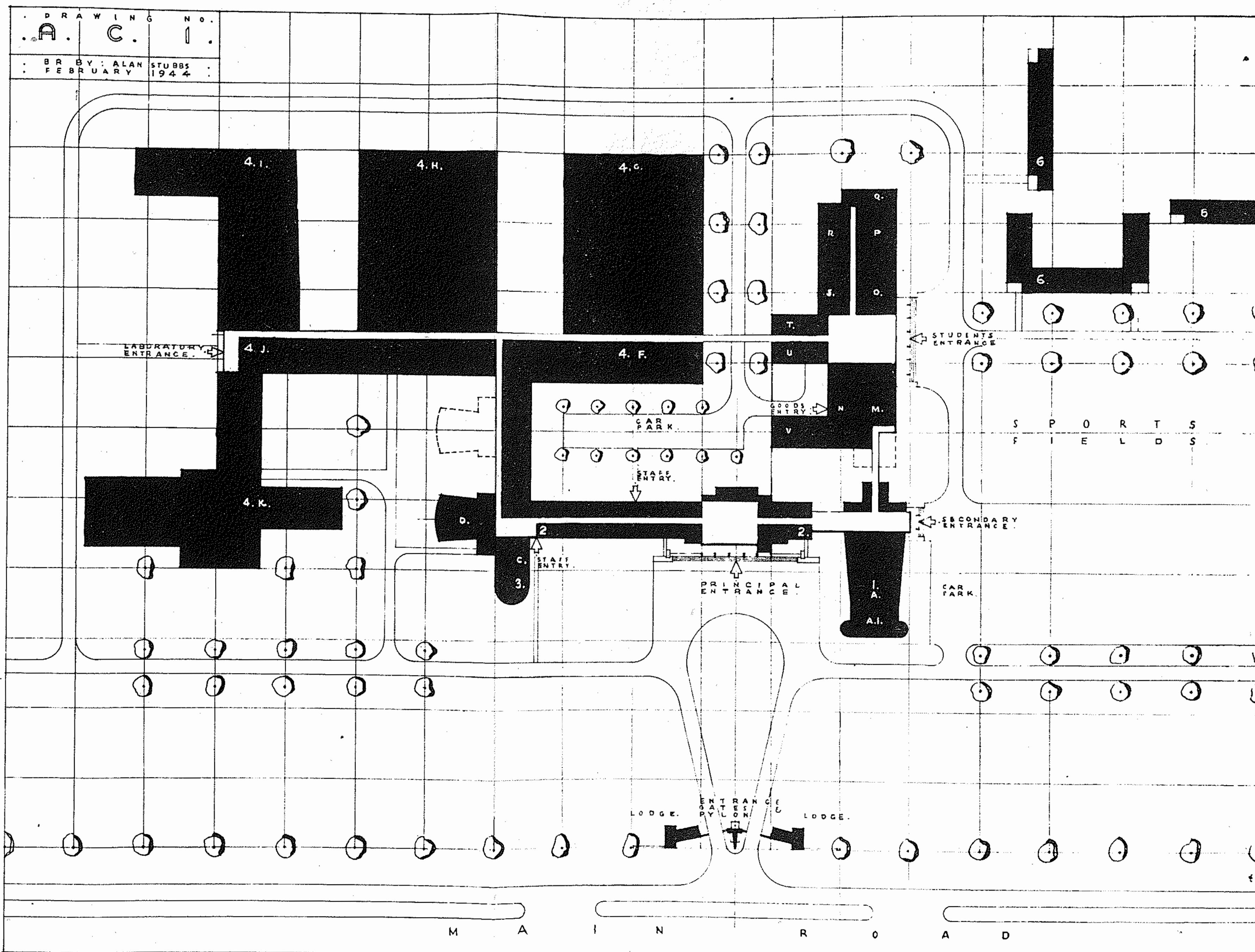
INFLUENCE ON PRODUCTION
PERIODICITY
PRACTICAL PROBLEMS

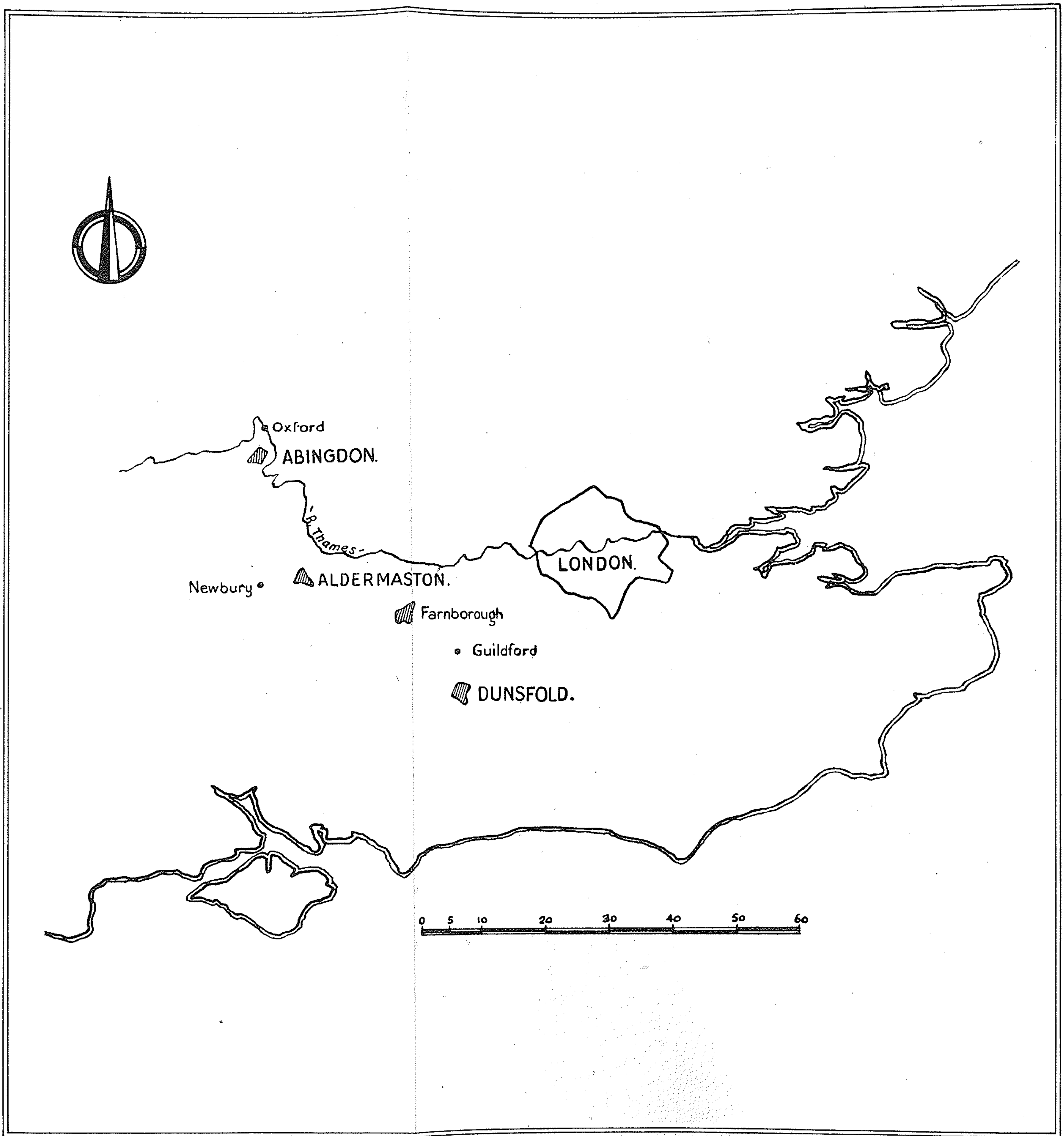


AERONAUTICAL COLLEGE:

PRELIMINARY LAYOUT OF THE COLLEGE BUILDINGS

PLAN DRAWN ON 100 FT GRID

MINISTRY OF WORKS.
DIRECTORATE OF AIRCRAFT PRODUCTION FACTORIES
THAMES HOUSE. LONDON. S.W.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