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The Economics of Aircraft Production; A Study of the Control of Overhead Costs In Aircraft Manufacture

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SUMMARY

This paper represents an attempt to appraise the different factors which must be considered in applying modern methods of cost control to aircraft production, and to suggest those positive measures best calculated to effect such control. The emphasis throughout is on control of overhead costs as these are by far the largest element in the total cost make-up.

After reviewing the factors contributing to the high cost of aircraft, such as fluctuation in demand, changing nature of the product, high degree of technical excellence demanded of the product and the contract system of procurement, the paper goes on to discuss the applicability to aircraft manufacture of such managerial devices as productivity measurement, budgetary control of fixed and variable overhead, the use of industrial consultancy and operational research techniques.

The writers conclude that the single most important factor which may contribute to cost reduction is the development of an attitude of cost consciousness throughout the production organisation. This will best be achieved by accountants and engineers uniting in their efforts to this common end.

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SECTION 1

The Nature of The Problem

1.0 During the last decade the complexity of aircraft has been increased to such an extent by technical improvements that a modern aeroplane costs approximately ten times as much as its pre-war equivalent. This is a fact which should be of grave concern to anyone associated with either the manufacture or the use of aircraft. Unless these high costs can be appreciably reduced, both the growth of air transportation and the maintenance of an adequate force for national defence might be jeopardised. The military aspect is of particular importance since, with the limited labour force in this country, emergency production may be severely curtailed unless the resources available are used with the greatest economy.

It is, therefore, desirable that the structure of the aircraft industry be critically examined to see if aircraft can be produced which will satisfy the user's technical requirements at a much lower cost. The cost of manufacture is a function of both the initial design of the aeroplane and the efficiency of the manufacturing concern. It is probable that economies are possible from the point of view of design, but as it is not within the competence of the writers to discuss this authoritatively, it is this latter aspect that will be considered here.

1.1 When these problems of economical manufacture are discussed by apologists for the present order of things the reasons which are presented to explain the present high level of cost normally fall into two general categories.

Firstly, that the mechanical complexity of the modern

aeroplane, consisting as it does of a large number of distinct parts, makes it difficult to utilise those mass production methods which have contributed so greatly to reducing costs in other industries.

(2) Secondly, the necessity of retaining a large production potential, not fully utilised in peacetime, inflates the rate of overhead which must be applied when manufacturing at partial capacity. Unless the demand for civil aircraft expands enormously, the cost of maintenance of a War Potential will remain an ever-present factor contributing to high cost in the aircraft industry.

1.2 Whilst it must be appreciated that these two characteristics of the aircraft industry are largely unavoidable in present circumstances, it is considered that there is a third factor also making for a high level of cost, and that is the absence of an attitude of cost-consciousness. Accountants in the airframe industry are more ready to attribute high costs to the technical requirements, which are beyond their control, than to consideration of the manufacturing efficiency of the organisation. Consequently, it is found that cost control systems have developed very slowly and in only an elementary form to date. Although it is realised that cost control in the aircraft industry is bound to be a somewhat more complex procedure than with many other products, it is considered that great reductions can be effected by the installation of a cost control system designed to suit the special conditions of the industry.

1.3 The object of this paper is to develop such a system of cost control for the aircraft industry, by analysing its characteristics and by the adaptation to it of management control techniques successfully applied in other fields. The emphasis will, all the while, be on the control of overheads as these are the more susceptible to managerial methods of control as distinct from improvements in production technique. It is considered that a broad framework for control can be developed which would apply throughout the industry, although special conditions in different companies would require modifications in detail. Bearing this in mind no attempt will be made to discuss the detailed application of the control system in a particular installation. It must be stressed that good cost control will not only produce a higher level of manufacturing efficiency but will also focus attention upon the technical features contributing to high cost.

1.4 Although the installation of a system of cost control will do much towards the reduction of costs, the mere mechanics of such a system are not sufficient in themselves. In order to achieve the maximum effectiveness, an attitude of cost consciousness must be encouraged at all levels of the organisation. Unless the importance of cost control is universally appreciated, then complete success will never be attained however good the system may appear on paper. The development of this attitude of mind within an organisation is far more difficult than the mere installation of the system and depends primarily

upon the personality and energy of the personnel controlling the system. This paper is necessarily confined to the development of the mechanism of cost control, but it must not be forgotten that ultimate success depends upon these imponderable human factors.

1.5 The problems of controlling overhead costs in the aircraft industry have never been systematically investigated. Consequently, there is a dearth of literature on this subject. Research is also hampered by the absence of the basic data on which any extensive research must proceed. Very little of value concerning the internal operations of any firms in the industry can be obtained from the Annual Reports and Accounts presented by the Directors, which is the only published source of information.

This paper is, therefore, confined to the analysis of broad requirements and the development of an outline system which would not only provide control but also provide comparable data which if made available would form the basis for subsequent research.

SECTION 2

Main Characteristics of Aircraft Manufacture Contributing to the High Cost of the Product

2.0 The features which contribute to high cost in aircraft manufacture may be conveniently described under four headings.

a) The severe fluctuations in aircraft requirements between war and peace.

b) The rapidly changing character of the product.

c) The high degree of technical excellence and complexity inherent in airframe requirements.

d) The contract system of purchase.

2.1 Fluctuations in Demand

2.11 At the beginning of this century the aeroplane was merely a novelty and the aircraft industry as such was non-existent. Forty years later, soon after the commencement of World War II, the aircraft industry had become the largest single industry in the country. An expansion of this magnitude would have been a great achievement had it been a process of gradual development. Unfortunately, this was not the case. The first great expansion took place under the stimulus of World War I, and although the aeroplane was at that time only in an elementary stage of development, the quantity of aircraft produced was considerable. After the war, however, requirements for aircraft were very small, supplying only limited quantities for re-equipment of the Royal Air Force and the small civilian demands. From 1935 onwards until the end of World War II, the industry again underwent a vast expansion programme.

At the end of World War II, although research programmes

were maintained at a high level, production contracts were forthcoming only for limited airline requirements and R.A.F. re-equipment, until the present re-armament programme commenced. The magnitude of the fluctuations is well illustrated by the example of a typical company which achieved a war time peak labour force of 14,000 (neglecting a considerable amount of sub-contract work) which fell to 3,400 in the immediate post war period, in spite of continued production orders for the R.A.F.

2.12 In view of these rapid expansions and contractions, it is not surprising that improvements in operating efficiency have been slow in development and that the current rate of overhead cost should be in the region of two and a half to three times the cost of direct labour. During periods when operating at partial capacity it has been essential to maintain a war potential of plant, equipment and skilled labour in order to ensure a rapid expansion in times of national emergency. When peak output has been achieved it has followed a rapid expansion and has never been maintained for a sufficiently long period to ensure maximum efficiency; especially since high output has always coincided with a national emergency when low costs have been of secondary importance to high production. However, with the increasing cost of aircraft, the problems of cost reduction must assume a new significance, since this country with its limited labour force and dwindling resources may find its output limited severely by the excessive cost of modern aircraft in both man-hours and money.

2.13 This problem of fluctuating output may remain a feature of the aircraft industry for many years, but the cost burden which it entails may be substantially reduced by good organisation and anticipation of future demands by management.

2.14 The only forseeable solution to the problem of a stable level of output appears to lie in the increased popularisation of air travel. If peace time civilian requirements were to expand to many times the present level, an effective production nucleus would be maintained and the transfer to war production would not present an appreciably greater difficulty than that at present faced by the motor industry. The lead which this country has gained in jet liner design and the possibilities which the exploitation of this advantage opens up, offer the best hope of a satisfactory solution.

2.20 <u>The Changing Nature of the Product</u>

The changing character of aircraft may be considered under three headings.

a) Revolutionary changes in production requirements and techniques.

b) Changes of aircraft type.

c) Modification to aircraft of standard type.

2.21 Revolutionary changes in production requirements and techniques.

2.211 Since its inception at the beginning of this century the aeroplane has passed through three distinct stages of development. During the first period lasting until the early 1930's, aircraft were mostly biplanes of fabric covered wooden construction. This form of construction was followed by all-metal aircraft of monocoque structure. The third change was produced by the introduction of the aircraft gas turbine enabling the achievement of high speeds hitherto unobtainable and requiring far closer production tolerances, especially of wings. Each of these advances in structural methods has produced profound modifications to production techniques and the type and grade of labour required. This again, is in sharp contrast with the motor industry which has followed a path of steady progress unpunctuated by sudden revolutions in design technique. The important influence of the above on costing is that cost data for one period are invalid for comparison with previous periods due to the altered conditions.

2.22 Changes of Aircraft type.

2.220 Advance in aeronautical research has been so rapid that within three or four years of being put into production an aircraft design becomes obsolescent. This reduces the length of production runs which can be achieved on any one type.

2.221 Here again, one meets several factors contributing to high cost. Firstly, there is initial high cost of jigs and tools, which is increasing rapidly, since the accuracy of the profiles required on modern high-speed aircraft requires a great amount of accurate and expensive jigging. When these tooling costs are amortised over only a limited number of aircraft, they become an appreciable proportion of the total cost. Similarly, for small production programmes on one type it may become uneconomical to use the same degree of jigging which could be installed for higher production.

2.222 Secondly, the number of man hours required to produce any one aircraft decreases with the cumulative number of aircraft produced according to the well known "80% Law". With a limited production a factory is always operating at the end of the curve when the direct labour requirements are high, giving rise to direct labour costs which would progressively decrease were production not curtailed at an early stage.

2.223 Thirdly, where production on any type of aircraft is maintained for only a short period, conditions have no opportunity of becoming stabilised. Consequently, the setting of cost standards for control purposes is thereby made more difficult.

2.224 As yet there are no indications of slackening in the tempo of advance in aeronautical science. Consequently there is no reason to suppose that any given aircraft type will be called upon to give greater length of service than in the past,

and that aircraft manufacturers must continue to cater for a complete change in the types manufactured at frequent intervals. Nevertheless, there is scope for the reduction of cost in this field by cheaper jigging and better cost control.

2.23 Modifications

2.231 Owing to the rapid advances in aeronautical research and changing service requirements, an aircraft type undergoes a number of modifications during the course of production. The range of modifications required may vary from major redesign of structural components at one extreme, to minor changes to interior furnishings at the other. Nevertheless, over a period of several years, the number of modifications to one aircraft type may be numbered in thousands. In one large aircraft factory in this country it is claimed that no two identical aeroplanes had been produced over a period of ten years. Although this is an exceptional example, it does illustrate the vital influence of modifications on production programmes.

2.232 The cost of a modification, furthermore, cannot be measured solely in direct man hours and services required to effect it. Through disruption of the smooth flow of production, the setting of efficiency criteria becomes exceedingly difficult and where the product is varying the establishment of standard costs ceases to become an exact system of cost control. Consequently, although the true cost of carrying out modifications is impossible to establish, it is nevertheless appreciable.

2.233 This problem is one which should receive considerable consideration. It is worthy of note that during the World War II, Modification Centres were established in the U.S.A. where modifications were carried out on standard airframes produced by the manufacturers. This enabled a much stricter control to be maintained in the manufacturing concern, with consequent high efficiency and lower cost. Whether the total cost of manufacture and modification centre taken together was reduced has not been conclusively established.

2.3 High Degree of Technical Excellence and Technical Complexity of the Product.

2.31 Aircraft sell on their technical excellence almost irrespective of cost. This is equally true for both civil and military aircraft. The civilian operator is interested in purchasing an aircraft which will provide a minimum total operating cost during its useful life. Since the initial cost of the aircraft is approximately 10% of the total operating costs of a civilian airliner, small increases in performance soon balance the extra initial cost to produce them. Similarly, the services require an aircraft superior to that of their opponents, and here again small gains in performance produce disproportionate results in combat. Consequently, the whole emphasis in the aircraft industry has been upon better rather than cheaper aircraft. Although technical progress must continue unhindered, it is essential that more attention should now be paid to cost reduction.

2.32 A modern aeroplane contains several hundred thousand distinct parts, all produced to a high degree of accuracy from expensive material. Consequently, a machine operator will produce batches of different components rather than spend all his time carrying out the same operation on the same part. This entails the absorption of much labour in setting operations, which in some cases may actually exceed the total machining time. This is an unavoidable characteristic of the aircraft industry. Greater standardisation of parts would lead to considerable economies but the practicability of standardisation is considered remote by aircraft designers. Although the problem of aircraft design, already formidable, would be considerably increased if an attempt was made for further standardisation, it is considered that this subject is worthy of detailed examination due to the economies which could be achieved.

2.4 Contract System of Procurement

2.41 The cost of the modern aeroplane is so great that it would be beyond the resources of an aircraft company to embark upon a production programme, unless firm contracts were first established to cover the experimental, jigging, and eventual production costs.

2.42 The process of price establishment runs somewhat after the following manner. Aircraft having no recognised market price as with other products, the price must be fixed by agreement between the purchaser and the producer. The purchaser in this country is normally the State, acting either through the Ministry of Supply or the operating corporations. In order to establish a fair price the purchaser must have available to him some basis for estimating the cost to the producer. This takes the form of viewing the firm's drawings and estimating the direct labour and materials required. The manufacturer also has an estimate for the requirements of direct labour and materials and it is thus possible for the two interested parties to negotiate a figure for these items to be included in the final price. Overhead costs are applied as a percentage to the direct labour, on the basis of previous overhead costs and estimated production.

2.43 On this basis it can be seen that provided a manufacturer does not become less efficient than previously, he is bound to make a margin of profit. It has been necessary to generalise on this subject, and it is not easy to visualise an alternative method of price establishment.* Nevertheless, there is little incentive under this system for the manufacturer to reduce his costs.

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* During World War II there operated a scheme known as the "McClintock Agreement" by which an aircraft firm could earn a "bonus" by producing the work in less than estimated time, much as a pieceworker in the factory. But this scheme, like any other piecework scheme, requires quantity production to operate successfully. It is not surprising, therefore, that in the immediate post-war period the McClintock scheme became inoperative.

2.5 Summary

In this section the chief characteristics of the aircraft industry contributing to the high cost of aircraft have been briefly described. Although many of these features must be accepted as inevitable much can be done to reduce the incidence of these costs if they are examined critically. In a later section it will be seen how the factors described here may be catered for in an adequate system of cost control.

SECTION 3

General Discussion of Overhead Costs and the Determination of Controllable Factors

3.1 Classification of Overhead Cost

3.11 Overhead costs are normally treated as if they were divisible classes; fixed overhead costs and variable overhead costs. Fixed costs are defined as those which undergo no variation with changes in volume of production. They are alternatively referred to as 'residual costs' since they are the proportion of the total cost which would have to be borne by the company, even if output were to fall to zero. Conversely, variable costs are those which vary in direct sympathy with the volume of production and would not be incurred were there no production at all.

3.12 In cost accounting literature reference is also often made to what are termed 'semi-variable' costs. This classification is introduced to overcome a difficulty often met with in practical accountancy, when an accounting item of cost contains elements that are partially fixed and partially variable. Maintenance costs may well be such an item, since they are partly entailed by routine maintenance of plant and equipment (fixed cost) and partly due to repair work caused by the breakdown of production machines (variable cost). In all such cases it is theoretically possible, although not economically practical, to break down these semi-variable items into their elements of fixed and variable cost. Consequently, the expression 'semi-variable' cost will not be used in the ensuing discussion.

3.2 Fixed Overhead Costs

3.21 The term 'fixed cost' may easily lead to misconceptions as to its implications unless fully understood. In this respect the name 'residual cost' is preferable since it gives a far clearer insight into the true nature of these costs. Over a short accounting period fixed costs may truly be fixed, but over a longer period they do vary, as a result of expansion (or, less frequently, contraction) of the productive capacity in terms of machines, equipment and productive facilities provided. These variations are not, however, strictly variable with the volume of production, although the fixed overhead costs will be greater for increased potential volume of production. It must be

emphasised that owing to the variable nature of these, they are controllable.

3.22 The industrialisation which has been taking place throughout the world during the last two centuries has been primarily brought about by the replacement of skilled manual labour by machinery, requiring less skilled labour, for its operation. Expressed alternatively, this process may be said to have reduced direct labour costs, by replacing labour by machinery, which entails an increase in overhead costs, the major portion of which is a fixed cost. Although great progress in cheapening production has resulted and will undoubtedly continue to result, from the process of replacement of man-power by machinery, the increase in fixed costs which this process entails introduces an element which requires careful and constant scrutiny if the benefits of mechanisation are to be enjoyed.

3.23 In the early years of industrialisation, when the economies in labour cost were vastly greater than the depreciation and operating costs of the machinery, the process of mechanisation could be carried out indiscriminately without any real danger of losses being incurred. Nowadays, however, the most profitable fields of improvement have been fully exploited and the margin between the cost of operating older machinery and new labour saving equipment has decreased, in spite of the increasing cost of labour. Although full use should be made of modern advances, all proposals for new expenditure on plant and equipment need a rigorous examination.

3.24 This examination normally takes the form of an engineering economic analysis to determine whether the expenditure is justifiable on the grounds of economy. This problem is not so simple as it might at first appear. In order to make an accurate analysis the utilisation of the equipment must be known. The true figure for the utilisation is extremely difficult to establish, especially in the aircraft industry where it may be very low, since it is not that number of hours for which the machine is capable of operating in a year, but the number of operating hours that the estimated production programme can support in a year. Consequently it is seen that an accurate economic analysis would involve a knowledge of the future level of production in the company over the life of the machinery (say 10 years). Owing to the fluctuating nature of the demand in the aircraft industry, it is impossible to estimate future production accurately. Nevertheless, a figure for utilisation based on good judgement and a sound knowledge of current commercial and international problems is less likely to lead to error than a facile assumption of full utilisation.

3.25 The decision to purchase new plant and equipment should thus be made at the highest possible level of management, in conjunction with an economic analysis which may be supplied by a qualified engineer. There will, however, be exceptions to this rule when the existing machinery is inadequate to perform the operations required and technical considerations make the purchase essential.

3.26 Control of this aspect of overhead cost is of as great importance (if not greater where flexibility is essential) as in any other aspect of cost control. The price of a wrong decision affecting fixed overhead is in the form of high costs, which once incurred may not be easily reduced owing to their semi-permanent nature.

3.3 Variable Overhead Costs

3.31 Items of variable overhead cost are, by definition, strictly proportional to the volume of production. Most important amongst these is the cost of indirect labour,[1] which accounts for approximately three-fifths of the total overhead cost in the aircraft industry. The magnitude of the indirect labour is such that the ratio of indirect to direct labour is of the order of 60:40. There are, however, certain classes of indirect labour which may not be strictly regarded as a variable cost - managerial staffs may be regarded as a fixed cost since they are relatively stable over normal fluctuations in output, although only a small number could be regarded as 'residual'. Small variations in output may not always produce the expected change in variable overhead cost, due to local over-loading or under-loading of the available labour force.

3.32 Throughout the industry there has been a growth in the size of the indirect labour force during the last fifty years. This has followed naturally as a result of the development of 'division of labour' and specialisation of function, which has shifted responsibility for many of the planning operations formerly carried out by direct labour on the shop floor, to specialised departments. Consequently, progress in the managerial field has lead to an increase in the level of variable costs, comparable to the increase in fixed costs due to mechanisation.

3.33 When considering the control of variable overhead costs the problem largely reduces to one of ensuring the variable nature of indirect labour. The natural tendency is for the indirect labour force to increase with increases of output, but to remain constant or decrease only slowly when output falls. Consequently, during periods of increasing production their justified demands for additional staff are met, but during periods of falling output this additional staff is retained, due to the difficulty of adequate control and the concealment of redundancy, as well as natural optimism of better days ahead.

3.4 Selection of Controllable Factors of Overhead Cost

3.41 Since all items of cost are normally taken to be either independent of, or strictly proportional to, the volume of production, one would expect a straight line relationship between total overhead cost and the volume of production (Fig.1). When,

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1 The categories of labour in the aircraft industry classed as indirect are enumerated in Appendix I.

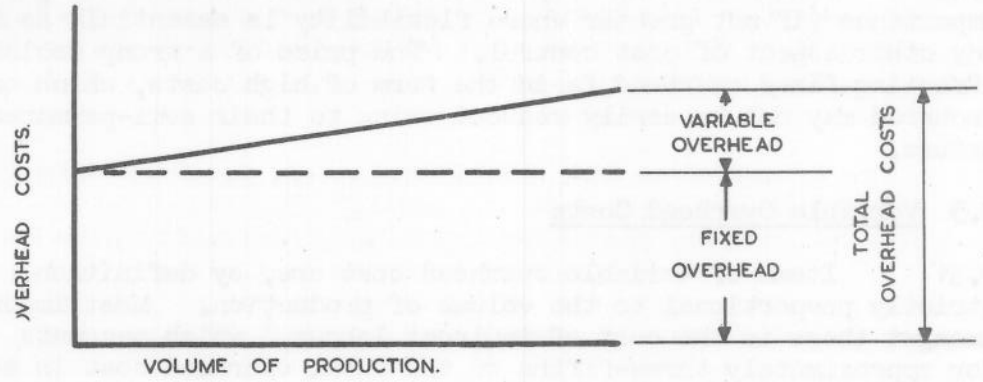

FIG. 1. THEORETICAL RELATIONSHIP BETWEEN OVERHEAD COSTS AND OUTPUT.

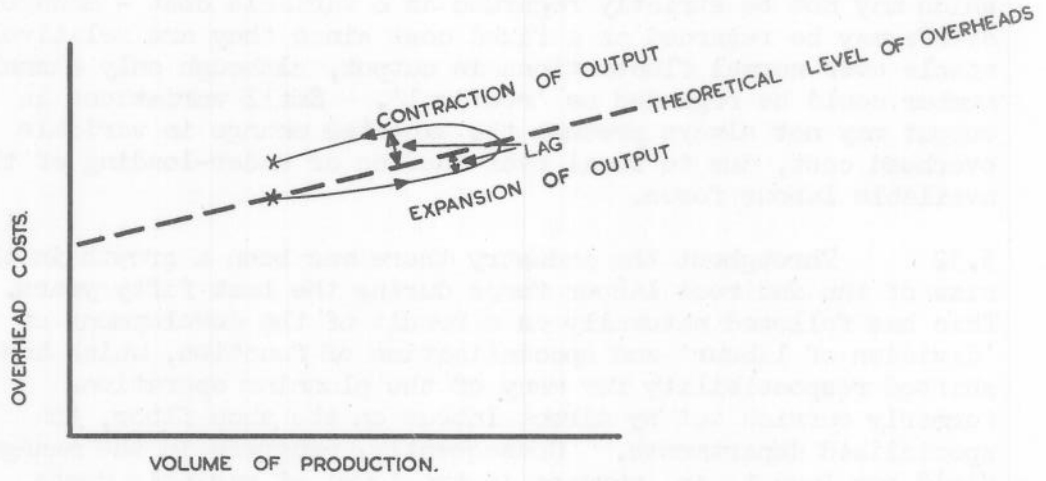

FIG. 2. TYPICAL OPERATING RESULTS.

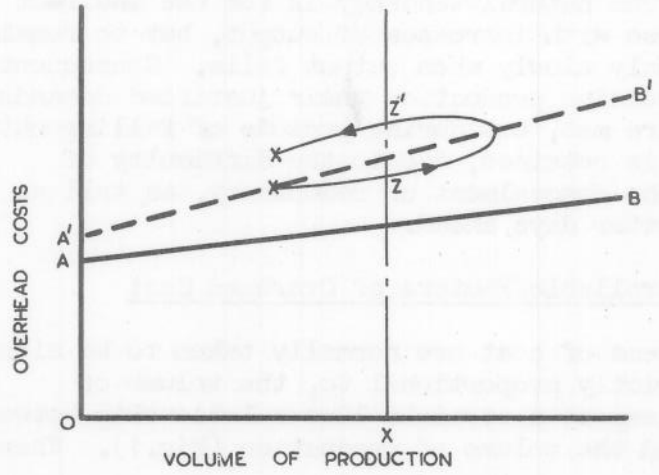

FIG. 3. COMPARISON OF ACTUAL OVERHEAD COSTS WITH THE THEORETICAL LEVEL.

however, the actual realisation of a company over a number of years, is plotted on this basis, the result is a curve of the form shown in Fig. 2. The contrast between these two curves is shown in Fig. 3, where an ideal theoretical curve and a typical operation curve are shown together.

3.42 It is seen from Fig. 3 that the actual level of overhead costs is appreciably higher than the ideal. The object of a good cost system is to bring the actual costs into conformity with the ideal. Unfortunately, although it is known that a straight line relationship should exist, the actual level of cost obtainable is impossible to establish. However, by comparison of these two curves it is possible to extract the salient features contributing to the higher level of cost which are:-

a) The level of the fixed (residual) costs OA' is higher than the optimum OA.

b) The slope of A'B' is greater than that of AB, showing that the rate of increase of variable overhead with production is greater than necessary.

c) Following the actual figures over a cycle of varying production it is seen that there is an appreciable lag between changes in volume of production, and the corresponding changes in cost. During increased production this lag is not so appreciable, but is very marked during periods of decreasing output. This is illustrated by considering the overhead costs at volume of production x (Fig. 3), where the level of cost is Z' when output is falling, but only Z when output is increasing. The distance Z'Z is a measure of the additional cost, which should be eliminated by the cost control system.

3.43 Summary

From the above considerations, it is possible to determine four principles for the establishment of a cost control system.

a) An attempt must be made to determine the optimum level of overhead costs which the firm may be expected to achieve. It has been seen that the ideal level is impossible to determine, but by making comparisons within the industry it should be possible to evaluate the lowest contemporary figures.

b) The fixed costs should be maintained at the lowest figure composible with efficient operation, with strictest control being exercised over expenditure on plant and equipment.

c) The rate of variable overhead cost should be reduced by increasing the operating efficiency of the company.

d) It must be ensured that variable overhead costs are strictly variable with the volume of production, especially during periods of decreasing output.

SECTION 4

Selection of a Basis for the Control of Overhead Costs in the Aircraft Industry

4.0 It was concluded in Section 3, that to ensure an adequate control of overhead costs, it is desirable to:

a) Determine the optimum level for overhead costs which should be attained under favourable conditions.

b) Install a system which will ensure the attainment of this predetermined level by:-

i) Controlling fixed Overhead Cost.

ii) Reducing the rate of variable Overhead Cost.

iii) Ensuring that variable Overhead Cost is directly proportional to the volume of production.

It is now proposed to discuss each of these conditions separately and determine how they may be best satisfied.

4.10 Determination of the Optimum Level of Overhead Cost

The primary objective of a manufacturing concern should be to manufacture the product for the minimum total cost per unit. This does not imply that the company with the lowest level of overhead cost will necessarily achieve the lowest total cost for the product, since direct costs are largely replaceable by overhead cost. The same product may be produced under greatly varying conditions, dependent upon the degree of mechanisation and specialisation of planning functions. If the product is manufactured by skilled craftsmen using few machines, the total cost will be high, due to excessive direct labour costs. Conversely, if the labour force is reduced to a minimum by the installation of machinery, then the cost is again likely to be high owing to prohibitive overhead costs. Between these two extremes there must exist a ratio of direct costs to overhead costs which will give the lowest total cost. It is this optimum condition which management is unconsciously striving to determine.

In a strictly competitive industry this optimum condition will be approached by a process of successive approximation. Those firms with high costs will have a low margin of profit if they are to sell at a competitive price. Consequently, there will be a continuous striving for reduced costs and any company failing to achieve a satisfactory solution to this problem will eventually be forced into liquidation, or at best, will earn only small profits.

Also, where a standard product is manufactured over a number of years, unsatisfactory trends may be detected by comparison of present costs with past data. With the accumulated data it should be possible to reduce the cost of the article by the elimination of inefficiencies and, as experience increases, gradually approach the optimum level.

4.11 It has been seen that, in a commercial sense, the aircraft industry is not competitive, thus those firms with high costs do not necessarily find difficulty in obtaining contracts, as would be the case in other industries. In fact it is true to say that no effective measure exists in the aircraft industry by which the performance of one company can be compared with another.

This problem is accentuated by the changing nature of aircraft. Cost data derived from different types of aircraft are in no way comparable and production runs are so short that it is impossible to derive much information of value from cost trends.

4.12 The whole process in a competitive market may be likened to a closed circuit. A company with high costs finds that the consequent high selling price reduces the volume of sales. In an effort to rectify this, the company must re-organise and, by incorporating all the latest techniques, may well reduce the cost of the article below that of its competitors. This, in turn, will react upon the competitors, and will engender a continual striving for reduced costs in the industry.

In the aircraft industry this circuit is open and individual firms are influenced only slightly by economies effected elsewhere.

4.13 It is not forseeable that the aircraft industry will ever operate in an atmosphere of unbridled competition, for it is at best an oligopoly. It is, therefore, necessary to supply the impetus which competition provides by some synthetic means. This requirement can be supplied by establishing a system for the comparison of corresponding statistics throughout the industry. This solution is closely related to Productivity Measurement but presupposes the availability of the required data.

4.14 In brief, it may be said that the determination of the optimum level for overhead costs by the normal methods is not possible. The nearest approach is given by the best figures achieved in the industry. These figures are at present unavailable but the desirability of some form of Productivity Measurement is clearly indicated.

4.20 Control of Fixed Overhead Cost

4.21 In the general discussion on the aircraft industry it was stressed that one of the most important characteristics of this industry is the large fluctuation in output. To accommodate these fluctuations, the structure of a firm must be

extremely flexible. Flexibility is, however, indirectly proportional to the magnitude of the fixed or residual costs. In contrast, the full exploitation of modern production techniques involves great expenditure on machinery. This is particularly true of the airframe plant with its requirements of a large range of specialised plant and equipment. Any solution must of necessity be a compromise between these two conflicting aims.

4.22 The solution of this dilemma lies in the maintenance of the minimum amount of plant and equipment required to meet the estimated future production without impairing the technical excellence of the aircraft. In periods of limited production full utilisation of special machine tools such as spar milling machines, not easily replaceable, cannot be hoped for. However, a much higher utilisation should be obtained from general purpose machine tools which can be purchased very easily or supplemented by sub-contract work during periods of high production. The necessity for retaining a War Potential must be recognised but it must be ensured that the unabsorbed resources are balanced in order to avoid local 'bottlenecks' when expansion occurs.

4.23 Strict control should also be maintained on expenditure on new items of plant and equipment. This control should be a function of top management the importance of which cannot be overstressed.

4.3 Control of Variable Overhead Cost

The two problems of reducing the level of variable overhead costs and of ensuring that they are directly proportional to the volume of output, are closely associated. They are both largely a function of:-

a) The cost control system in operation

b) The general level of operating efficiency

4.4 Choice of a System

It is now necessary to select the system of cost accounting which will ensure the most effective control in the aircraft industry. There are basically four systems from which this choice may be made, namely:-

a) Historical Costing

b) Marginal Costing

c) Higher Control

d) Budgetary Control and Standard Costing

It is not intended to describe each of these systems in detail but merely to outline their chief characteristics and suitability for application to the aircraft industry.

4.41 Historical Costing

This is the name generally given to the traditional method of cost accounting which is now largely being replaced by systems designed to give a greater degree of managerial control. Historical Costing is concerned solely with the recording of actual costs as they occur, and summarising them periodically for the preparation of Job Cost Accounts and Overhead Expense Accounts. The information is not presented in a form or at a time suitable for meeting the requirements of managerial control, or forecasting the future costs.

The inadequacy of this form of Cost accounting is generally appreciated in the aircraft industry, although it is still the basis for costing in a number of companies.

4.42 Marginal Costing

Marginal costing is largely concerned with the differential costs involved in varying the volume of production. As the output of a factory rises the overall cost of the product will fall, but it may be necessary to lower the price in order to create a sufficient demand to sell the increased output. This entails a lower profit per unit sold but if the increase in sales is sufficiently large the total profit will be greater. The object of a company producing under these conditions is to stabilise its output at a figure which will yield the maximum total profit and marginal costing has been developed to provide a satisfactory solution to this problem.

Such a system is ideally suitable for a company which is mass producing small articles, for which there is a large demand, the size of which is extremely sensitive to price. This is clearly unsuitable for the aircraft industry which only manufactures under contract. Thus an airframe manufacturing company is not a free agent in determining how many aircraft it will construct and a system of costing designed to stress the sales function is inappropriate.

4.43 Higher Control

Higher Control is the name given to what is really a modification and enlargement of historical cost accounting to give a degree of managerial control. Monthly statements are presented to management giving the current business, technical, trading and financial position for the enterprise, based on a moving annual total. By studying the trends in these accounts, an effective basis of control is established where the product and production methods remain sensibly unaltered over a long period.

Although higher control is suitable for a wide range of industrial enterprises, it is considered unsuitable for the aircraft industry where the changing character of the product renders the study of trends relatively valueless.

4.44 Budgetary Control

Budgetary Control relies upon the examination of past performance in order to establish budgets for future costs taking into account any circumstances which may have altered. Thereafter the actual achievement may be compared with the budgets and, by throwing variances into relief, management has a clear guide as to which aspects require urgent attention. Budgets may be altered during an accounting period in order to allow for modifications to the production programme which were not envisaged when the budget figures were initially set. Although these alterations should be avoided whenever possible they do allow for the unpredictable nature of production programmes in the aircraft industry.

For these reasons, and others which will be noted later, Budgetary Control is considered to be admirably suited to the requirements of the aircraft industry.

4.5 Improvement of the Level of Operating Efficiency

4.51 When discussing the problems of cost reduction it must not be forgotten that costs are merely a convenient universal measure for the numerous activities which combine to form a living industrial unit. However efficient a cost control system may be, it can only attempt to ensure that the framework within which it is operating is controlled to a level, dependent upon the internal organisation of the company. Only in exceptional cases will it be possible for the cost control system to isolate inherent weakness in the organisation as it exists.

4.52 This may be seen as it affects Budgetary Control which is the system best suited to the aircraft industry. Budgets must, of necessity, be based upon past cost data and, consequently, if a company has been operating at a low level of efficiency any inefficiencies will tend to be included in the budgets for future costs. This is inevitable since budgets must be realistic. In a system which controls by the 'exception' principle, it is only possible to determine variances from the generally accepted standard, not to revise this standard. Nevertheless, a dynamic management should be continually striving to lower costs by improved efficiency. It is therefore, necessary to investigate how the control system may be supplemented in order to ensure constant review of this aspect of a firm's organisation.

4.53 The duties of a departmental manager may broadly be divided into two functions. Firstly he is delegated authority to ensure the efficient functioning of the technical operations performed in the department. Secondly, he is a link in the chain of communications, both vertically up the line of authority and horizontally with other departmental managers at the same level. In both these aspects inefficiences are likely to occur. A perfect organisation has never existed and management must be constantly searching for improvements.

4.54 The efficiency of the specialist functions of a department is essentially the responsibility of the manager who, with his specialised knowledge, must remain the supreme authority in that field. Efficiency must rely upon the selection of the most suitable personnel to fill managerial positions and the replacement of the unsatisfactory.

There appears to be greater scope for improvements in the field of communications, where the major inefficiencies are most likely to occur. Cumbersome paper work, lack of liaison and understanding between departments and the inclination of many technicians to shun administrative duties all contribute to inefficiencies.

4.55 It is considered that these difficulties may be overcome in three ways.

a) The engagement of outside Consultants where a major re-organisation is deemed necessary.

b) The establishment of an Efficiency Section to investigate routine problems.

c) The establishment of an Economy Committee where senior executives may discuss mutual difficulties contributing to high costs.

4.6 Elimination of Lag Between Changes of Output and the Associated Changes in Cost

4.61 When the volume of production is changing, the effect of lag can be catered for in the establishment of variable budgets. If the budgets are set accurately and volume variances are allowed for, then control should become automatic. It is in this aspect of cost control that Budgetary Control is seen to the best advantage.

4.7 Summary

In this section there has been passed in review the measures necessary to achieve adequate control over overhead cost and the determination of its optimum level. A choice of systems for achieving this end have been considered and a system of Budgetary Control has been deemed the most appropriate for the purpose. The need for proper channels of authority and allocation of responsibility for the control of overhead has been stressed and the importance of flexibility in the establishment of budgets has been noted. It remains for us now to consider the foregoing measures more fully in the ensuing section.

SECTION 5

Measures for Achieving the Control of Overhead Costs

5.0 From the analysis of the requirements for effective control of overhead costs given in Section 4, it is held that an adequate system for the aircraft industry would be provided by the following five measures.

i) Productivity Measurement, and the adoption of uniform costing to facilitate cost comparisons throughout the industry.

ii) Budgeting of Fixed and Variable Overhead employing the Flexible Budget principle.

iii) Employment of Industrial Consultants.

iv) Establishment of an Economy Committee.

v) Establishment of an 'Operational Research' Section.

Each of these items will now be discussed in greater detail in order to elucidate the problems which will be met in their application and how these difficulties may be overcome.

5.1 Productivity Measurement

The study of Productivity Measurement is as yet in its early stages. It has been seen , however, that herein lies a basis for the creation of a competitive spirit for cost reduction which is at present lacking in the aircraft industry.

It is convenient to discuss this subject under three separate headings:-

i) Overall Productivity Comparisons

ii) The Productivity of Direct Labour

iii) More Detailed Comparisons of Departmental Costs

5.11 Overall Productivity Measurement

Productivity has been defined as the ratio of production of wealth (goods, services and human satisfaction) to human effort expended. The productivity of a manufacturing concern, comprising as it does all departments and services, is extremely difficult to assess. A formula has been proposed by Sir Ewart Smith[1] by which the productivity of any firm or industry may be

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1. See 'Measurement of the effectiveness of the production unit' by Sir Ewart Smith and Dr. R. Beeching. British Institute of Management, Winter Proceedings 1948/49, No. 4

measured. He takes into account the sum of all human effort embodied in the product, in the form of direct labour and the man power equivalent of capital equipment, services rendered and changes in raw material. Although the formula expresses the requirements of Productivity Measurement satisfactorily, the practical obstacles to its application are considerable. The obstacles lie in the difficulty of assessing accurately the man power equivalents. In order to achieve an index to express the effectiveness of an aircraft manufacturing company, allowance would have to be made for the increasing productivity of direct labour due solely to the "learning curve" and also for the maintenance of War Potential.[1]

5.12 Departmental Comparisons

5.120 Every firm displays both efficient and inefficient features. It is extremely unlikely that the best firm is uniformly good or, the worst, uniformly bad. Consequently if the sum of the lowest individual departmental costs achieved in the industry were obtained, it would undoubtedly be lower than the total cost for the most efficient firm. Although an overall productivity measure will show which are the best firms, it will not indicate what could be achieved if the best practices were universally adopted. Great value would, therefore, be derived from comparisons made at departmental level.

5.121 At present such comparisons are usually impossible and where possible would be worthless. The chief difficulties are:-

a) Lack of standardisation of nomenclature and function of departments.

b) Lack of uniform costing.

c) Opposition from executives who fear unfavourable comparisons and have little faith in the value of statistics.

5.122 Much confusion is caused by the different names attached to the same functions throughout industry. Such words as 'planning' and 'production control' are applied to cover a large range of differing functions. The desirability of standardising such terms is unquestionable and the adoption of a standard nomenclature would not entail much difficulty.

5.123 All costing data, in whatever terms it may be collected is eventually converted into terms of money. It would, therefore be most convenient if such comparisons, as were considered desirable, were made on this basis. At present, even amongst firms in the same financial group, cost data are prepared on an individual basis and are therefore not strictly comparable. The adoption of uniform costing would thus be essential before any

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1 The work of T.P. Wright in America on productivity of direct

P.T.O.

Footnote Contd.

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labour has established a number of statistical relationships which have been verified by extensive data collected in the U.S.A. and elsewhere during World War II. This had a profound effect upon management thought in the U.S. and stimulated a healthy rivalry between companies. The value of this work is probably not so widely appreciated in this country and comparable data on which similar investigations might be conducted is not so readily available. See, however, College of Aeronautics Report No. 30: "The Time to Achieve Peak Output in Aircraft Production" - P.J. Stanley.

The value of the results obtained in this single field justify the demand for considerable research into the other aspects of aircraft manufacture which have previously been ignored owing to their assumed complexity and uncontrollability.

detailed cost comparisons were attempted. This would require the full co-operation of the accountants throughout the industry, although the necessary stimulus could be provided by the Ministry of Supply, if it insisted that all figures for overhead cost be submitted on a uniform basis.

5.124 No insuperable difficulties stand in the way of uniform costing in the aircraft industry, although its desirability may, in the minds of some accountants, be in doubt. The position revealed by cost data, prepared on a comparable basis, is unpredictable and they may well reveal inefficiencies hitherto unsuspected. This may well explain much of the opposition, but much preliminary work must be undertaken before the installation of such a system. Distrust for statistics must also be eradicated and the operation of such statistical relationships as the '80% Law' should be more widely known amongst accountants.

5.13 It can be seen from the foregoing discussion that much research remains to be done before an efficient basis for comparisons within the industry will become available. Nevertheless, the potential value of such measurements is very great and it is strongly recommended that the groundwork necessary for these researches, namely standardisation of nomenclature and uniform costing be given active consideration.

5.20 Control of Fixed Cost

5.21 It has been seen in previous sections that the flexibility of a manufacturing concern is inversely proportional to the level of fixed overhead costs and that although the maximum flexibility is particularly desirable in the aircraft industry the nature of the product militates very strongly against it in practice. It is, therefore, imperative that this aspect of control be given the most detailed attention, especially during times of expanding production, since expenditure on capital items which at that time may seem warranted may not be justifiable when the prospects of the concern are viewed over a longer period. It cannot be overstressed that this problem should be given a large measure of attention by the higher levels of management, for not only are decisions on this matter of a lasting nature but require a high degree of personal judgement.

5.220 Control of fixed overhead costs may be exercised in two ways:-

a) Control of expenditure on additional capital items.

b) Frequent review of items contributing to the present level of fixed overhead with a view to the elimination of equipment which has become redundant.

5.221 To achieve adequate control of expenditure on items of capital equipment, all requests for expenditure must be carefully vetted by an authority superior to the department requesting it. This is especially important in the aircraft industry where the rapid advances made call for continual additions to research

equipment. It is of primary importance that research should in no way be hampered by lack of apparatus but great discretion must be exercised before a decision be given which involves the purchase of any apparatus which may be of only temporary value. A technician who is working on a particular problem for many months or even years is bound to overrate the importance of his work and may demand apparatus far in excess of his basic requirements. It is, therefore, extremely important that the authority for the purchase be vested in a body which is capable of viewing the proposal in the light of the overall long-term picture.

This difficulty may be overcome if all departments submit a quarterly budget for capital expenditure, broken down into its component items. This budget should be submitted either to the Board of Directors, or a sub-committee appointed for this purpose, for its consideration and approval. Any items which are considered inessential or of excessive cost should be the subject of a special scrutiny. The composition of the body undertaking the scrutiny would depend to some extent upon the structure of the company, but could well be a sub-committee under the chairmanship of a Director (not connected with the department requesting the expenditure) for large items and the Economy Committee (see Section 5.5) for less expensive items.

Economic analysis such as that of the "Break-even" type should be used wherever possible. This would be impossible for research equipment, where the returns are immeasurable, but should always be the case with production machines unless special technical considerations make it impracticable.

5.222 Information as to the level of fixed overhead costs existing at any time would be provided by the Chief Accountant or Controller in accordance with the Budgetary Control System. These should be scrutinised in great detail. It is normal practice that the higher the level of management the less detailed are the figures submitted. Due to the special significance of fixed overhead it is considered that the figures relating to this aspect of cost should be in far greater detail than for other items. These figures should be the regular concern of the Economy Committee referred to above.

5.30 Budgetary Control

It is beyond the scope of this present paper to attempt a detailed description of Budgetary Control, which is adequately covered in accountancy literature. A great deal of practical experience has also been gained from its application to a wide range of industries. Owing to its adaptable nature, it is readily fashioned to the requirements of the aircraft industry without major modification to the existing reporting and costing systems. Consequently, the following discussion will be mainly limited to the basic requirements of any costing system, and the preliminary steps which should be taken when applying Budgetary Control to ensure that these requirements are met.

Budgetary Control will cover the whole scope of the

company, involving direct labour and materials, and overheads (both fixed and variable). Nevertheless, its primary function is in relation to overhead cost. It may well be maintained that even when applied to direct costs it is really dealing with an aspect of overhead cost, since any aircraft design has a basic requirement of labour and materials, any excesses being due to scrap material and parts, and idle time. Since these are a direct result of inadequate planning, supervision, or management they should be regarded as an overhead. In a well designed system of factory accounting scrap material and idle time are separately recorded and should be charged as an overhead cost.

5.310 Factors Involved in Cost Accounting

The purpose of a cost accounting system should be to provide 'a reliable, detailed, historical record of the facts of business, so classified and evaluated as to enable management or accountant to rearrange the data, as required by each emergent problem.' * In achieving this purpose a costing system serves three distinct functions.

a) Provision of data for financial requirements.

b) Provision of a basis for effective managerial control.

c) Co-ordination of routine departmental reports.

5.311 In order to ensure that these functions are fulfilled with the maximum effectiveness and economy, there are four principles which should be observed.

a) The costing system should be the main channel of communication within the organisation. All information collected should provide positive control. Many of the returns submitted to management are only of transitory interest, but continue to be submitted long after they have ceased to serve a useful purpose. Figures should not be presented in excessive detail and those provided should be in easily readable form capable of rapid assimilation.

b) As far as possible the costing system should rely upon figures normally required for the routine operation of the departments concerned. The accumulation of special data for control purposes is costly, and should be avoided wherever possible.

c) Cost data should be rapidly available to ensure adequate control. Contrary to financial accountancy practice, speed in presentation is here of greater importance than absolute accuracy.

d) The cost of the control system is itself one of the factors involved and should be kept to a minimum.

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* B. Goetz. 'Management Planning and Control'.

5.312 It must always be borne in mind that although a Budgetary Control System may be installed in accordance with the above principles, it may still fail to achieve its purpose.

An adequate system is in itself not sufficient; it must be efficiently worked. To yield a dynamic control there must be a two-way system of communications. Cost data form the basis of reports which draw attention to the need for action, but unless they give rise to decisions which are transmitted back through the organisation the whole purpose of the data has been lost.

The cost control system must also instil a feeling of responsibility for cost, at all levels of the organisation. This aspect depends upon a multitude of human factors, but unless everyone in the concern is imbued with cost consciousness the full value of Budgetary Control will never be gained.

5.320 Preparation of Budgetary Control System

Budgetary control consists of three distinct phases,

a) Accurate recording and presentation of cost data.

b) Setting of Budgets for subsequent periods.

c) Comparison of achievement with budgets.

5.321 There are three stages in the first phase, namely recording, tabulation, and summarising for presentation to management.

The introduction of a new form of cost control is a suitable time for an overhaul of the communication system throughout the organisation. It can thus be ensured that the system is economical, conforms to the principles outlined above and meets the requirements of Budgetary Control. It is preferable to redesign it in its entirety rather than to graft Budgetary Control onto an existing system which may subsequently require revision. For this purpose the employment of Industrial Consultants is recommended, since their experience and specialised knowledge is likely to lead to the most satisfactory solution.

The use of Hollerith or Powers-Samas Tabulating Machinery is now almost universal throughout the aircraft industry. It is thus a simple and speedy matter to obtain the data in the required summarised form.

The summarised totals must then be presented to management in a form which is easily assimilated and where variances from the budget figures are brought into relief. Attached at Appendix III is a possible form which these summaries may take, showing the main headings for an aircraft company.

5.322 The setting of accurate budgets is the most difficult problem which confronts the Controller or Chief Accountant.

Before discussing this, however, it is convenient to study the relationship between the financial and the cost accounts. This may be illustrated by reference to Fig. 4 which shows a simple diagrammatic breakdown of overhead cost.

	(a)	(b)	(c)	(d)	(e)
	Total Overhead Cost	DEPT A	DEPT B	DEPT C	TOTAL All Depts.
(i)	Expense Item 1	£1,000	£ 500	£ 250	£1,750
(ii)	2	£ 200	£ 150	£ 50	£ 400
(iii)	3	£ 300	£ 600	£ 500	£1,400
(iv)	TOTAL All Expense	£1,500	£1,250	£ 800	£3,550

Fig. 4 - Breakdown of Overhead Cost

The figure of £3,550 is the total overhead cost in the case and may be considered to consist of either total expenses incurred or total departmental costs. This example is over-simplified, however, since the experiences during any one period are not necessarily embodied in the products of that period, and consequently the cost total will not be the same as the expense total. This practical difficulty may be overcome by interlocking the financial and cost accounts by a Third Entry Journal,* or, alternatively, by the adoption of an Integrated Accounting System employing the control account principle. Management will be interested in both these aspects and should require budgets of total overhead cost broken down into (a) expense items and (b) departmental costs. Departmental managers should only be supplied with the total departmental budget broken down into its expense items.

In setting a departmental budget fixed and variable costs must be clearly distinguished. The fixed items will normally be carried forward unchanged, from one period to the next, unless there has been an alteration in capital items. The variable costs will require modification to produce a budget conforming to the estimated volume of production. It is thus possible to build up the budget by synthesis. A check is provided by the plotting of graphs of the form of Fig. 2 which can be drawn for any department. By interpolation it is possible to obtain a figure for the total departmental cost at that level

* For a detailed description of Third Entry Method see H.A. Simpson. 'Industrial Accountancy'.

of production, which should closely agree with the total, previously derived from the cost items. It may not be economical to determine the exact allocation of some service costs departmentally (e.g. lighting). Nevertheless, the inclusion of an approximate figure for these items will draw the attention of executives to their responsibility for such costs.

All too often it is found that where Budgetary Control is being applied in the aircraft industry accurately determined budgets are not compiled. Control cannot hope to be effective unless the budgets are scientifically determined and plus variances are genuine indications of inefficiency rather than of inadequate budgeting.

5.323 At the end of each budget period the actual achievement should be prepared with as little delay as possible, to enable prompt and effective action to be taken where needful. The exact length of the budgetary period must be decided by the controller but should be as short as practicable. A weekly budget would be ideal but it may be found that a month is the most practicable period. In addition there should be quarterly, annual and long term budgets which although less accurate and less suitable for control purposes will provide a valuable background for managerial decisions.

5.4 Industrial Consultants

5.40 A number of aircraft companies have had recourse to Industrial Consultants where reorganisation of the whole or part of the firm's structure has appeared desirable. Such a course of action is desirable where the general level of efficiency is low, and a major reorganisation is required.

5.41 Much of the success obtained by consultants from outside the firm is achieved by the establishment of recognised principles in the place of a haphazard system, which has grown with the company without any conscious planning effort. This work is of far greater value when establishing the broad framework of a system than when it is concerned with minor modifications to an existing system where an intimate knowledge of the particular industry is necessary.

5.42 It is therefore considered that the use of Industrial Consultants should be limited to major reorganisation such as that recommended for the reporting system before the application of Budgetary Control. Once an efficient system has been adopted there will still be changes required from time to time to meet new circumstances. It is considered that this task is most suitably undertaken by an Efficiency Section.

5.5 Economy Committee

5.50 It has been noted earlier that with the increasing specialised knowledge now required by executives, there has been a marked tendency towards lack of appreciation of the work undertaken by others with whose problems they are not acquainted.

This is a failing of initial training and subsequent experience, and is most marked in the relations between accountants and engineers in many a firm. It is now more than ever important that accountants should have an appreciation of the technical problems with which their engineers are grappling, and by the same token should engineers appreciate the contribution that accountants are making to economy of production.

5.51 It is considered that a committee consisting of the Chief Designer, Works Manager, Chief Inspector, Chief Accountant (Controller) and Cost Accountant meeting regularly at weekly intervals should be constituted. At one large aircraft company well-known to the writers, such a committee has been in existence for several years, and the effect has been extremely beneficial.

5.52 The agenda would consist of any item emanating from one department which gives rise to costs in another which it is considered could be reduced by slight modification. Personal contact at this level of management would provide a quicker and more satisfactory solution to current problems, than would be the case if they were left to subordinates. Although the primary object of this committee would be to find a solution to current problems contributing to high costs, it is considered that the interchange of views at this level would eventually become of lasting importance through the prevention of these costs at source due to a realisation and elimination of their causes.

5.60 Operational Research Section

It is evident that there is a continuous need for the examination of a firm's organisation in order to increase its efficiency. It is suggested that this can be best achieved by the establishment of a small section whose sole purpose is to carry out investigations of this nature.

5.61 The section would consist of three or four members, the chief of whom should have a broad knowledge of the firm with preferably some experience in Industrial Consultancy, and the remainder, junior staff who are considered suitable for eventual promotion to executive duties. Although directly responsible to the Chief Accountant (Controller), this section should be regarded as a service to the company as a whole rather than an integral part of the Controller's staff.

5.62 The Operational Research Section would operate in three distinct ways, depending upon the nature of the investigation.

The first type of investigation would be one covering several departments. An example of this type of work may well be the examination of the flow of paper work and the elimination of unnecessary returns. Modifications in this field are continually required, and can only be adequately controlled if kept under constant review by staff, who are fully conversant with the use to which any return is put throughout the organisation. For this purpose, the section would be operating directly under the

Controller, and in close collaboration with the Heads of the Departments concerned.

Secondly, members of the section may be detached to work in an advisory capacity for a special investigation at the request of a Head of Department. An example of what is envisaged here is an examination into the relative economic merits of Lithographic or Photographic Lofting, for the Head of the Lofting Department. This would require a lengthy economic analysis, which the executive concerned may be unable to undertake owing to lack of time or ability.

Thirdly, the collection of data required for managerial control which is not normally supplied may be delegated to this section.

5.63 In order to operate effectively, the co-operation of all executives with whom the section comes into contact is essential. The true relationship of this section, as a staff function, to the departmental or line authority would need clarification at the outset in order to absolve it from any suspicion of prying into departmental affairs. Consequently, it is of the utmost importance that the Controller should establish the section tactfully and should stress that it is a service to the organisation as a whole.

5.64 Besides improving the general level of efficiency it is considered that year or two spent in the Operational Research Section would provide a valuable training ground for junior executives. They would be afforded an opportunity of studying the organisation as a whole and of developing a broad viewpoint which would be invaluable in later years and would serve to eliminate the narrow departmentalised outlook which is apt to make co-operation amongst executives sometimes difficult.

5.7 Summary

Cost is the only universal measure in which the labour, materials and services embodied in an industrial product can be ultimately expressed. The cost data which is collected within an organisation furnishes, therefore, an invaluable basis for assessing the effectiveness of management and manufacturing efficiency. If the fullest use is not made of this information a valuable tool of management is being neglected.

6.0 CONCLUSION

To sum up the argument which has been propounded in the preceeding pages, our general conclusions are, then, the following:

6.1 Owing to limited civil requirements, the survival of the aircraft industry has in the past been dependent upon Military contracts. Consequently, the emphasis has been placed predominantly upon the performance of the aircraft, cost considerations having been largely neglected. However, the increasing cost of modern aircraft at a time when the national resources are being

stretched to the utmost, coupled with the importance of developing a flourishing industry well adjusted to the economical production of civil aircraft, makes it imperative that this subject of cost control in aircraft manufacture be given more detailed consideration.

6.2 Cost control as a managerial technique has received too little attention and such control systems as are in operation are far less highly developed than in other branches of industry. It is considered that appreciable economies in manufacturing costs could be effected if the full use were made of cost data for managerial control.

6.3 The factors contributing to the present high cost of aircraft are both technical and human. The chief technical features are (a) Fluctuations in Demand (b) the changing nature of the product (c) High degree of technical excellence and complexity of the product and (d) the contract system of procurement which fails to provide an incentive for cost reduction. But whilst it must be recognised that such factors are largely unavoidable, it is contended that it is the general acceptance of high cost, and the absence of cost consciousness which are the most potent cause of excessive cost.

6.4 It is considered that an adequate system of cost control particularly suited to the control of overhead costs would be provided by the following measures:

6.41 Productivity Measurement and the comparison of cost data throughout the industry. This would provide the spirit of competition which is at present lacking. This would probably require considerable research and the application of uniform costing before its success could be ensured, but the benefits ensuing would easily justify the effort.

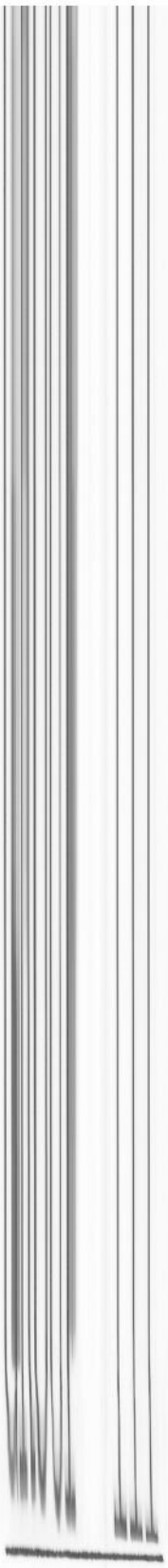
6.42 The strict control of fixed cost. This is particularly important in the aircraft industry where the conflicting demands of financial flexibility and technical excellence of the product, make a compromise difficult to achieve.

6.43 Budgetary Control to ensure adequate control of variable overhead costs.

6.44 The use of Industrial Consultants whose experience and specialist knowledge is invaluable where a major reorganisation is required.

6.45 The establishment of an Economy Committee where current problems contributing to high cost would be discussed at a high level.

6.46 The establishment of an Operational Research Section to carry out investigations leading to a general improvement in the level of operating efficiency.



Supervisory

Foremen, Chargehands.
Works Inspection.
Setters.

GROUP IV

Jigs and Tools

Toolmakers, Jig and Fixture Makers.
Fitters on Jig Assembly and Maintenance.
Pattern Makers.

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6.45 The establishment of an Economy Committee where current problems contributing to high cost would be discussed at a high level.

6.46 The establishment of an Operational Research Section to carry out investigations leading to a general improvement in the level of operating efficiency.

6.5 The development of a good cost control system is essential but will not be adequate unless accompanied by general attitude of cost consciousness amongst management, from top to bottom. It involves a breakdown of the present narrow departmental outlook amongst executives and a universal widening of engineering knowledge amongst accountants and accounting knowledge amongst engineers.

APPENDIX I

CATEGORIES OF LABOUR CLASSIFIED AS INDIRECT LABOUR

BY THE MINISTRY OF SUPPLY

GROUP I

Managerial, Technical and Office Staff

Administrative, Management and Office Staff.
Design, Drawing Office, Technical and Experimental Staff.
Supervisory Staff and all Experimental Shop Labour.
Progress, Planning, Estimating, Buying Staff.
Rate Fixers and Time and Motion Study Staff.
All Shop Clerical Staff.

GROUP II

Works Services

Watchmen, Works Police, Firemen, Gatekeepers.
Welfare, First Aid, Canteen Staff.
Maintenance, Electricians, Painters, Carpenters, etc.
Millwrights.
Boiler-House, Substation, Compressor-House Men.
Labourers and Cleaners.

GROUP III

Supervisory

Foremen, Chargehands.
Works Inspection.
Setters.

GROUP IV

Jigs and Tools

Toolmakers, Jig and Fixture Makers.
Fitters on Jig Assembly and Maintenance.
Pattern Makers.

GROUP V

Process, Stores and Despatching Staff

Workers in Protective, Anodic, Degreasing, etc.
Heat Treatment.
Storekeepers.
Foundry.
Transport Drivers and Transport Maintenance.
Pakcers and Despatchers.

APPENDIX II

MODIFICATION OF SIR EWART SMITH'S PRODUCTIVITY EQUATION TO PROVIDE A CRITERION OF PRODUCTIVITY IN THE AIRCRAFT INDUSTRY

Sir Ewart Smith has developed a relationship by which the productivity in any industry may be measured by reducing all the factors influencing production to man power equivalents.

$$\text{Productivity} = \frac{\text{Volume of Output/annum}}{\text{Average number of men employed + man power equivalent of capital equipment + man power equivalent of services rendered + man power equivalent of changes in raw material.}}$$

This may be rewritten symbolically as:-

$$P = \frac{W}{Ld + Li + C + S + M}$$

where W = Structure weight/annum
Ld = Direct Labour employed
Li = Indirect Labour employed
C = Man power equivalent of capital equipment
S = " " " " services rendered
M = " " " " changes in raw material

If this formula were applied to the aircraft industry in this form, the productivity would be shown to undergo both short and long cycle fluctuations. These are unavoidable features of the aircraft industry but to establish a basis of comparison within the industry it is necessary to isolate their causes and to eliminate them by modifications to the formula.

The two factors giving rise to these major fluctuations in productivity in the aircraft industry are:-

a) Progressive diminution of direct man hours required to produce an aircraft as the cumulative production of that type of aircraft increases (80% Law).

b) Incomplete utilisation of plant and equipment due to only partial absorption of the potential during peace production.

Each of these problems will now be considered separately and correction factors developed.

a) Correction Factor to Eliminate the Effect of the '80% Law'

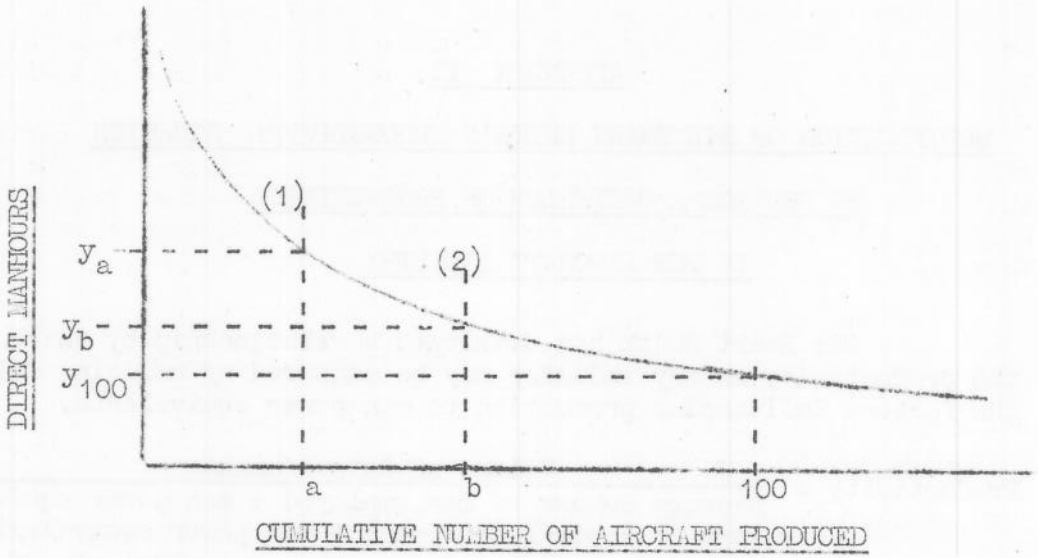

FIG. 5: '80% Law' Relationship

The direct man hours required to produce an aircraft decrease with the cumulative number of aircraft of that type produced in accordance with the statistical '80% Law' (see Fig.5) The productivity of direct labour of a company operating at point (1) on the curve is obviously lower than for a company at point (2). Since this variation is beyond the control of the respective managements, it is necessary to eliminate this factor when substituting in the productivity equation, if a true measure of the operating efficiency is required. This may be achieved by relating all direct labour figures to a given datum, the hundredth aircraft being convenient for this purpose.

The standardised direct labour figures then may be expressed as:-

$$Ld \times \frac{y_{100}}{y}$$

and if several types of aircraft are being produced as:-

$$Ld_a = \frac{y_{100}}{y_a} + Ld_b \times \frac{y_{100}}{y_b} + \ldots$$

Although this standardised direct labour force may bear little relation to the actual force employed, it should serve to make the figures for different companies comparable.

b) Correction Factor for War Potential

During peace time most of the plant and equipment in an aircraft factory will be operating only at partial utilisation. The margin by which the potential exceeds the requirements is a matter for the judgement of the administration and should, as far as possible, be eliminated from a productivity measurement designed to measure the operating efficiency of the factory. It may be assumed that War Potential does not appreciably affect the level of direct and indirect labour, services rendered and raw material.

It is therefore necessary to correct only for the partial utilisation of capital equipment. If the mean utilisation for this item is U% then the capacity absorbed for current production will be UC/100, and this figure should be substituted in the formula.

The determination of the utilisation figure would not be easily achieved in practice. Nevertheless, if it were considered worthwhile to expend the considerable labour required to determine C, S and M, then the additional labour to determine U could also be justified in order to make the comparison effective.

Modified Form of the Productivity Equation

Combining the correction factors proposed above the equation now becomes:

$$E = \frac{W}{\left(Ld_a \times \frac{y_{100}}{y_a} + Ld_b \times \frac{y_{100}}{y_b} + \quad\right) + L_u + \frac{UC}{100} + S + M}$$

where E = effectiveness of the aircraft factory.

A correct comparison between the effectiveness of different factories in the aircraft industry would now be obtained. The term effectiveness is now used since the modifications invalidate the strict use of the word 'productivity'. The chief obstacle to the use of this formula is the extreme difficulty of establishing the numerical man power equivalent for capital equipment, services rendered and changes to raw material.

APPENDIX III

TYPICAL BUDGETARY CONTROL STATEMENTS

A. Overhead Summary Sheet
B. Detailed Expense Budget

A. OVERHEAD COST SUMMARY SHEET PERIOD

Item	Budget	Actual	Variance	Variance % of Budget
Indirect Wages				( )*
Departmental Charges				
Repairs and Depreciation				
Standing Charges				
Salaries and Supervision (Production)				
Salaries and Supervision (Design and Experimental)				
Head Office Charges				
TOTAL OVERHEAD COST				

* ( ) % Variance for previous period _____

TOTAL OVERHEAD COST AS % OF DIRECT WAGES = _____

B. DETAILED EXPENSE BUDGET STATEMENT

PERIOD

Item	Budget	Actual	Variance	Variance % of Budget
Indirect Wages				
GROUP I*				
" II				
" III				
" IV				
" V				
Setting Up Time				
Waiting Time				
Production Committee				
Educ. & Training				
Accident Insurance				
State Insurance				
Sub-Total				
Departmental Charges				
Petrol				
Electric Power				
Fuel				
Gas				
Water				
Consumable Stores				
Loose Tools				
Stationery				
Telephones				
Postage				
D.O. Supplies				
Patent Expenses				
Royalties				
Travelling Expenses				
Indirect Material				
Office Equipment				
Advertising & Publicity				
Consultants & Prof. Fees				
Apprentices & Students Fees				
Welfare Contributions				
Sub-Total				
Repairs & Depreciation				
Repair Wages				
Repair Materials				
Repairs contracted				
Depreciation				
Sub-Total				

* See Appendix I.

Detailed Expense Budget Statement (Contd.)

Item	Budget	Actual	Variance	Variance % of Budget
Standing Charges				
Rent				
Rates				
Insurance - Fire				
General				
Pilots				
Hire of Plant				
Sub-Total				
Salaries & Supervision (Production)				
Production Bonus				
Accident Insurance				
Overtime				
Monthly Staff Salaries				
Weekly Staff Salaries				
State Insurance				
State Pension				
Sub-Total				
Salaries & Supervision (Design & Experimental)				
Monthly Staff Salaries				
Weekly Staff Salaries				
Overtime				
State Insurance				
State Pension				
Pilots Superannuation				
Sub-Total				
Head Office Charges				
Sub-Total				
TOTAL OVERHEAD COST				

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