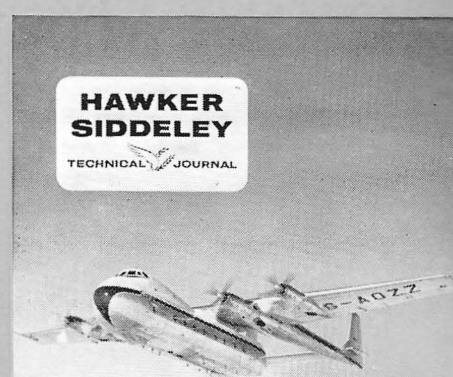
HAWKER SIDDELEY GROUP



The Armstrong Whitworth 'Argosy', the first pressurized turbo-prop freightercoach, broke all production records for an aircraft of its size and complexity. The aircraft's designer, Mr. E. D. Keen, writes in this issue on *Design for Production*

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Edited by
James S. Dall

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TECHNICAL INFORMATION FOR INDUSTRY

R. A. WALL, F.L.A., *Librarian, A. V. Roe and Co. Limited, Weapons Research Division*

The rapid advance of science and technology and the enormous growth of technical publishing have made it difficult for the specialist to keep abreast of his subject. Typical efforts to help the specialist, with particular reference to industrial information services, are reviewed

THE immense progress of science and technology during the last fifty years has brought about a corresponding increase in technical publishing. The multiplicity of information media makes it difficult for the specialist to keep in touch with the latest developments in his field. This article outlines typical efforts to help the specialist, and to this end describes communication, the growth of documentation, the importance of information and its retrieval, forms of publication, possible functions of an information service and its staff, economic aspects, and future trends. Details of library processes are, of course, reviewed only in brief.

Communication

All recorded information is a result of attempts at communication. In the days of ancient Greece, it was possible for one mind to encompass the whole realm of human knowledge. Communication was simple, involving a limited and therefore easily assimilated terminology, and there was no national language difficulty. There were no societies or institutions eager to publish the work of members, and there was no urgent scientific news. Because science was independent of technology, which was much less well developed, speed was not an important factor in technical communication. No one lost a market or a fortune if news was a week late. It was, in fact, an age the modern academician might yearn for—one of pure and independent research.

With the immense growth of both science and technology came increased specialization. No longer may one mind encompass all knowledge. The effect of specialization is cumulative: the canalization of effort in thousands of limited subject areas brings rapid advances; and the specific subjects which at first seem limited grow into large areas of knowledge, further subdivision being necessary within the subjects. The whole process may be compared with that of biological growth by cell division.

There are, however, dangerous side-effects in specialization. Although communication within the cells is good, lack of knowledge and terminological difficulties severely hinder the cross-fertilization of ideas between cell and cell. The ideal, if it were possible, would be the linking and cross-linking of cells in at least as efficient a manner as they are in the human mind itself. Perhaps one should modify the latter to 'the mind of a linguist', for with the spread of civilization and the participation of many nations in research and development, language difficulties became a further barrier to effective communication.

Complex modern industries have to incorporate and coordinate many specialist fields of activity. Examples are the aircraft, missile, chemical, electronic and nuclear engineering industries. In the case of the aircraft and missile industries, this now involves employing specialists in aerodynamics and structures, mathematics, chemistry, physics and metallurgy; electronics, guidance and control systems, and instruments; and propulsion. As a new industry grows from small beginnings, more and more specialists are drawn from other fields to help speed its progress, and the industry eventually creates its own areas of subject specialization. These may be subdivisions of existing areas, like computer programming, or subject complexes like aeronautical or missile engineering.

Managements need a means of information coordination, cutting across areas of specialization, preventing duplication of effort, providing a means of communication, and stepping up research efficiency and industrial productivity. Coordinators are in ever-increasingly short supply in the modern world, owing to subject specialization during education and in industry. Even the most efficient manager cannot, however, absorb or transmit the detailed knowledge required by his specialist groups, nor can he keep abreast of the mass of new ideas communicated by documents, periodicals and other media. The industrial library or information service, whichever it is called, distributes the necessary raw material of information to the specialists. Since the library is a clearing house both for incoming information and day-to-day enquiries, it can assist managements to maintain coordination.

Documentation

In its widest sense, documentation means the recording of information in any form whatsoever. Recent statistics reported by 'Chemical Abstracts' indicate that, of the total of 20 million items analysed, as many as 40 per cent were issued during the last ten years—and these were selected items, chosen according to both subject and authority. Documentation has expanded at a far greater rate than the subjects themselves. First, there is variation in the scope, point of view, or aspect treated. Then there are the different levels of treatment, from elementary to advanced. Numerous forms of publication are used, namely periodicals, research reports, reference books, text books, separates or preprints, patents, trade literature, and films. Any of these may eventually find its way on to microfilm or some other form of space-saving microrecord. All may vary in value according to whether they are irresponsible or authoritative, or whether the information has been lucidly communicated by good presentation. Any item can be of permanent interest or merely ephemeral, subject to regular revision or sporadic correction or none at all, and may be superseded by an item issued in an entirely different form or produced by a different source. In short, the number of variables makes it a complex business.

The unfortunate specialist, it seems, must try to develop two heads—one deep in his own immediate problems, and the other studying the current work of other men in the same or related fields. His task is greatly assisted if the relevant material is being acquired by the library, preferably well in advance of requests, and being made available automatically in accordance with his known subject interests.

The Importance of Technical Information

The primary aim of an industrial or

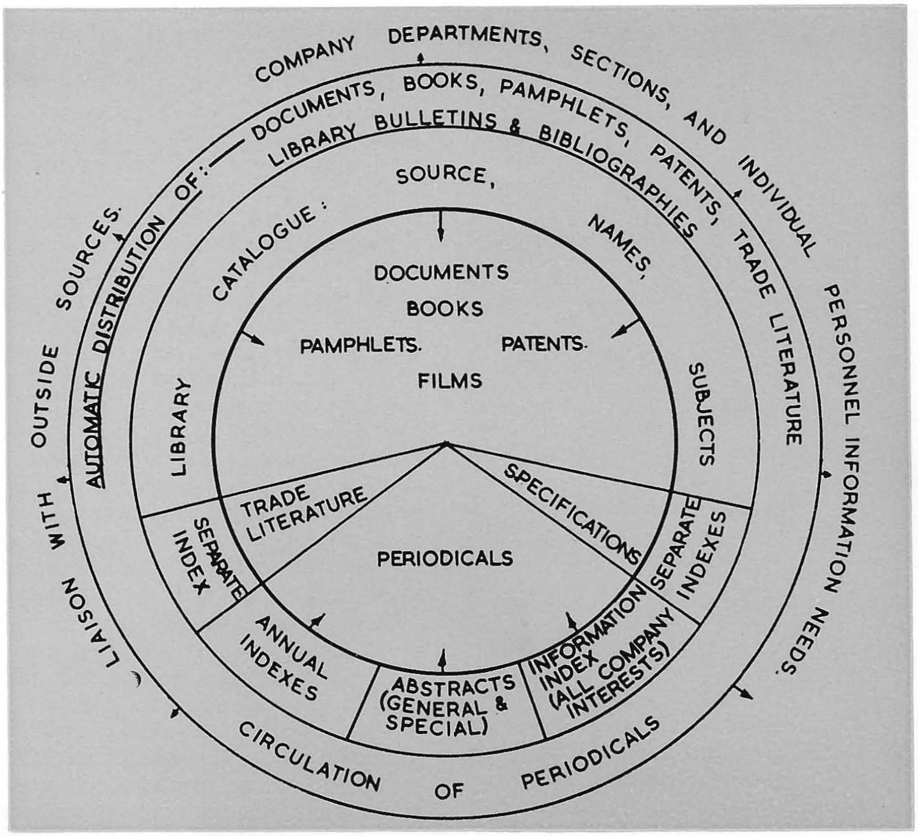


Fig. 1: Short-comings of information retrieval systems can be minimized by the library staff's knowledge of outside sources and familiarity with search techniques. In this simplified diagram are shown the distribution of information material and typical search routes

research information service is to help to avoid the duplication of costly experiments already done elsewhere. This should be done without asking, for the library staff should be fully aware of the work in progress and watch out for new information. The success of the system depends on the extent to which the staff are informed of current developments within the firm. It has been suggested (Ref. 1) that lack of knowledge of work being done elsewhere is probably the greatest cause of inefficiency in research. When communication is not merely poor, but prevented, an enormous waste of resources can result. The recent Geneva Conference on the Peaceful Uses of Atomic Energy gave a striking example of this.

Dr. W. Klein, Deputy Director of the Austrian Productivity Centre, has put other aspects in a nutshell:

'New products are replacing old ones, and unless firms keep abreast of the latest technical developments concerning raw materials, production processes, packaging methods, etc., they may well find themselves out of business. . . . Technical information is, therefore, an essential factor in modern industrial practice and a crucial means of reaching higher productivity. . . . It serves progress, saves expenditure and labour, and contributes considerably towards keeping a firm at a high level of efficiency.' (Ref. 2, pages 30 & 31.)

Even if a firm has a guaranteed market, the use of obsolete production methods can represent an extensive waste of labour and materials.

All new ideas which are openly published, as opposed to those in private research reports or covered by patents, may of course be freely applied by anyone in his work. This is a prime motive of the communicator or author. But the mere contact with ideas, whether they are new or old, can inspire completely original ones, for communicated ideas are stimuli to the creative faculty. A good plan for the scientist, engineer or technician, when temporarily at a loss, is to visit the library and seek fresh inspiration from the knowledge recorded there.

Companies are always watching their markets, not only to anticipate changes in the fortune of present activities, but also to watch for new openings. To make an effective assessment, they must know of the manufacturing activities of all other firms engaged in the same field, in so far as these are indicated in newspapers, periodicals, directories and publicity material or communicated by the trade grapevine. The most up-to-date information often appears in small portions, and when detailed records are required it is usual for the library, if it has a 'commercial section', to assist in compiling them. Some information, however, may be gleaned from periodicals and trade literature in the average technical library.

The last use of technical information which will be discussed here is that of providing essential working data for everyone in the organization, from the general manager to the factory or clerical worker. The enquiries are legion, and vary from dictionary or directory information to full-scale literature searches on new, or even new-old, techniques. A laboratory or factory worker needs, for example, data on his materials, instruments and processes, while engineers require standards, specifications, information on machinery, components, electronic circuits—a list of their needs would almost equal a technical library catalogue. Specific enquiries vary in scope and have relations with other subjects, and enquirers are therefore asked to define not only their needs but their purpose in seeking the information.

Specialists normally require little help in the task of physically searching the literature of their own subjects, and indeed they could miss profitable information 'by-ways', which may provide useful ideas, if they avoided tackling the search personally. In these cases, the help given by the staff is more concerned with the supply of additional sources or of advice on search techniques than with the retrieval of detailed information itself. All special subjects, however, have fringe or related ones, or need the application of techniques borrowed from an ostensibly unrelated subject field. It is with enquiries involving subject areas outside his normal scope that the specialist needs the most help from the librarian or information officer.

Information Retrieval

Information retrieval systems are means of classifying, abstracting, cataloguing, and filing recorded information in such a way that any desired subject matter can be re-located and retrieved from the collection.

The growth of documentation has already been discussed. Valuable information is liable to become submerged in the flood of material. Documentation sources are of two types, primary and secondary. Primary sources include periodicals, research reports, proceedings of conferences, books, etc., while secondary sources consist of abstracting services, bibliographies and the like.

Abstracts seek to provide keys to the mass of information produced. It is far easier to study abstracts than to wade through primary sources to select new

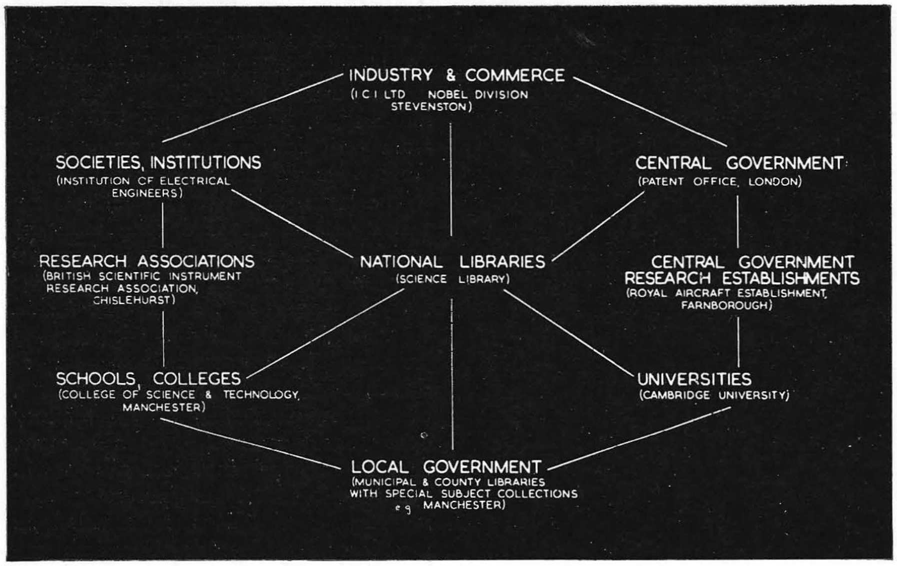


Fig. 2: No special library can be completely independent of outside sources. This diagram illustrates the pattern of libraries which may interlend, one library of each type being shown

material for the specialist. Unfortunately, abstracts vary in quality and are poorly coordinated in respect of subject coverage and national or international scope. In the U.S.S.R., abstracting is centralized by the Academy of Sciences, which produces a coordinated series of subject abstracting journals. The largest service in the West is undoubtedly the U.S.A. 'Chemical Abstracts', which is international in range and covers all subjects closely or remotely connected with chemistry. The principal drawback with abstracts, however, is the time lag. In 'Chemical Abstracts' this may be as much as two years. Libraries often scan the periodicals as well as the abstracts in their own field, when they have sufficient resources, and produce their own abstracts bulletins or contents lists. Such services have two advantages: a close degree of selection; and early publication, usually within a couple of weeks of scanning current sources.

Mechanized methods of speeding up retrieval systems are being sought, especially in the U.S.A. and the U.S.S.R. Information processing will be the subject of an international conference in Paris between the 15th and 20th June, 1959. Punched card systems are ideal for the recording and retrieval of actual data, for example on the properties of chemical compounds. Many claims of success have been made in the application of punched cards to bibliographical sources, but it has yet to be proved that the benefits of such systems are great enough to justify the expense of the equipment and the required encoding operations. Examples of assessments at present being made are:

The ASLIB (Association of Special Libraries and Information Bureaux) Aeronautical Group investigation at Cranfield, where the same batch of aerodynamics documents is being indexed by several different methods, including punched cards;

The intended programme of the new Research Information Center and Advisory Service on Information Processing, recently established in the U.S.A. by the National Bureau of Standards and the National Science Foundation. The latter provided a grant of $105,000 for initial establishment and operation during the first year. (Ref. 3.)

Meanwhile the existing systems depend on a balance between choice of classification or indexing scheme and quality of staff. The Universal Decimal Classification is the one most widely used in technical libraries. It is constantly under revision to keep pace with the growth of subjects, but many libraries find it necessary to make interim adjustments or devise special classifications of their own. Every classification or indexing scheme, however, has its own inadequacies. The staff's knowledge of the library stock and of outside sources, together with familiarity with search techniques, and, if possible, intuitive faculties, provide short cuts and seek to compensate for the faults of retrieval systems. Fig. 1 shows information materials distribution and search routes.

The language barrier sets another problem. Much work is being done by the Department of Scientific and Industrial Research, especially in the acquisition of Soviet material. Details of the availability of Russian information, which is receiving great attention, are beyond the scope of the present article, but some surveys have already appeared. (Refs. 4 and 5.)

Forms of Information

It is not possible, in this review article, to examine all the forms listed above under Documentation. Instead, generalizations will be made on some of the most valuable forms in order of their importance.

Fig. 3: An example of a well equipped technical library, that of High Duty Alloys Ltd., Slough. This view shows shelves containing British Standard, D.T.D. and Patent Specifications, and general reference books

Fig. 4: Another view of the library of High Duty Alloys Ltd., Slough. The main catalogue (centre foreground) contains author and subject entries arranged according to the Universal Decimal Classification system. The data files in the background hold pamphlet and reprint material grouped under subject by the U.D.C. system

Documents include research reports from government, independent, or educational establishments, from research associations such as the Production Engineering Research Association, from the central government itself or from international bodies, and from companies. The special value of research documents lies in their early advanced treatment of specific subjects. They are often restricted in circulation, for either proprietary or security reasons, are written by experts, and are often the most up-to-date form of detailed research information.

Periodicals give the latest 'free' information. A great deal of that information never finds its way into books or other forms, hence the necessity of maintaining bound collections in libraries. There are thousands of titles being issued, and even a small special library may find it necessary to subscribe to several hundreds of them. Some articles may repeat information which first appeared in open research reports, but the great majority are original. The *proceedings* of conferences and the *transactions* of societies, since they are both completely topical and authoritative, are of special importance.

Books may be roughly divided into reference works and text-books. The first are essential for the provision of facts and formulae. The second should give the state of the art at the time of writing, or give instruction in a subject. Authors often draw extensively on periodical sources, hence a good book may shorten a full literature search.

Details of the value of *patents* as a source of information are outside the scope of this article. Briefly, they must give sufficient data to allow 'a person skilled in the art' to understand the product or process covered. Naturally, this information cannot normally be used without obtaining a licence from the inventor, but it is nevertheless of great interest. The Crown, however, and contractors to the Crown, enjoy special rights in certain circumstances.

Industrial Library and Information Service

The work which can be done by an industrial library on the problems and materials discussed in previous sections will now be surveyed.

Industrial special libraries are tailored to the needs of the organization, and for this reason it is not appropriate to generalize on the question of functions. They are, however, able to assume certain dynamic functions impossible for public libraries, which have universal subject coverage—mainly at a general level—and handle all types of enquirer.

In these days it is generally understood that any special library seeks to:

Order new material in anticipation of requests, in accordance with the subject interests involved, and build up a stock for retrospective searching;

Classify and catalogue the publications on arrival, and make them available for loan;

Fig. 5: The library of Imperial Chemical Industries Ltd., Dyestuffs Division, is an excellent example of a large industrial library service. In addition to the main library illustrated here, the service includes technical and patents libraries, a records and report section and index room, storage space and general administrative and workshop accommodation. Photograph: Imperial Chemical Industries

Produce bulletins which report new additions to the library;

Satisfy requests for bibliographical references, whether from stock, by purchase, or by borrowing from another library;

Satisfy specific subject requests;

Produce bibliographies on topics of special interest;

Provide facilities for on-the-spot consultation of the library stock by the technical personnel themselves, that is, reading or reference accommodation;

Index, file, and sometimes produce, the parent organization's own research reports;

Circulate periodicals regularly to the personnel most concerned;

Provide a photocopying service.

In an industrial special library, the following dynamic functions can be added. These should be taken as examples, and be compared with their results, as discussed above under 'The Importance of Technical Information':

Distributing new material, without waiting for requests, to the personnel most concerned. Important publications therefore reach key personnel as early as possible, and before the library bulletin reports their acquisition;

Scanning new periodicals and making a select information index to principal articles. Publishing the details periodically in the form of a contents list or an abstracts bulletin;

Holding information meetings on topics affecting more than one group, thus closely defining subject interests, and assisting the coordination of information flow from the library and between personnel;

Producing literature reviews or surveys on important topics.

No special library can hope to be completely independent of outside sources, and it is necessary to maintain liaison with government, public and university libraries, and the libraries of research organizations or firms. The first responsibility of a special library is to the organization which it serves, and lending is therefore done with a great deal more caution than in public services. Much can be done, however, by cooperation, and the pattern of libraries which may interlend is illustrated in Fig. 2. Liaison with bodies other than libraries is mentioned in the next section.

An example of a large industrial library service is that of Imperial Chemical Industries Limited, Dyestuffs Division, which has main, technical and patents libraries, a records and reports section, a technical section and index room, general administrative and workshop accommodation, and a basement store. Opened in mid-1955, the imposing new building devotes 11,500 square feet to these purposes. A lecture theatre occupies the top floor, and the building is centrally situated among the research laboratories. There is a separate commercial library located in the administrative area. Part of the main library is illustrated in Fig. 5. (Ref. 6.) Figs. 3 and 4 show parts of the High Duty Alloys Ltd. library at Slough.

Staff

The staff of a special library are even more important than the stock of publications. This arises in two ways:

(1) The stock is largely wasted, and valuable information may remain hidden, unless the staff are skilled in the techniques of exploiting it.

(2) The information needs of a company involve a great many fringe or related subjects which cannot usually be included in the library for economic reasons. Moreover, enquiries very frequently involve seeking research documents of an 'unpublished' nature, not already held in the library, or searching for information which is not available in a recorded form. The librarian or information officer must be capable of locating the desired data, provided it does exist, in outside sources—whether these are libraries or individual research workers.

The Library Association qualifications involve a course of professional education followed by a series of examinations, and a six-year period of experience in an approved library or information service. The educational and conditioning process covers all that is implied by the term 'information work', plus organization and administration. These qualifications are not the only guarantee of individual ability. Many men and women have entered the profession and made a great success of it through sheer enthusiasm, adaptability and aptitude. As in all other professions, ability must be proved in practice. The qualities and aptitudes required include:

An approachable personality — the librarian must be a receptive 'communicant' before he can be an effective 'communicator' — and administrative ability;

A good general knowledge of the subject field involved. The librarian or information officer is trained, through early instruction in the logical processes of classification, to locate information without the aid of specialist subject knowledge. If a more detailed knowledge of a principal subject field can be incorporated in the mosaic of general education, so much the better, for searching efficiency will be improved in that subject;

A thorough understanding of the principles involved in the organization of information for retrieval, namely, selection of material, classification and indexing, and library routine systems;

A dynamic approach to the work. The librarian must seek out the facts needed, and try to keep ahead of demand.

Economic Aspects

The size and scope of the library is very dependent upon the particular needs of the parent organization. The librarian should pay strict attention to streamlining routines, and keep the stocks and service policies under continuous review to meet the changing needs of the organization. It is therefore one of his tasks to decide, often in collaboration with subject specialists, what material should be bought and made available permanently and which items may be borrowed from an outside source. In addition to building up a library stock, the library usually becomes the sole supply route for publications required by technicians for individual and regular use, thus ensuring minimum duplication of copies within the firm.

A good library service costs money, and acceptance of libraries has been slow in the past owing to the difficulty of assessing their output in concrete financial terms. One can only surmise, from an examination of typical enquiries, what would have happened if certain data had not been forthcoming, and what financial loss would have befallen the company as a result. There are many recorded instances of firms having suffered great loss through failure to keep abreast of the progress of their competitors, through the use of obsolete methods, or owing to a shortage of new ideas. Other factors have been described earlier in this article. The importance of technical information and its coordination in libraries has, however, received increasing attention during the last twenty years. More and more firms are founding their own services and relying upon them to contribute towards effective management.

Future Trends

Some mention has been made of the current and projected research in machine methods of information retrieval. Efforts are also being directed against the language barrier by research on mechanical translation. These, however, are tackling only one end of the problem. There is no doubt that improved coordination of sources would greatly assist communication.

The Russians have centralized their principal abstracting services. They also have a fair degree of coordination in the whole field of technical publishing. It is not just a missile and space technology race that has been embarked upon between East and West; it is a race between two entire industrial and economic structures. Prestige is at stake, and world markets may be the prize. Communication can be considered an important factor in this endeavour.

In the Western world there is little coordination other than that which has come about through mergers between publishing houses or through the influence of government grants. The grant from the National Science Foundation to encourage the production of Russian translations is an example. Abstracting services are not coordinated either in subject coverage or in publishing delay. Thus the subject coverage discrepancies in information sources go on, and they may well continue to go on, for they are a result of complete freedom in publishing.

A free press, however, is essential to the Western way of life, and any form of control would have far-reaching and disastrous effects. These remarks lead to the suggestion that a good deal could be accomplished without control, if the publishers would agree to define their subject fields more closely and if abstracting services could likewise come to some mutual arrangement. So the presses roar on with their task of producing recorded information, and the mass of documentation flows out through the libraries to engineers and research workers. Meanwhile, information processing research continues to seek new methods and improved efficiency.

REFERENCES

1. Availability of scientific information.
   Nature, 17th January, 1959, p. 135.

2. Technical information services in Europe: report on the third meeting of technical information officers, Rome, 19th-23rd March, 1956.
   Paris, O.E.E.C.: European Productivity Agency, 1958.

3. Research Advisory Service on Information Processing.
   National Bureau of Standards (U.S.A.), Technical News Bulletin, December, 1958, p. 233.

4. Providing U.S. scientists with Soviet scientific information.
   National Science Foundation, 1958.

5. The dissemination of the knowledge of Soviet scientific work in Western countries.
   A. E. Stubbs.
   Aslib Proceedings, November, 1957, pp. 333-340.

6. The libraries of the Dyestuffs Division.
   Imperial Chemical Industries Limited, Dyestuffs Division.

POWER IN COAL MINES

Development of a 300 kVA dry type Flameproof Mining Transformer

D. H. SMITH, B.Sc.(Eng.), A.M.I.E.E., *Chief Engineer, Transformer Division, Brush Electrical Engineering Co., Ltd., Loughborough*

Increasing power demands for coal cutting and handling machinery have made necessary the development of a special explosion-proof type of transformer which can be safely located near the coal face. The need to avoid the use of oil necessitated the study of dry type air filled construction using the new silicone bonded Class 'C' types of insulation which permit safe operation at high internal temperatures. This article describes the development of such a transformer, with illustrations showing constructional features and details of tests carried out to prove its satisfactory performance

In recent years, development of mechanized coal mining has seen the use of coal cutting and loading machinery of ever increasing size, such that the provision of an electrical supply at the correct voltage has presented difficult problems. With the advent of large machines of the Dosco 'Miner' type, the total power in use may vary from 200 to 300 h.p. and the problem is to provide an adequate power supply at the correct voltage under all conditions of operation.

Hitherto, power has been supplied through a 250 kVA orthodox oil filled type of transwitch unit situated at a point not less than 300 yards from the coal face. To cater for the higher current demanded by modern machinery, long low-tension cables of heavy section are necessary, the arrangement being unwieldy and difficult to manage. It also suffers from excessive voltage variations at the coal face owing to voltage drops in the cables on full load and, particularly, during starting-up conditions.

To overcome these drawbacks it is necessary to locate the transformer close to the machinery at the coal face, thus permitting the use of longer, smaller and more flexible H.V. supply cables, with shorter, heavy L.V. cables, and with a consequently lower voltage drop. To meet these conditions the dry type air filled flameproof transformer described in this article has been developed, utilizing the latest kinds of silicone bonded Class 'C' insulation, which are capable of withstanding for long periods operating temperatures in the region of 200 to 250°C.

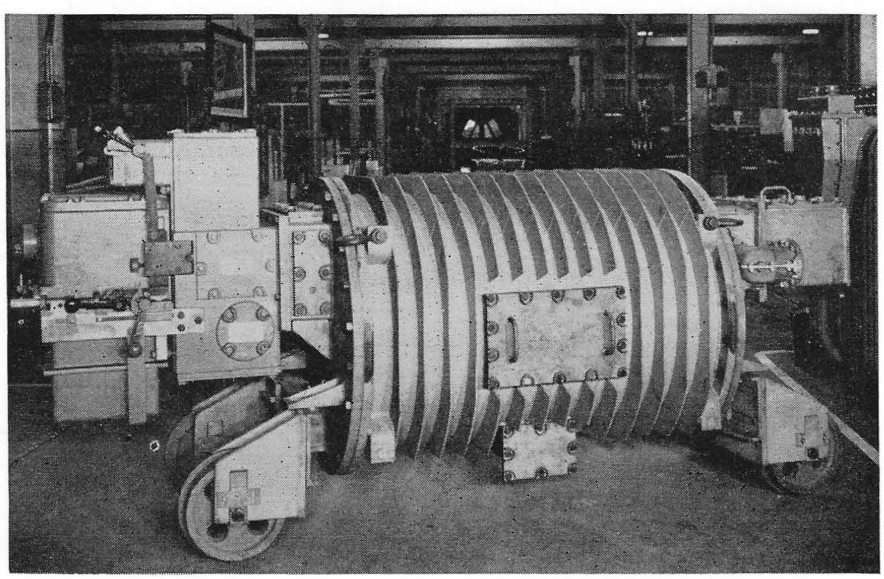
The advantages of this arrangement can be summarized as better voltage regulation, cheaper cabling with a smaller number of heavy cable joints, and greater flexibility combined with safety in operation.

Description

Fig. 1 shows the general arrangement of the new Brush 300 kVA 3-phase. 3,300/565 volt, dry type flameproof mining transformer arranged as a complete transwitch unit. This equipment, which is the first flameproof certified transwitch unit to be completely manufactured in Great Britain, complies generally with the National Coal Board Specification P.109/1954, and the Transformer Specification B.S.171 where applicable. The H.V. windings are fitted with off-circuit tappings at minus 5 per cent and minus 10 per cent, and these can be changed by links which are accessible through a cover shown on the front of the tank. At the bottom of the tank is shown a drain sump with a removable side plate for periodical drainage of water which may accumulate owing to breathing. At the left hand incoming end is mounted a 3.3 kV flameproof Switchgear & Cowan's Type 'MG2' oil circuit breaker, arranged with visible-isolation features and designed to fit on the standard flange detailed in Specification P.109/1954.

The circuit breaker adaptor chamber is arranged to receive 200 amp. cable flit-plugs which can be located at either side. When an H.V. circuit breaker is not used an alternative arrangement comprising a terminal box with flit-plug adaptors can be used. The L.V. end is arranged for 315 amp. outgoing flit-plugs, and also a voltmeter, with additional provision for an ammeter if required. The transformer is securely bolted in to the tank which is arranged for vertical or horizontal slinging for transport. Adjustable wheels are fitted and arranged to give alternative

Fig. 1: Brush 300 kVA dry type flameproof mining transformer fitted with incoming circuit breaker and arranged for outgoing flit-plug cable boxes



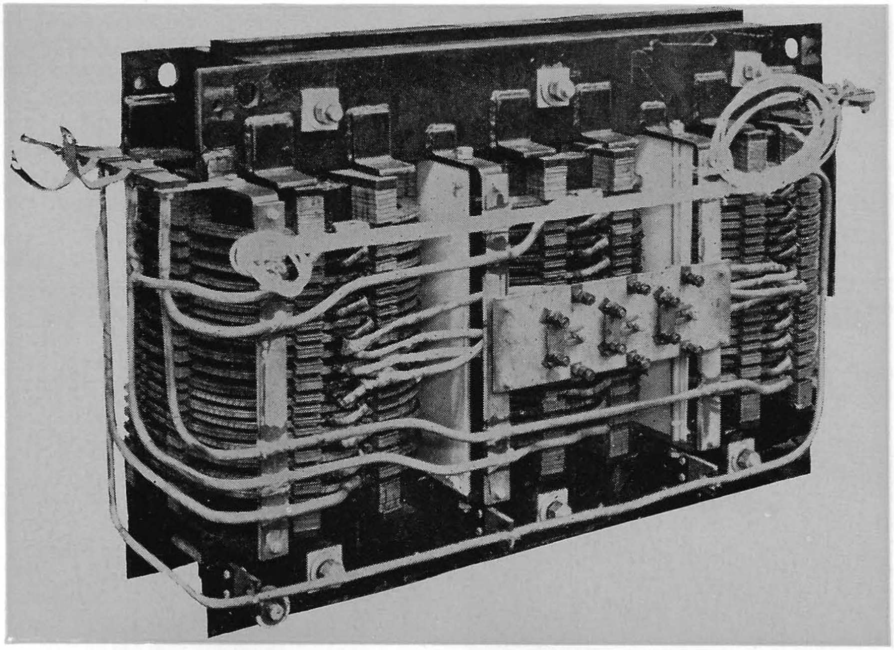


Fig. 2: Transformer core and coils

ground clearance to rail of 1 inch or 5 inches, and provision is made for a swivel motion of 10 degrees in either direction to assist in negotiating sharp curves. The axles are arranged to suit rail gauges between 18 inches and 36 inches.

The transformer case is of circular cylindrical construction and is provided with exterior and interior cooling fins designed to keep the maximum case temperature to a figure not exceeding 85°C, i.e. a temperature rise of 60 cent. deg. above 25°C ambient temperature. Actual temperature rise figures are given later.

The total weight of the complete equipment, including circuit breaker, is 6,990 lb. and the dimensions are as follows:

Length of transformer tank without end covers	—4 ft. $2\frac{1}{2}$ inches.
Complete overall length	—9 ft. $2\frac{3}{8}$ inches with oil circuit breaker plugged in.
	—9 ft. $8\frac{1}{4}$ inches with oil circuit breaker in isolated position.
	—10 ft. $5\frac{1}{2}$ inches with oil circuit breaker clear of slide rails.
Overall width over cooling fins	—3 ft. $2\frac{1}{2}$ inches.
Height above rail level with wheels arranged for 1 inch rail clearance	—3 ft. 10 inches.

Construction

Fig. 2 shows the transformer core and coils completely assembled before mounting in the case. This view is taken from the H.V. side and shows the tapping link arrangement, and also the H.V. leads brought to the end of the transformer.

Fig. 3 shows a view of the transformer in its tank with the H.V. end cover removed. This view also shows the internal cooling fins welded to the side of the case and arranged to dissipate the heat by conduction to the corresponding fins on the outside of the case. Also shown are the small rollers used for running the core and coils into the tank, and the arrangement for solidly bolting the clamps to the tank to prevent internal movement in transit, even when shipped in the vertical position.

It will be noted that in order to obtain maximum mechanical strength consistent with minimum weight and dimensions, a cylindrical tank has been used terminating at the ends in massive cover plates which carry both the incoming and outgoing terminal assemblies and also the adjustable wheel attachments.

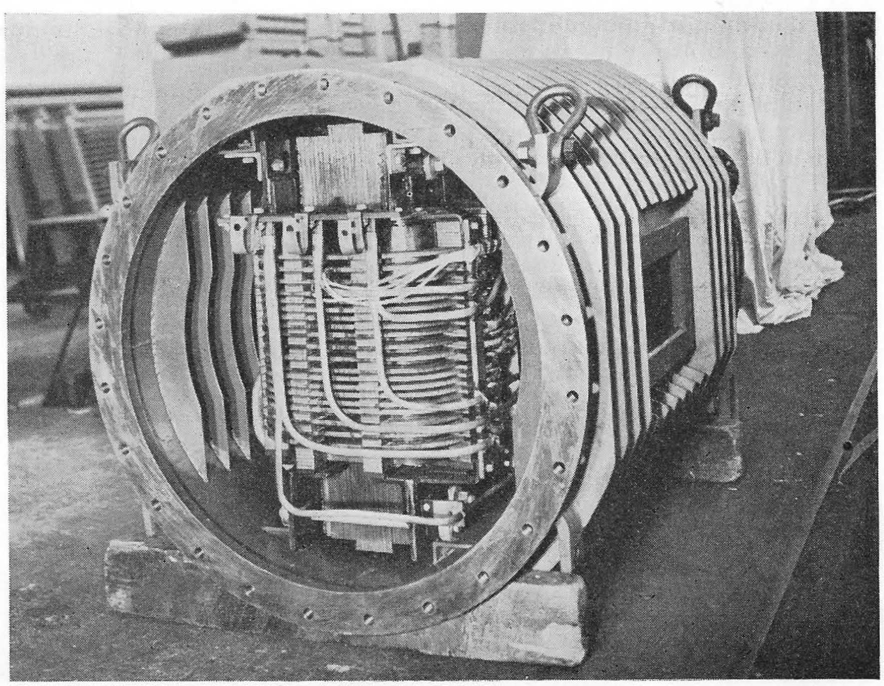
Transformer Core

The transformer core shown in Fig. 4 is of the 3-limb construction with interleaved joints. The core laminations are of cold rolled low loss oriented steel which permits the use of a high core induction, thus helping to reduce size and weight of the transformer, and assisting in the production of low iron losses. The core design and cooling surface is correlated with the watts loss to ensure that maximum permissible temperatures are not exceeded. The core laminations are insulated with 'alcorlin' or 'magnite', the yoke clamping bolts being insulated from the core by glass fibre tubes.

Insulation

In British Standard Specification No. 2757, insulating materials for electrical machinery and apparatus are classified and limits are assigned to their operating temperatures on the basis of thermal stability in service. Dry type transformers of the kind described in this article embody Class 'H' and Class 'C' insulation for which maximum operating tempera-

Fig. 3: Transformer in tank with H.V. end cover removed



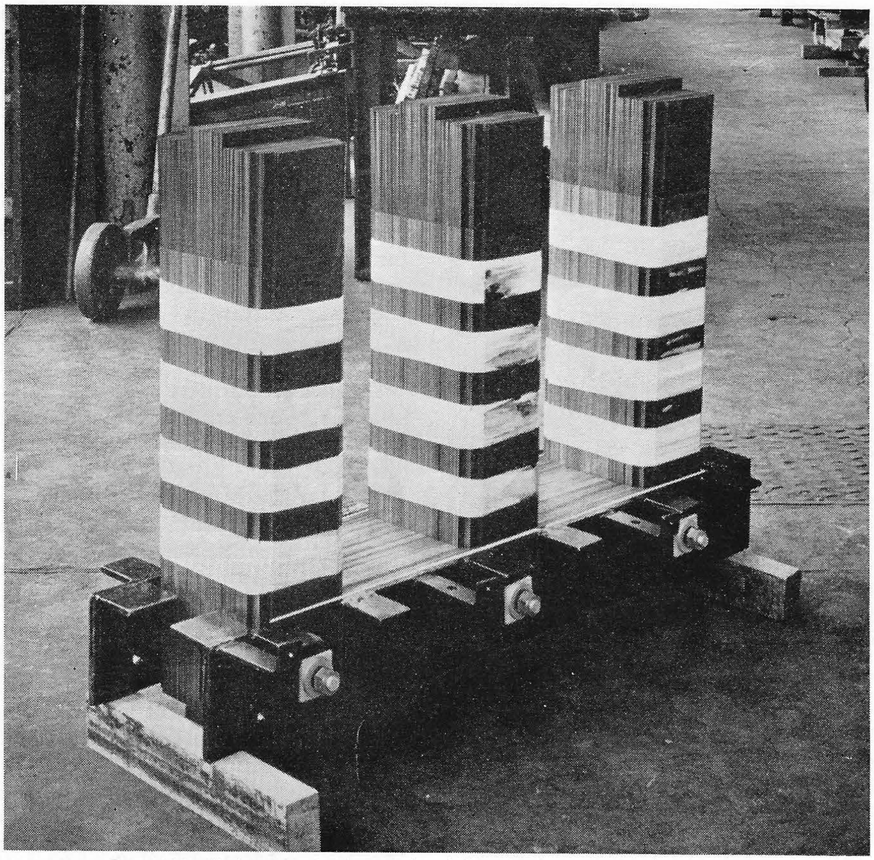


Fig. 4: Cold rolled steel 3-limb core, banded with glass tape ready to receive coils

tures of 180°C and above 180°C respectively are permitted. These new materials have rendered possible the design and construction of an oil-less type of transformer for use in situations where, owing to fire risk, oil is not permissible.

Class 'H' insulation consists of materials such as silicones, elastomers, and combinations of materials such as mica, glass fibre, asbestos, etc., with suitable bonding, impregnating, or coating substances, such as appropriate silicone resins. Other materials or combination of materials may be included if, by experience, they can be shown to be capable of operation at the Class 'H' temperatures.

Class 'C' insulation consists of materials or combinations of materials such as mica, porcelain, glass quartz, and asbestos, with or without an inorganic binder. Other materials or combination of materials may be included in this class if they can be shown to be capable of operation at temperatures above the Class 'H' limit. Specific materials or combinations of materials in this class will have a temperature limit which is dependent on their physical, chemical and electrical properties.

Windings

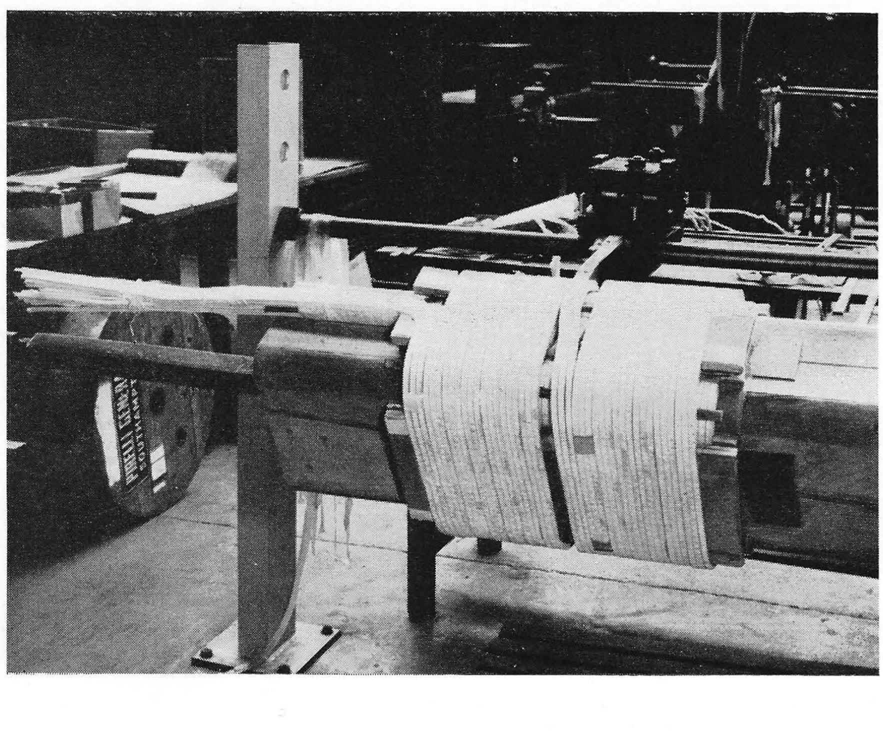
In order to achieve maximum space utilization so as to reduce dimensions to a minimum, the windings are of rectangular shape with rounded corners. The L.V. windings are of double layer helical construction with cooling ducts between layers on both inside and outside surfaces. Asbestos paper taped multi-strip conductors are used, the joints between conductors and busbars being brazed. Conductor insulation is based on the use of an electrofine asbestos paper, which has been produced by refining asbestos to a high degree of purity. This material has reasonably good mechanical strength, and in order to improve this, and to give consistent dielectric strength under all operating conditions, the coils and insulation are sealed by a thorough impregnation with silicone varnish.

The H.V. winding is of the double disc coil type with external brazed joints. Ample cooling ducts are provided by spacing between coils with moulded porcelain spacers which are interlocked with longitudinal spacing sticks made of mica compound material. The major inter-winding insulation consists of a glass-mica-glass cylinder. Each limb of L.V. and H.V. windings is completely assembled with all insulation in position, dried out under mechanical pressure and impregnated with silicone varnish. This arrangement produces a very solid and robust coil assembly, this being essential to withstand mechanical shocks which may be experienced in service.

Technical Characteristics

Losses. The ratio of iron to copper loss is governed by the requirements to keep dimensions to a minimum while at the same time working up to the maximum value of temperature permissible. For this unit, which is rated at 300 kVA, the iron and copper losses referred to a reference temperature of 75°C are 2,000 and 2,500 watts respectively. The impedance is 2.6 per cent, this being specially low to give good voltage regulation. The design is such as to permit some variation of impedance which can be varied on future units up to 4 per cent if necessary.

Fig. 5: Completed L.V. winding in winding lathe



Temperature Rise. The external temperature rise of the transformer case has been limited by specification to a maximum of 60°C above ambient air of 25°C On test the figure was actually 59°C with a temperature of 12°C. less at the external edge of the adjacent cooling fin.

The internal design has been arranged to limit the maximum hottest spot temperature rise to 195°C, which with an ambient temperature of 25°C corresponds to a maximum temperature of 220°C, this being reached after continuous operation at a load of 300 kVA.

A heat run was carried out at a loading of 300 kVA and temperature rises recorded by means of thermocouples at various points inside the windings, at the top of the transformer core, and on the outside of the case. The chart shown in Fig. 6 indicates graphically the temperature rises recorded during the 38-hour continuous heat run as follows:

Thermocouple—

No. 1 At the top of the L.V. winding on centre B phase.

No. 4 At the top of the H.V. duct next to the winding on B phase.

No. 8 The H.V. duct at the top on C phase.

No. 10 The middle L.V. duct at the bottom of B phase.

No. 20 The maximum outside temperature rise at the top centre of the case.

The positions of the various thermocouples are shown in Fig. 7 and Fig. 8, and the maximum temperature rises recorded at the end of the heat run at the various points of measurement are listed in Fig. 9.

Application of Temperature Rise Curves to Normal Loading Conditions

Owing to the nature of the load the current fluctuates frequently, the load curve consisting of a number of short duration maximum peak values rising to approximately 200 per cent of the average value and falling to longer time minimum values of approximately 60 per cent of the average value.

Consideration of the heat run time curve shows that the maximum steady temperatures are reached in not less than 30 hours' continuous operation at a steady 300 kVA loading, and after 10 hours from starting the maximum temperature rise is only 116°C, or approximately 70 per cent of the maximum permissible value.

After the conclusion of the above tests this transformer successfully passed the standard flameproof explosion tests applicable to this type of equipment for Group 1 gases for coal mining application.

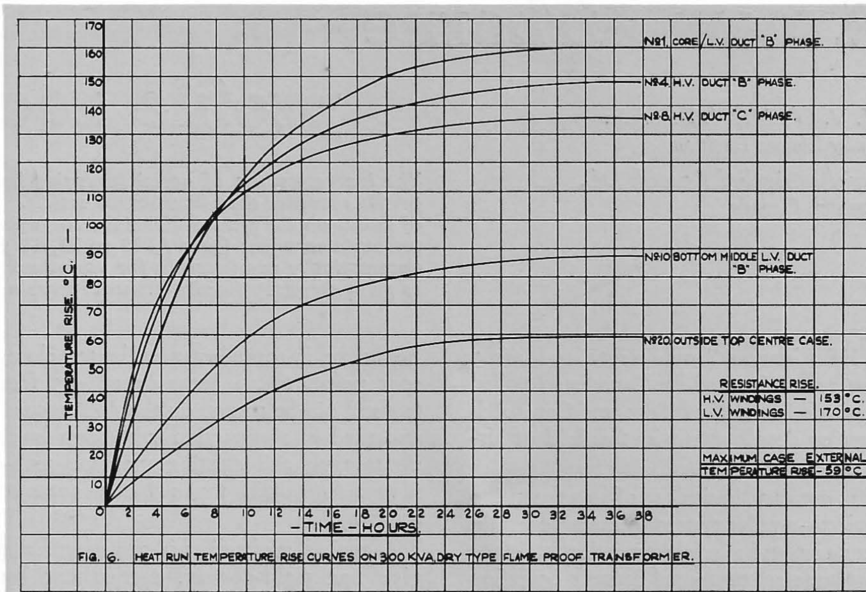


Fig. 6.

Fig. 7.

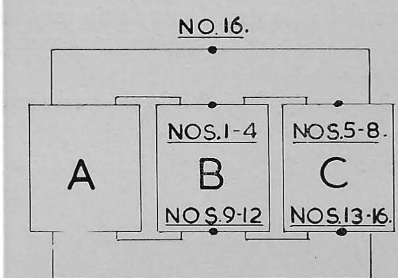


Fig. 8.

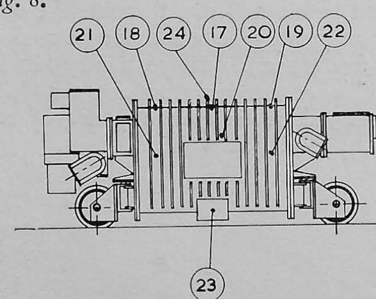


Fig. 9: **TABLE OF TEMPERATURE RISES °C ABOVE AMBIENT AT VARIOUS THERMO-COUPLE POSITIONS**

Thermo-couple No.	*Position*	*Temperature Rise °C*
	INTERNAL	
1	B Phase—Core—L.V. Duct—Top	160°C
2	B Phase—Middle L.V. Duct—Top	170°C
3	B Phase—L.V. to H.V. Duct—Top	168°C
4	B Phase—H.V. Duct—Top	148°C
5	C Phase—Core—L.V. Duct—Top	160°C
6	C Phase—Middle L.V. Duct—Top	157°C
7	C Phase—L.V. to H.V. Duct—Top	147°C
8	C Phase—H.V. Duct—Top	135°C
9	B Phase—Core—L.V. Duct—Bottom	84°C
10	B Phase—Middle L.V. Duct—Bottom	87°C
11	B Phase—L.V. to H.V. Duct—Bottom	79°C
12	B Phase—H.V. Duct—Bottom	73°C
13	C Phase—Core—L.V. Duct—Bottom	80°C
14	C Phase—L.V. to H.V. Duct—Bottom	77°C
15	C Phase—L.V. to H.V. Duct—Bottom	66°C
16	Over B Phase—Top of Core	163°C
	EXTERNAL	
17	Case Surface at Top Centre	59°C
18	Case Surface at Top H.V. End	55°C
19	Case Surface at Top L.V. End	56°C
20	Side Centre 60° from Vertical	48°C
21	Side H.V. End 60° from Vertical	45°C
22	Side L.V. End 60° from Vertical	44°C
23	Bottom side centre-drain cover	26°C
24	Edge of cooling fin at top centre	36°C

A new airborne profile recorder

W. V. O'LEARY, B.Sc.E.E.
Senior Liaison Engineer
Canadian Applied Research Ltd., Toronto, Canada

The increasing use of aerial surveying has led to the development of the new airborne profile recorder described in this article. The equipment determines the relative heights of points on the ground along the surveying aircraft's flight path, and can thus measure terrain clearances from 1,000 to 35,000 ft. A height deviation indicator (hypsometer) automatically compensates for variations from the chosen barometric flying height, and so gives an exceptionally accurate terrain profile record.

THE Airborne Profile Recorder Mark 5 System, engineered by Canadian Applied Research Limited of Toronto, Canada, is a major development in the field of airborne surveying.

It consists basically of two sensing devices—a radar system to measure terrain clearance, and a height deviation indicator (hypsometer) to record aircraft deviation from a pre-determined isobaric surface.

It can provide a profile with a relative accuracy of at least ±10 feet (3 m.) over good terrain and can, therefore, be used for mapping with a contour interval of 50 feet (15 m.). Where it may not be feasible economically to use the APR Mark 5 alone because the spacing of grid lines may, in some instances, be too close, spot points to an accuracy of ±5 feet (1,5 m.) can be chosen on the APR record and used in conjunction with high level photograph and existing mapping techniques to obtain much better contour accuracy.

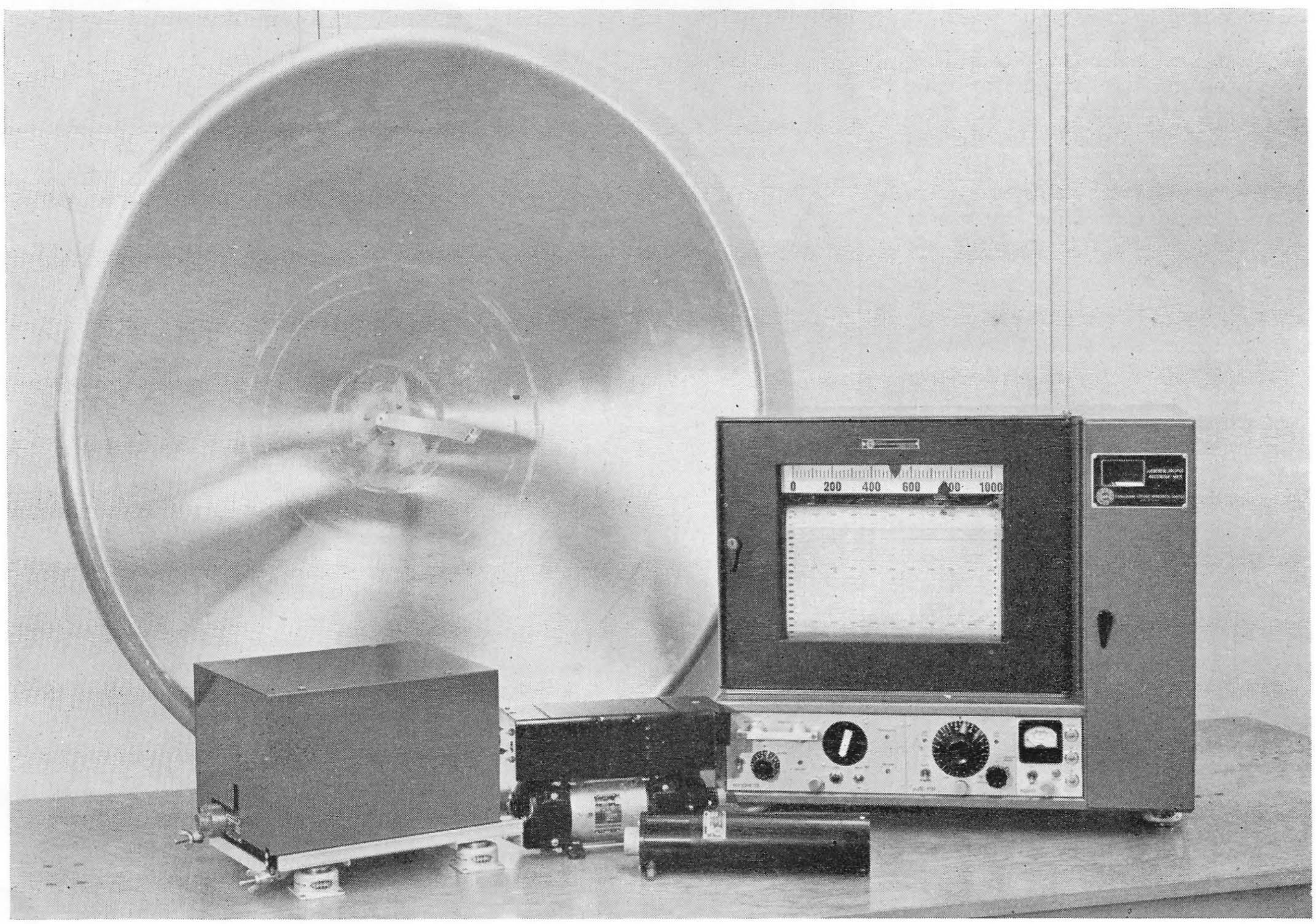
A typical application is a survey for a pipe line right-of-way, carried out by running three equally spaced lines with the centre one following the proposed route. High level photography supplies adequate details for filling in between the lines and a very satisfactory strip may be drawn for use by the engineer in planning construction.

Another application is in reconnaissance work, choosing a route for power, oil, or rail lines. Once a route has been determined by preliminary flying, a strip map can be provided as above.

The most useful purpose for the APR Mark 5 is considered to be in conjunction with existing photo-survey methods, such as the multiplex system or the Wild A5 'Autograph', for which it can provide very accurate ground elevation control and vertical scale information.

The instrument has been chosen for use in the New Mapper of the World, (Fig. 3,) which shows it installed in a newly designed C-130 prop-jet aircraft by Lockheed. The cargo section of the aircraft, as large as a railroad freight car,

Fig. 1: The Airborne Profile Recorder Mark 5



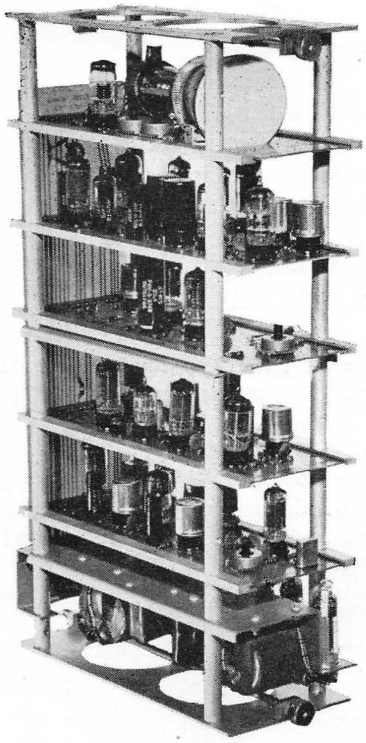


Fig. 2: The radar tower

provides plenty of work space. Lockheed is building 15 of these aircraft to assist the U.S. Air Force in a gigantic mapping project to bring the world's geography up to date. The APR Mark 5, the principal equipment for aerial mapping, was chosen for the project after rigorous testing by the USAF.

History

Several articles were written during the period 1946 to 1951 on the use of an airborne radar system to provide ground elevation control for vertical camera surveys. The National Research Council of Canada, Canadian Applied Research Limited (then PSC Applied Research), and the Photographic Survey Corporation Limited carried out many test flights and actual surveys during this period, evaluating the use of the pulsed radar method.

By 1948 accuracies of ±20 feet (6 m.) were obtained using special flying routines. The state of the art remained at this level until 1956 when the first APR Mark 5 systems were test flown on evaluation flights over well surveyed test beds.

These tests showed that the accuracy of the 'terrain clearance' record had been improved to ±10 feet (3 m.) over good terrain. The accuracy of the 'terrain profile' record had been improved to ±10 feet (3 m.) over good terrain. The chart, or record span, had been reduced from 2,500 feet (760 m.) to 1,000 feet (300 m.) and the system time constant had been decreased to approximately 0.25 seconds. These two features combined to improve the system resolution over rough terrain. Also, semi-automatic operation had been incorporated into the system allowing the APR operator to perform some other duties.

Technical Features

A major improvement in accuracy of recording has been achieved by the development of a pressure sensing device of extreme sensitivity.

The application of plug-in printed circuitry to the radar timing and control circuits is an important feature and is unique in airborne radar applications. This feature, arranged on a modular plan, greatly improves the reliability of the system and permits easy servicing, even at high altitudes.

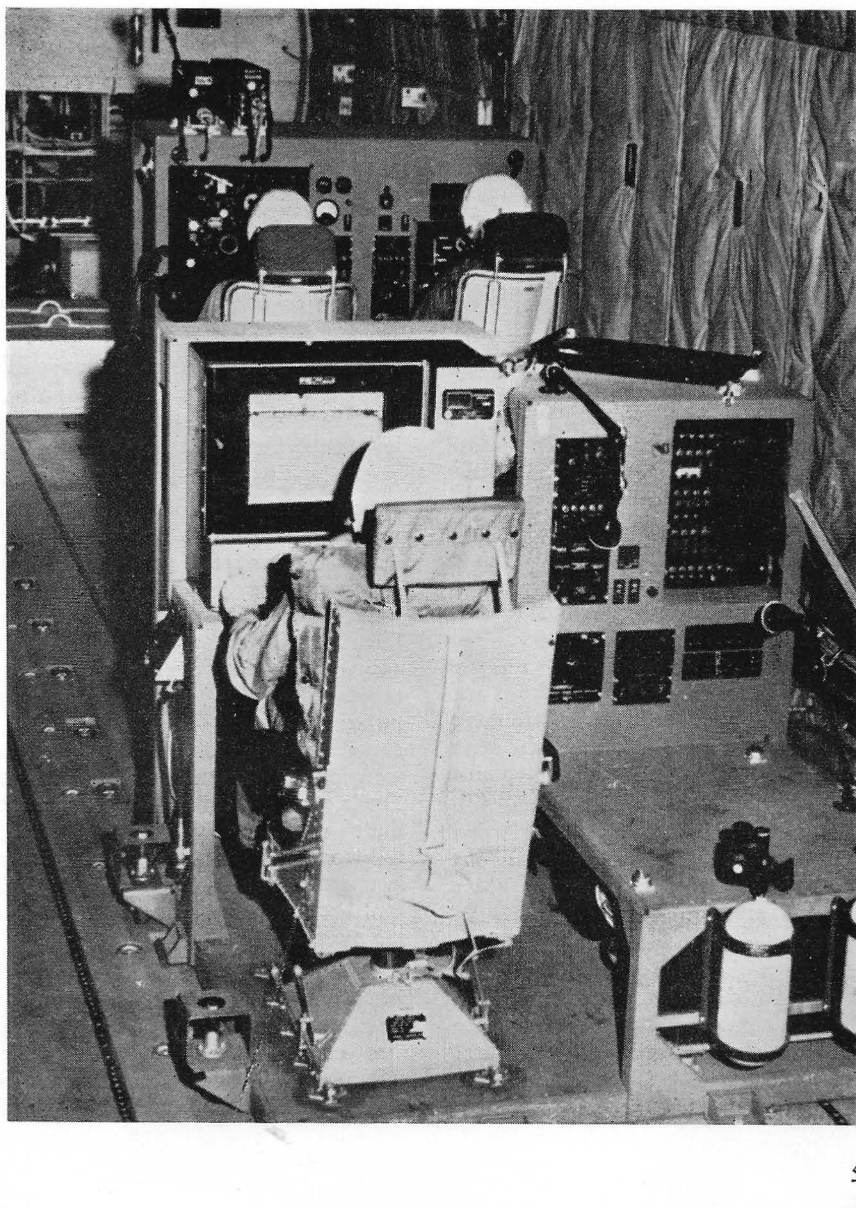
Both the size and the weight of the equipment are extremely small for a 10-kilowatt radar system.

Fig. 2 shows the radar tower. Timing circuits, discriminator circuits and the visual monitor circuit are mounted on printed circuit boards. These are plugged into the rear printed cable board. Power supplies are mounted at the base of the tower. Consistency of circuit parameters in mass production and simplified airborne servicing were the design objectives achieved in this style of construction.

Fig. 4 is a block diagram of the system showing the main operational circuits.

The APR Mark 5 is a pulse radar device. A very short pulse (0.10 microsecond) of radio energy is directed vertically toward the ground in a very narrow beam approximately 2,000 times per second. The time between the departure of a pulse of energy from the aircraft and its return

Fig. 3: Electronic equipment and cameras installed in a Lockheed C-130



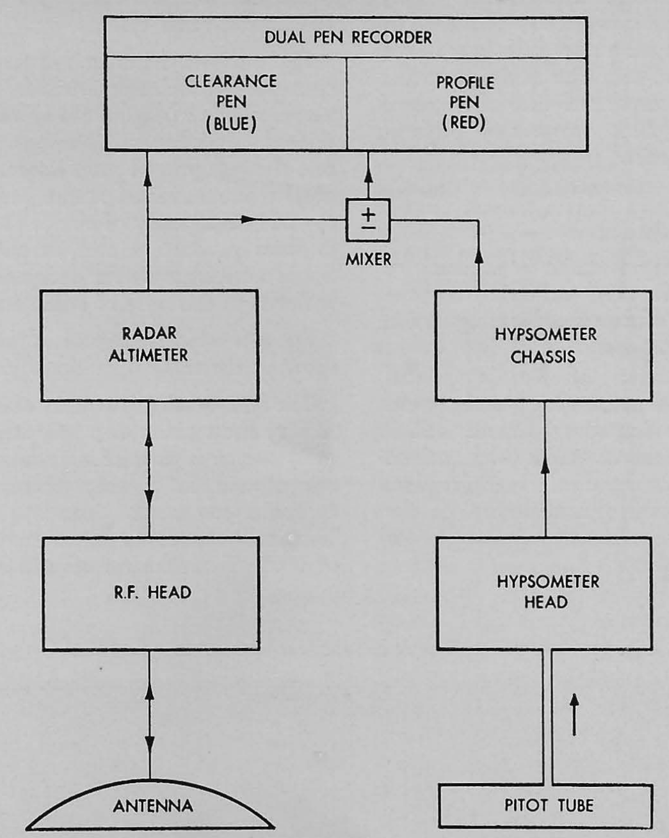


Fig. 4: Block diagram of the APR system

after reflection by the surface of the earth is measured (the antenna system serves as both radiator and receptor). Since the velocity of radio waves is, for the purpose of these accuracies, constant and accurately known, the instrument can be calibrated directly in distance.

A ranging circuit translates the echo delay time into a control voltage, which is measured on a potentiometer type recording meter to give terrain clearance. The hypsometer translates changes in pressure with altitude into a control voltage and applies a correction to the terrain clearance reading on a second channel in the same recording meter to give a terrain profile record.

Precision has been attained by referring all time measurements to a precise crystal oscillator, having an accuracy of better than one part in 100,000.

Each transmitted pulse is initiated by a pulse from the timing crystal oscillator, spaced approximately 1/2,000 sec. from the previous transmitted pulse and the timing is referred to one of the subsequent oscillator pulses. Although a large number of measurements are made in each second, the distance will not actually change by a large amount between successive measurements, even for large terrain relief and moderate aircraft speed.

The sampling rate of 2,000 pulses per second is necessary to operate the automatic timing circuits and to provide a statistically favourable number of measurements to any particular terrain area irradiated by the beam. The system response time (0.25 seconds) has been arranged to achieve the maximum advantage from averaging a number of measurements, consistent with a reasonable automatic following rate for distance variation. A deviation in excess of 5-10 feet (1,5-3 m.) magnitude with respect to the mean value may occur in any single measurement owing to random changes in transmitter delay, received pulse shape, etc., but the circuits are designed to give the mean measurement.

Time Reference Method. Timing pulses are generated by a crystal oscillator at a frequency of 983.4 k.c.s. This frequently was calculated to provide a timing reference throughout the system for the average atmospheric conditions at approximately 17,000 feet (5 000 m.) as follows:

Velocity of Propagation:

$$C \text{ in vacuo} = 9.83567 \times 10^8 \text{ feet/sec.}$$

The crystal oscillator is required to provide 500-foot steps.

t = period of crystal = time required for pulse to traverse $500 \times 2 = 1{,}000$ feet.

$$t = \frac{1000}{9.83567 \times 10^8}$$

$$\therefore f = \frac{9.83567 \times 10^8}{10^3} = 9.83567 \times 10^5 \text{ c.p.s. (vacuum)}$$

Index of refraction, average figure for varying atmosphere at sea level $= 1.0002926$

$$f = \frac{9.83567 \times 10^5}{1.0002926} = 9.83361 \times 10^5 \text{ c.p.s.}$$

Since aerial surveys are flown between 5,000 and 30,000 feet—f corrected for 17,000 feet where N/D = 1.000015

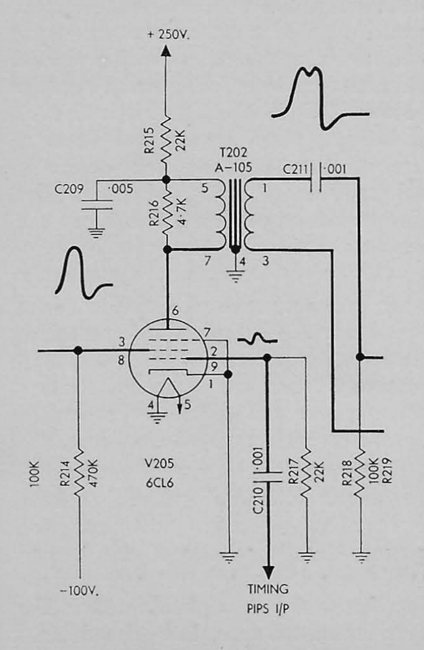
$$f = \frac{9.83567 \times 10^5}{1.00015} = 9.83419 \times 10^5$$

Crystal frequency = 983.4 k.c.s.

Two 'blocking oscillator' count-down circuits are used in the system, one to provide the transmitter trigger and a gate pulse to drive the 'automatic range selector' circuit; the second to provide a gate pulse to drive the 'automatic vernier ranging' circuit. In each case a pulse coincidence circuit is used to lock the count-down circuit to the time reference oscillator. This circuit is shown in Fig. 5.

The blocking oscillator output is fed to the screen of the tube and the timing

Fig. 5: Coincidence circuit



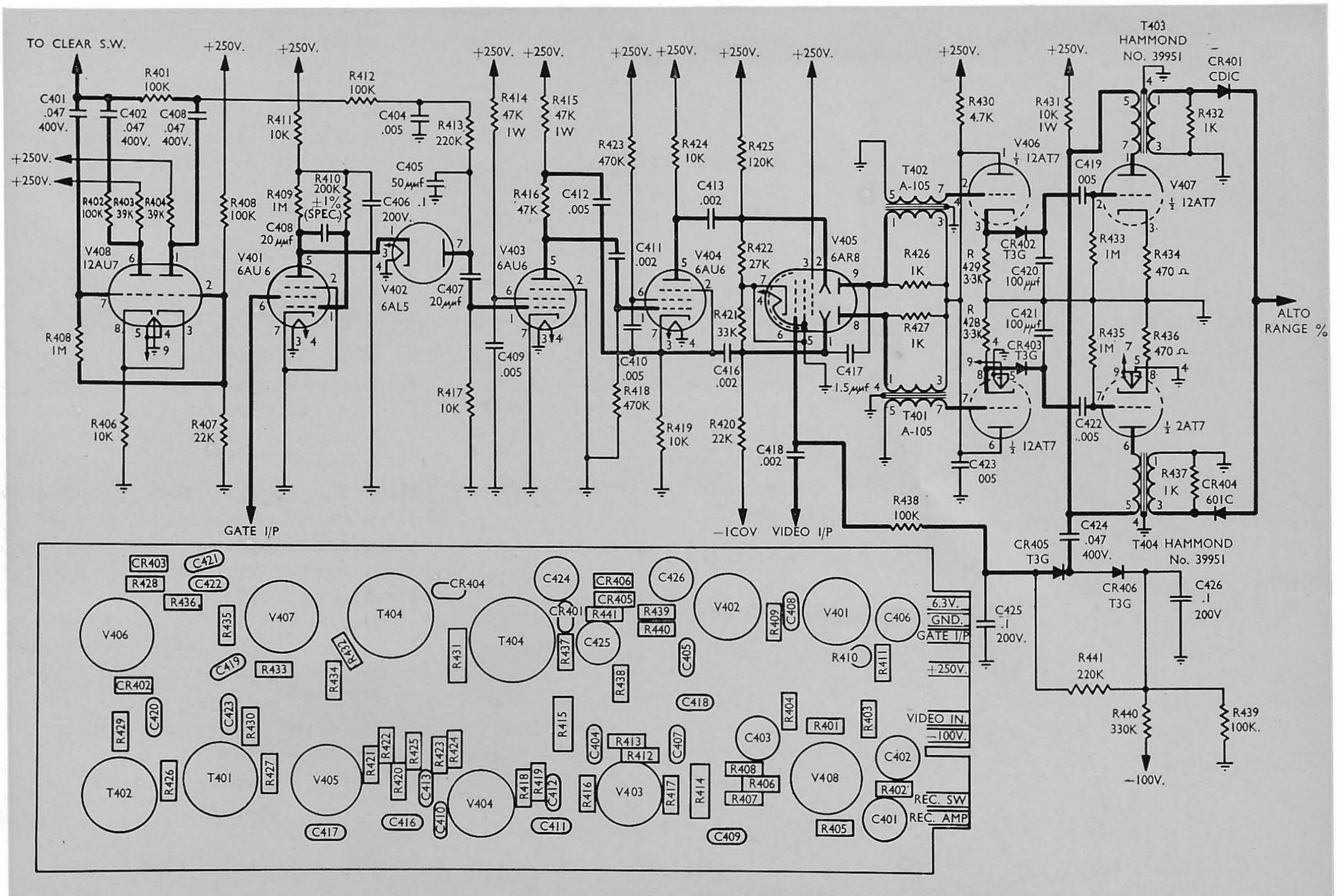


Fig. 6(a): The auto range

pips are fed to the control grid. Circuit parameters are such that the tube will conduct on receipt of a timing pulse. In the second blocking oscillator, pre-set controls in the system which vary the time position of the blocking oscillator output are adjusted until an inverted timing pulse appears on top of the blocking oscillator pulse. This is a calibration adjustment.

Time Discrimination. Time discrimination is performed in the 'automatic vernier ranging' circuit, Fig. 6.

Automatic Vernier Ranging Circuit

The output of the second coincidence stage in the automatic range selector circuit is fed to a cathode follower miller drive tube which has a small amount of clipping action in the cathode circuit. A reasonably square waveform is fed to the screen of V-401, a miller run down stage. V-402, the pick-off diode, conducts a portion of the miller output proportional to the value of d.c. voltage applied to the diode plate. V-403 amplifies the output of the diode and applies a pulse to V-404, a phase inverter. V-405 is a two-channel sheet beam tube where the time discrimination is carried out. V-404 feeds two pulses to the deflection plates of V-405 as shown. These are the switching gates for the tube.

The echo output of the video receiver is fed to the control grid of V-405, the action then is:

(*a*) Should the echo arrive before cross-over, channel 1 conducts.

(*b*) Should the echo arrive at cross-over, there is no conduction.

(*c*) Should the echo arrive after cross-over, channel 2 will conduct.

V-406 and V-407 are twin triodes arranged in two channels of pulse-stretching amplifiers followed by a half wave rectifier. When channel 1 conducts, a positive d.c. voltage appears at the output. When channel 2 conducts, a negative d.c. voltage appears at the output.

The d.c. voltage output of the automatic vernier ranging circuit is fed to a ring modulator and servo amplifier system and the clearance pen of the

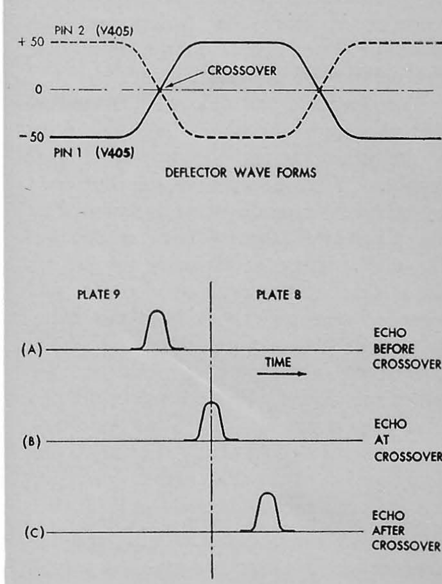


Fig. 6(b): Time discriminator operation

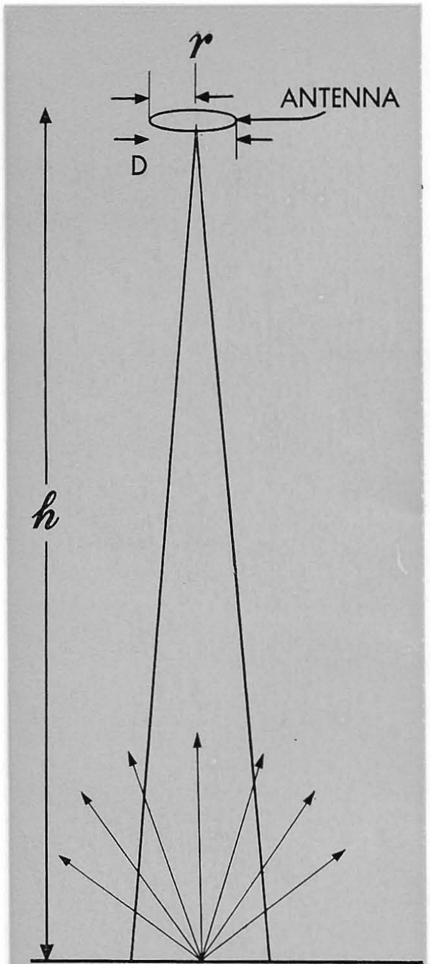


Fig. 7: Distribution of a perfectly scattered echo

recorder is driven in proportion and direction dependent upon the amplitude and polarity of the d.c. voltage.

The clearance pen slide wire is used as part of a feed-back loop. The slide wire is connected across the 250 volt d.c. supply. The slider, mechanically connected to the recording pen, is returned to the plate of V-402 (pick-off diode, see Fig. 6(*a*)). Then, as the echo appears on either side of the cross-over point, the recorder pen moves driving the plate voltage of V-402 more or less positive. This changes the pick-off point on the miller run down which in turn shifts the cross-over point in time. Thus the cross-over point is automatically moved to the time position of the echo and the recorder pen indicates this time position in feet.

Crystal Video Receiver. The original airborne profile recorders contained microwave circuitry in the receiver section. In the APR Mark 5, the Klystron, mixer and IF stages were removed and a crystal video circuit was designed to replace them. This was possible owing to recent improvements in video crystal sensitivities. The possibility of using a video crystal receiver can be shown as follows:

The following assumptions are made—

(1) All transmitted energy reaches the ground.

(2) Normal cosine distribution from ground as per scattered nature.

(3) In Fig. 7, $h >> \gamma$ and $h >> D$.

Let h=30,000 ft. D=44 in. for 3 cm. Radiator eff=50 per cent.

$$\text{Radar Equation: } Pr = \frac{Ao\ Go\ Pt\ \delta}{(4\pi)\ 2h_4}$$

where Pr = power received
Pt = power transmitted
Ao = effective radiator cross-section
Go = maximum power gain of radiator
δ = effective area of reflector
h = range

$$\text{Let the gain of the system} = K = \frac{Pr}{Pt} \quad \cdots (1)$$

$$K = \frac{Ao\ Go\ \delta}{(4\pi)^2 h^4} \quad \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

Since all radiated energy reaches the target the antenna gain,

$\frac{Go\ \delta}{2\pi h^2}$ can be eliminated from (2)

$$K = \frac{Ao}{8\pi h^2} \quad \text{for isotropic ground reflection.}$$

Since reflected energy is confined to a 180° solid angle, a gain of 2 exists at the ground,

$$K = \frac{Ao}{4\pi h^2} \quad \cdots\cdots\cdots\cdots\cdots\cdots (3)$$

and for a 44 in. radiator at 30,000 feet.

$$K = \pi \frac{(22)^2}{(12)} \times \frac{1}{4\pi(3 \times 10^4)^2}$$
$$= 9.4 \times 10^{-10} \text{ say } 10 \times 10^{-10}$$

Assuming 90 per cent ground absorption and 50 per cent radiator efficiency then

$$K = \frac{10 \times 10^{-10}}{2 \times 10^{-1}} = 5 \times 10^{-11} \quad \cdots\cdots\cdots (4)$$

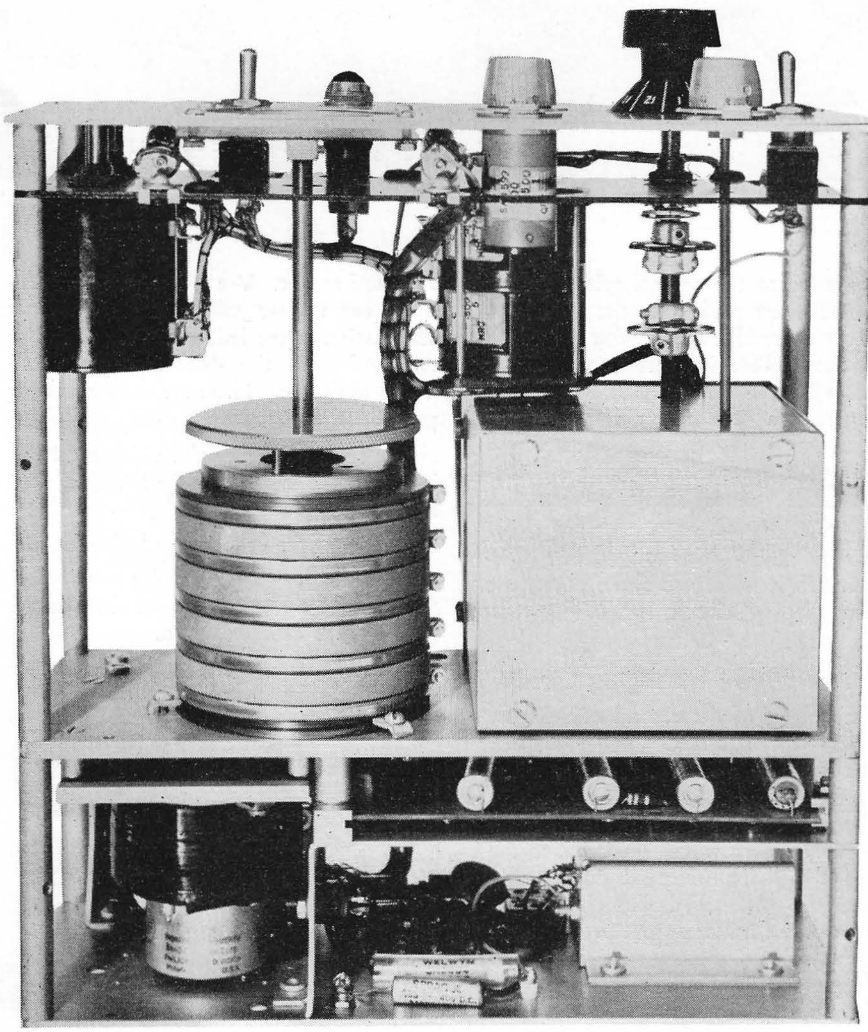
Now the tangential sensitivity of the video crystal proposed is 5×10^{-9} for a 7 mc. bandwidth.

Transmitter peak power required for a signal to noise ratio of 10^{-1}

$$\frac{5 \times 10^{-9}}{5 \times 10^{-11}} \times 10^2 = 10 \text{ kilowatts.}$$

This peak power is available from a

Fig. 9: APR hypsometer chassis assembly top view



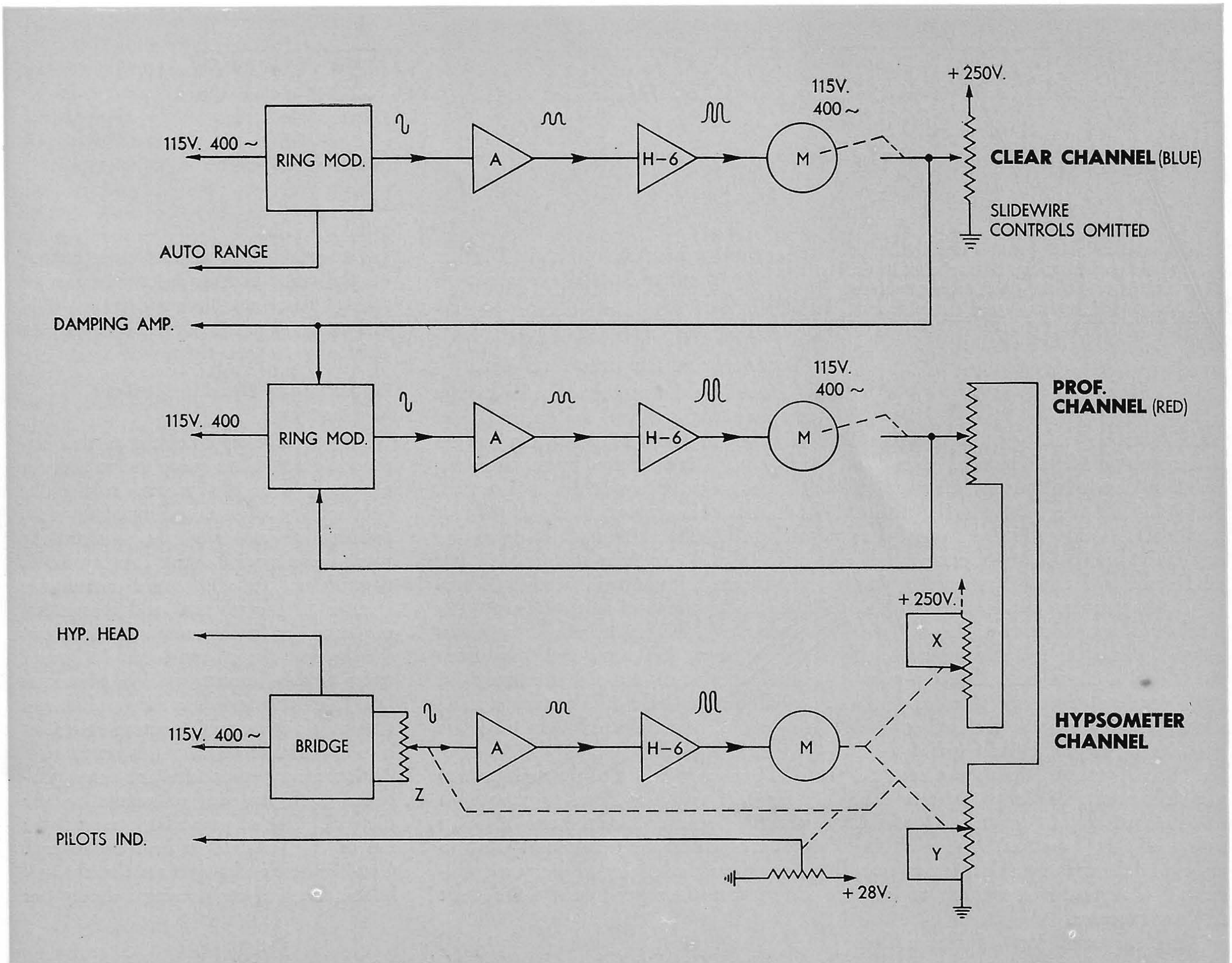


Fig. 8: Block diagram of recorder circuitry

2J42H magnetron which can be designed into a small compact transmitter.

Differential Altimeter or Hypsometer. The aneroid capsule altimeter had to be abandoned to attain the profile accuracies required in the new APR Mark 5 design. The hypsometer principle, a method of detecting changes in pressure altitude by measuring the changes in the boiling point of a stable fluid, was adapted to the APR Mark 5 system. Fig. 8 illustrates the method used to detect a change in aircraft altitude and add or subtract this change to the clearance record. Upon sensing a pressure altitude change, the sensing head unbalances the bridge and the error voltage is fed to the servo system which drives the servo motor. This motor drives three potentiometers shown in Fig. 9, top view of hypsometer control chassis:

(1) Potentiometer z is moved to set up the new balance point on the bridge.
(2) Potentiometers x and y are moved the same amount and change the pick-off voltage of the profile slide wire. The profile servo amplifier senses a difference in d.c. voltage of the two sliders and adjusts the profile slider until they are equal.

Factors Affecting Accuracy of the System

As with other methods of measurement, there are many factors which may affect the accuracy of the APR Mark 5 data. In order to realize maximum precision, therefore, a survey must be carefully planned and processed with these factors in mind. Some of the causes of error are:

A change in the velocity of propagation;
Slant height error;
Instrument noise and drift;
Selection of survey control points;
Isobaric gradients and anomalies.

Application

The airborne profile recorder is at present used for:

Simultaneous high level vertical and oblique photography;
Low level, flown over overlaps of previous survey photography;
Profiling survey, with or without simultaneous photography, for engineering projects, pipe lines, highways, etc.

Almost 90 per cent of the APR Mark 5 circuitry is mounted on printed circuit boards of the plug-in type. This ensures standard circuits in assembly line production and fast, easy servicing while flying at a high altitude.

GRAPHITE DEVELOPMENTS

G. J. METCALFE, M.Sc. Tech., *Head of Metallurgy Department*, *Hawker Siddeley Nuclear Power Co., Ltd., Slough, Bucks.*

New graphites and graphite materials, at present in the research and development stage, show vastly improved properties compared with the normal grades of graphite in current production

THE carbon and graphite available commercially are, in general, manufactured by first mixing suitable grades of finely divided coke with a binder such as pitch and following this by a pressing or extrusion process. Heating to temperatures of the order of 1,000°C causes the pitch to decompose to carbon and further heating to temperatures of the order of 2,800°C results in the rearrangement of the carbon atoms in the body to an essentially graphite structure. Because of the nature of this process the carbon and graphite bodies produced are by no means free from porosity. Thus, for example, the bulk density of the graphite used in conventional nuclear reactors is of the order of 1.7 gm./c.c. whereas the theoretical density of graphite is 2.25 gm./c.c. This represents a porosity of some 20% by volume.

With the evolution of the nuclear engineering industry, however, there is an incentive for the production of improved graphites for advanced reactors, e.g. high density graphites which impart improved neutron moderating properties and graphites with improved mechanical and physical properties. Most recently a requirement has arisen for a graphite with a very low permeability to gases, some million times less permeable than the conventional nuclear grade graphite. This material is required for use as fuel cans in high temperature gas-cooled reactors in which the operating temperature at the surface of the can is expected to be approximately double that used in the present generation of power reactors, i.e. around 800°C.

In February, 1958, Hawker Siddeley Nuclear Power Co. undertook, under contract to the United Kingdom Atomic Energy Authority, the development of a process to reduce the permeability of graphite by means of a process invented at the Royal Aircraft Establishment, in order to provide fuel cans for use in the high temperature gas-cooled reactor.

With the evolution of techniques on this process and the suggestion of applications outside nuclear engineering, Hawker Siddeley Nuclear Power are about to market the improved material for a wide variety of uses.

Treatment of Graphite Fuel Cans

Essentially the process of reducing the permeability involves the deposition of carbon within the pore structure of the graphite. This is achieved by impregnating the porous graphite with furfuryl alcohol, which contains approximately 61 per cent carbon. With various additions to the alcohol and carefully controlled heat treatments, this can be induced to decompose leaving carbon in the pores. The process, which is undergoing continuous development, has been scaled-up from small specimens to the treatment of graphite tubes over six feet (about 2 m.) in length. Examples of these tubes are shown in Fig. 1.

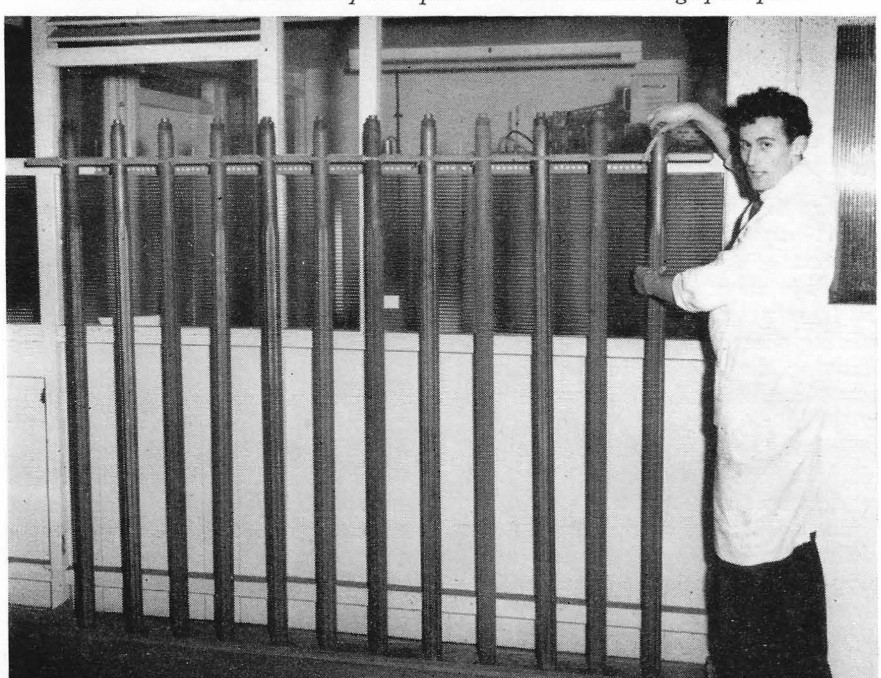
The main objective of the treatment of these fuel rods has been to provide a material through which the rate of fission product gas diffusion is sufficiently slow to allow the radioactivity to decay appreciably before these gases enter the coolant gas stream flowing past the outer surfaces of the can. Further improvements are taking place and it may be possible, ultimately, to produce a material which is essentially vacuum tight.

Applications Outside Nuclear Engineering

The possible applications of this improved graphite are many and varied, for not only does the process reduce the permeability to gases and liquids by very considerable amounts, but preliminary work being carried out at Langley shows that there are also some remarkable changes in the physical and mechanical properties. Furthermore, it has been shown that the material can be joined using furane cements, which possess at least as much strength as the graphite and retain their impermeable nature even after carbonization at elevated temperatures.

Numerous components are being processed with the aim of marketing the material. One of particular interest is the use of the graphite in heat exchangers. Graphite heat exchangers are already used in the chemical engineering industry but

Fig. 1: Graphite fuel cans over six feet (about 2m.) in length can now be treated to reduce their porosity. Essentially the method involves impregnating the graphite with furfuryl alcohol which is then thermally decomposed to leave carbon in the graphite pores



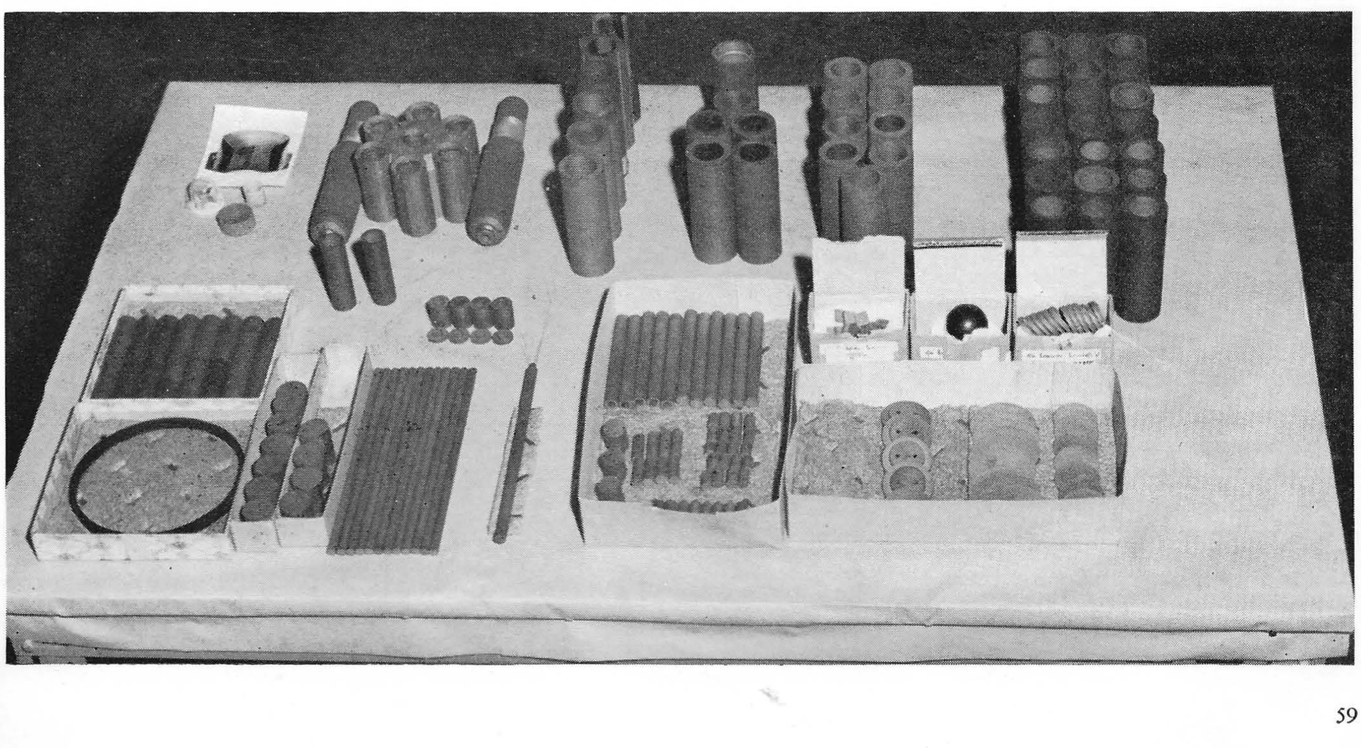
the temperature of operation is limited to 160-170°C since the resins with which the graphite is impregnated to impart impermeability to liquids decompose above these temperatures. The use of the present process will remove this limitation.

A large variety of carbons are produced commercially and efforts are being made to assess the appropriateness of a number of marketed carbons for treatment with furfuryl alcohol. In addition to these investigations numerous small components such as bursting discs, sealing rings, and bearings are being made in treated graphite and there is reason to hope that their behaviour under service conditions will be more satisfactory than the porous carbon graphite in use at present. Fig. 3 shows several components that have been treated and upon which reports are awaited. There is also a strong likelihood that the low permeability graphites will have fairly high resistance to liquid metals and there is a possibility that such graphites may be used for nozzles or even impellers for pumping liquid metals around circuits.

By giving a further heat treatment to graphite that has been subjected to impregnation treatments the oxidation resistance of the material is considerably improved and becomes much better than that of the base material.

For special applications, techniques are being developed to increase the oxidation and erosion resistance of the graphite.

Fig. 2 (above): The apparatus used for impregnating fuel cans. Fig. 3 (below): A selection of graphite components which have been treated to reduce porosity



DESIGN FOR PRODUCTION

E. D. KEEN, B.Sc., F.R.Ae.S., A.F.I.Ae.S. *Chief Designer,*
Sir W. G. Armstrong Whitworth Aircraft Ltd., Coventry.

In this article the author proposes that aeroplane design should be treated from the production angle right from the start, in order to achieve the dual object of producing the most efficient aircraft in the shortest possible time. Although the article deals primarily with this problem as it affects the aircraft industry, the general concept of designing for production is applicable to almost every branch of industry. The article, in a slightly longer form, was originally read before the Royal Aeronautical Society, and their permission to reproduce it is gratefully acknowledged

THE primary object in designing any new aircraft, whether civil or military, is to be able to produce a series of the most efficient, fully approved and tested production aircraft at the highest possible rate. In practice, however, optimum design and easy production never seem to coincide exactly. This means that design for quick and easy production must be the result of compromise.

Refinement of design for production covers many broad conceptions and, in its broadest sense, it should be the uppermost consideration from the very beginning of the design of the prototypes. The first part of this paper deals therefore with the design and production planning phases of a new aircraft when, by joint consultation with the production departments, the design is viewed from the production angle from the outset. The remainder of the paper deals with the revision of detail design to allow fabrication by more economical methods of production. This is a much narrower concept, but it offers a wide scope for economies in time and cost. Between these two extreme interpretations of the title of this paper, the pros and cons of various basic types of construction offer fruitful fields for discussion.

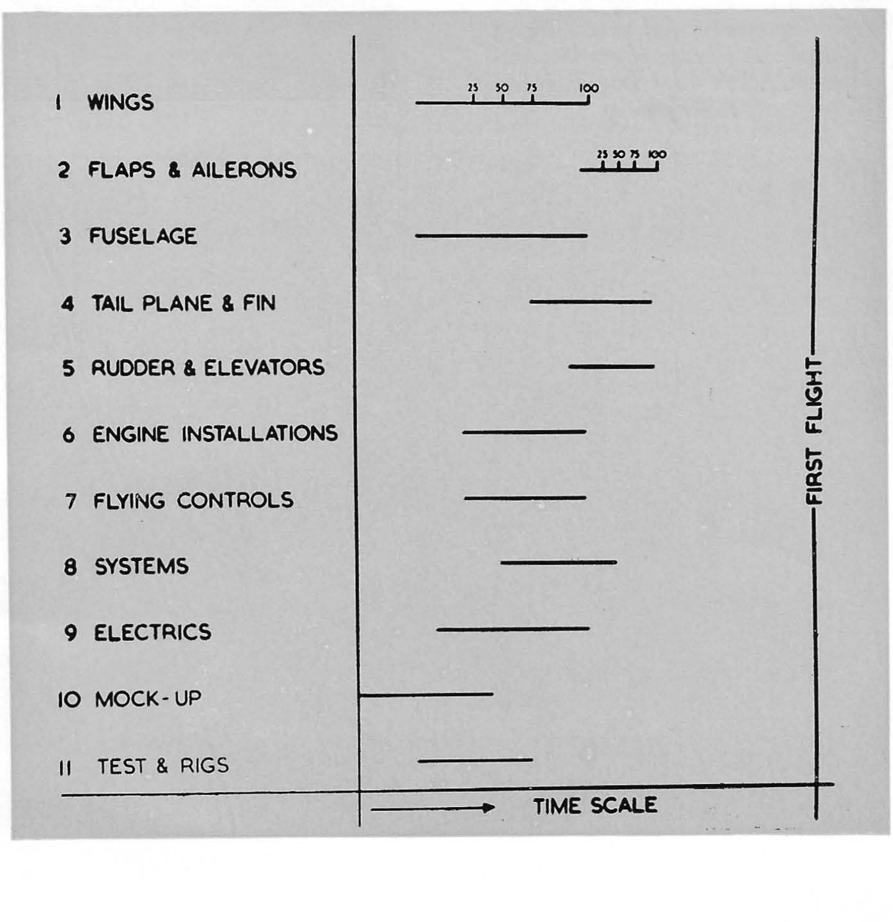
Planning for Production

Estimation of Design and Production Times

The foundation on which the grand plan for instituting a production run is based must be the promised dates by which the drawings will be issued. By reference to records of previous aircraft with suitable adjustments for size factor, complication factor, operational role, etc., estimates must be made of target dates for the issue of sufficient drawings to produce the first prototype. In Fig. 1 the horizontal lines give the period over which drawings will be issued, the left hand ends giving the dates of issue of the first drawing and the right hand ends the dates on which sufficient drawings are available to build the first prototype component. The top two lines also have marked on them the percentage of the total number of drawings to be issued by the given dates so that by the use of a normal type of progress sheet the actual achievements can be continuously compared with the estimates.

Correct phasing of components is essential if valuable time is not to be wasted. There has been too much of a tendency in the past to tackle the apparently easy things first. Tailplanes, fin, rudder, elevators, flaps and ailerons, because of their relative simplicity, have been drawn

Fig. 1: The basis for the production plan must be the promised dates by which the drawing will be issued. In this diagram, the left hand ends of the horizontal lines give the dates of issue of the first drawings, while the right hand ends give the dates on which sufficient drawings are available to build the first prototype



out and issued as quickly as possible, thus apparently impressing the production departments with how quickly the design office is getting on with the job. The shops, in their turn, also fall for this fatally easy exercise and the result is a collection of completed components getting dusty in the stores long before the real work on the fuselage and wings has been properly started. When wind tunnel results begin to flow into the design office, changes to these completed components are often indicated. This results in waste of time and money as well as causing bad feeling between works and design staffs.

It would obviously be much better to start on the difficult production tasks first; the large components which require more complicated jigs and tools, more floor space and, what is far more important, contain more equipment, always the bottle-neck in any aircraft production line. Thus, in the author's view, the smaller components should be left until later when there is less likelihood of alteration and allow a proper emphasis by the production departments on the difficult components first.

Meanwhile the production department will have been working on similar lines and will have produced an estimated aircraft delivery programme. Each part or assembly is given a priority to indicate its position in the fabrication cycle. The priority of any part is determined by its proximity to or remoteness from the completed aircraft. Normally this is the next lower priority to the assembly in which it is fitted, but in the case of parts with an exceptionally long 'make' cycle time, i.e. longer than 10 weeks, a still lower priority number may be allocated. Although the early priorities (1 and 2) are mainly machine shop and press shop parts, and main assemblies carry the later priorities (4, 5 and 6), there are many small parts which have later priorities if they are needed at a later stage of assembly. Each part or assembly has one priority only, although it may be used at two or more stages in fabrication. In these cases the priority is determined by the earliest requirement.

In the example, the eight priorities or stages are spread over a period of 37 weeks, the period between the individual priorities being determined by the type of work involved; for example, the equipment stage demands a period of five weeks. The number of weeks allowed is sufficient for the assembly requiring the longest period of erection, including paint requirements. Within limits the periods between priorities can be varied to facilitate changes in scheduled rates of output.

An assembly draws its constituent parts from both the assembly and 'making', in the previous priority. In the case of 'making', completion is called for three weeks prior to the issue of groups to allow for inspection, treatment, etc. A longer fabrication period is needed when a new aircraft is being brought into production. This extension can be kept to a minimum by issuing small initial batches of work.

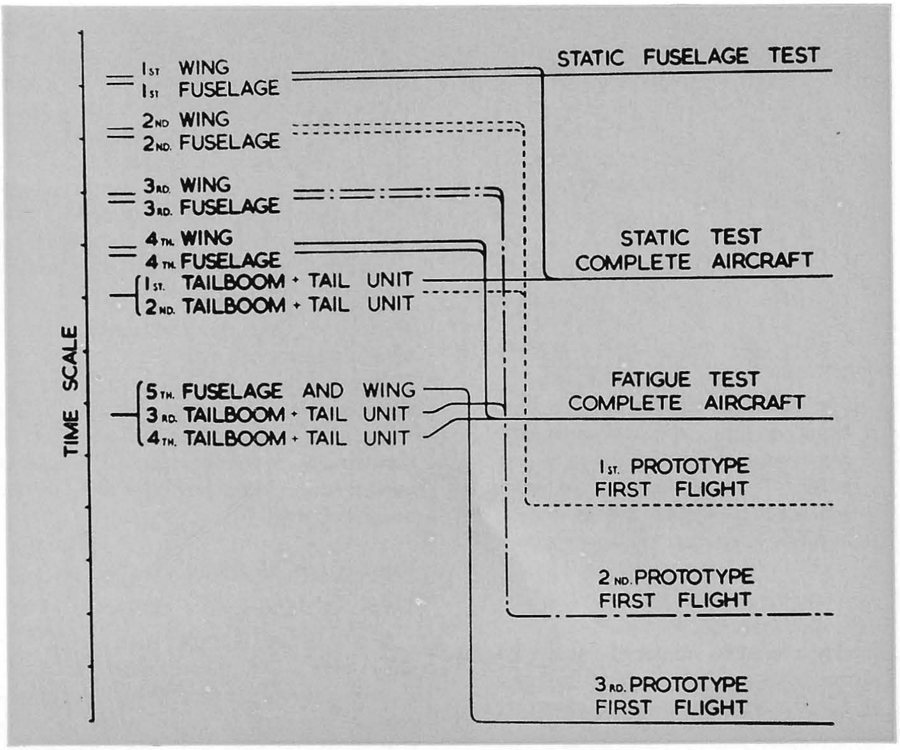


Fig. 2: An allocation chart covering the first five sets of major components, two of which are for test and three for prototypes. Nowadays, large structural test specimens amount to two additional, unequipped aircraft, the components for which must be allocated very early in the programme

From the stage breakdown the following programmes can be devised:

- Material delivery dates;
- Tool completion dates;
- Works order issue dates;
- Group issue dates to shops;
- Batch completion dates;
- Line assembly requirements.

The estimated flight date can only be determined when the drawing issue programme and the production programme are welded together in a logical sequence.

Integration of Test Specimens with Prototype Components

The days when the sole object of the workshop organization was to concentrate manufacture on those parts required for the first prototype in order to get a shiny new aircraft which would just about fly on the earliest possible date (and then claim a new record) are now fortunately disappearing. Manufacturers as a whole and production teams in particular are beginning to realize that a prototype aircraft without a pressure sealed structure or air-conditioning equipment, restricted in its speed range by non-completion of structural tests, resonance tests and the like, is more of a liability than an asset. Further, this contraption then goes to the S.B.A.C. Show where it obviously doesn't fly as fast as it should and emphasizes in the public mind the very long time between its first appearances and the time when production aircraft are in service.

Nowadays, large structural test specimens amount to two additional (unequipped) aircraft and the production departments must be prepared to allocate these extra components very early in the programme if the full benefit is to be obtained from the prototype aircraft. Fig. 2 is an allocation chart covering the first five sets of major components, two of which are for test and three for prototypes. The first fuselage has been allocated for static pressure tests and is also regarded by the workshops as a very useful exercise in establishing sealing techniques in preparation for the fully operational first prototype. In parallel with these arrangements test rigs have to be prepared to match up with the delivery dates of the specimens and here the entire resources of the company should be available to see that these programmes too, are met.

Integration of Engineering Programme with Production

Mention has already been made of the

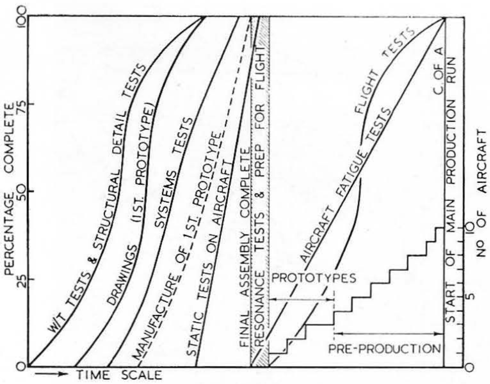


Fig. 3: This phasing diagram illustrates a fully approved production programme from initial design to final product. It can be used to assess achievements against targets and to highlight any items which have become out of phase

need to complete structural test specimens before flight and of the early completion of wind tunnel tests before constructing control surfaces and stabilizers. There are many other facets to the successful initiations of a fully approved production programme and the whole picture from initial design to final product is illustrated in the phasing diagram shown in Fig. 3. This shows the target for completion of the various stages with two main overall objectives. First, to construct prototype aircraft with as few flying and other operational restrictions as possible. Secondly, to establish a production run of fully approved and tested aircraft.

The chart in Fig. 3 can be used as a master progress chart to assess achievements against targets, and highlights the need for special efforts to correct any items which may become out of phase. Each item should have its own separate planning chart for this purpose. The diagram illustrates many important principles if the project is to be successful:

Wind tunnel tests should be completed as soon as possible so that stabilizers, control surfaces, etc., may be finalized in time to avoid changes in the shops;
For the same reason, mechanical tests on detail parts should also receive top priority in design and manufacture;
As much engineering development on all systems such as hydraulics, cabin air conditioning, fuel systems, engine installation, etc., should be completed on ground rigs before these items are installed in the aircraft;
The static tests on the airframe should be completed before the flight of the first prototype to avoid strength restrictions on flight manoeuvres or pressurization;
Stiffness and resonance tests should be completed and assessed before the flight of the first prototype to avoid speed restrictions during early flight tests;
Fatigue tests, both detail and airframe, should be completed by the commencement of the production programme;
Flight tests including winterization and tropical trials should be completed before the production run starts;
C.A. Release or C. of A. should be obtained before delivery of the first production aircraft.

This may seem an over-idealized picture of the prerequisites to early production. It cannot be denied, however, that all these enterprises need to be successfully completed. The author believes that all departments of the organization, including production, should be fully alive to the overall picture.

Production Methods

Established Methods

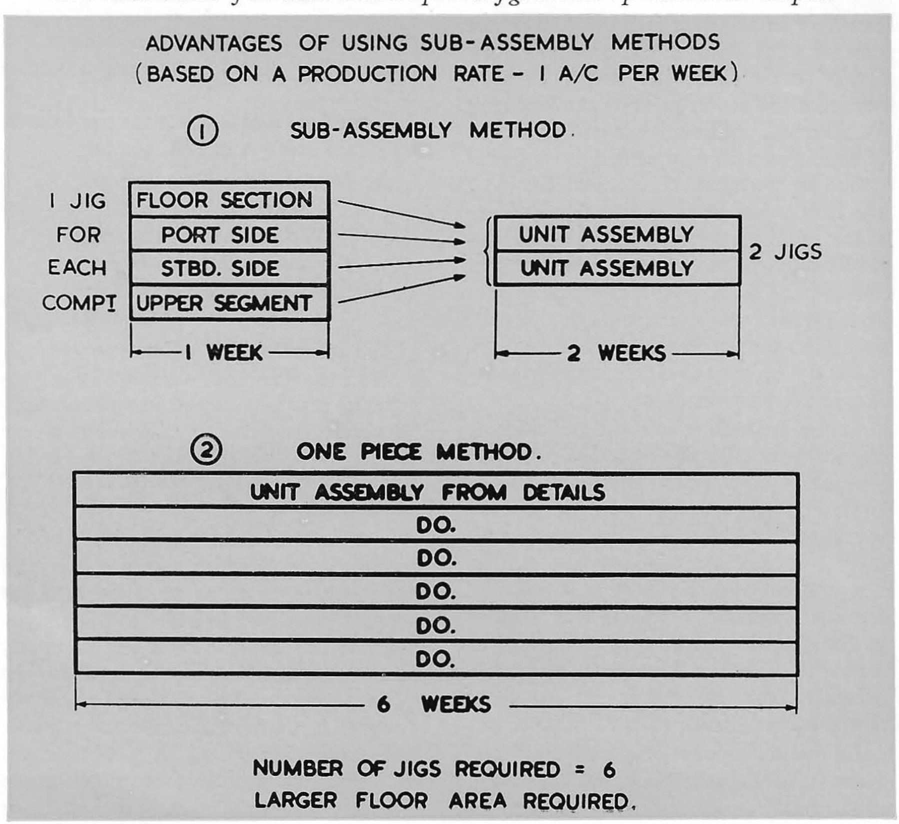
It is essential that the design office be fully aware of the facilities available immediately in the workshops. An enterprising production organization is constantly adding new equipment and introducing new processes which are potential improvements in production times. In the author's works, copies of manuals giving details of all the 'special plant' installed are circulated to all section leaders and filed for reference in the technical library.

Types of Construction and New Methods

The type of construction necessary for a new project may be dictated by design considerations if, for instance, flight speeds are much advanced beyond current designs. Early consultation with works departments is necessary to obtain new plant and introduce new techniques. In less sophisticated regimes, such as that of current civil aircraft, alternative methods are possible and here a compromise must be made between what is essential for design and what is expedient in the works. This process can also work in reverse where the production departments claim production advantages for new methods which have to be examined for suitability by the design office. In general it is difficult to introduce entirely new methods into a new design without causing delay and this is where a constant review of new methods during times when no new aircraft are being produced is essential.

It is difficult to forecast what will be needed in the future, however, unless a particular organization concentrates on one type only and is in a strong position to anticipate the next step. For those less fortunate organizations which have no idea what their next major project might

Fig. 4: The effect of breaking down a fuselage into components. In order to achieve a production cycle of one per week two main jigs and four much smaller sub-assembly jigs can be used instead of six much more complicated jigs to build up the structure complete



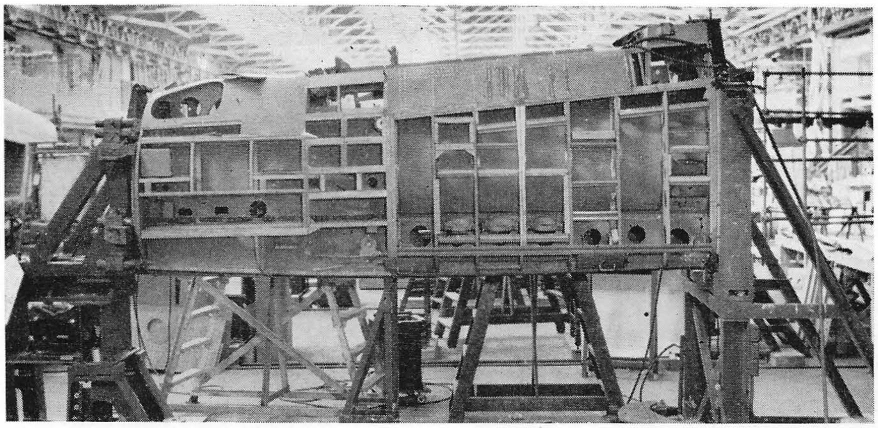


Fig. 5: Sub-assembly methods applied to a fighter fuselage. In general, the higher the production rate, the greater the amount of sub-assembly required

be it is practically impossible to anticipate future needs. Among new forms of construction, integral machining, metal gluing, metal honeycomb construction and chemical milling can be mentioned as all requiring a considerable amount of special plant preceded by considerable research programmes, the absence of which at the start of a new project can considerably lengthen the gestation period. If, for instance, metal gluing of parts in locations particularly liable to fatigue is considered essential by the design office, early notice must be given to the production departments to enable them to obtain the necessary plant.

Liaison Between Production and Design Departments

The key to success in guiding a new project through all its stages as previously described is effective liaison between production and design at all levels. Day-to-day queries from the shop floor are usually handled through the process planning department representatives using shop query forms with or without prior verbal consultation with the particular design office section concerned. This scheme to work well demands immediate and sympathetic consideration by the design office and depends for its success on the goodwill existing between the departments. Modern tendencies for design offices and works to be separated makes this harder to work and intrinsically demands a higher standard of accuracy and clarity on initial drawings if irritating delays are not to occur. In the design stage many methods of liaison are current. Two systems only will be dealt with here, namely production advisers and the development committee.

Production advisers are usually people with a wide experience of the production methods current in the factory and who are attached to the design office. Their duties vary in different organizations from merely consultative to a responsibility for vetting all drawings for suitability for production.

The development committee, if it is to be successful, must consist of members of very high executive standing with the power to make decisions on the spot or to order more detailed investigations by sub-committee. This committee should meet as soon as the chief designer can give any indication of the probable shape and size of the project and certainly well in advance of issue of drawings. The regular members may consist of the following:

Production Departments:
- Works manager,
- Chief planning engineer,
- Assistant production manager in charge of project,
- Members of general manager's staff,
- Quality manager,
- Process development manager,
- Chief estimator,
- Chief Superintendent,
- Chief jig and tool designer.

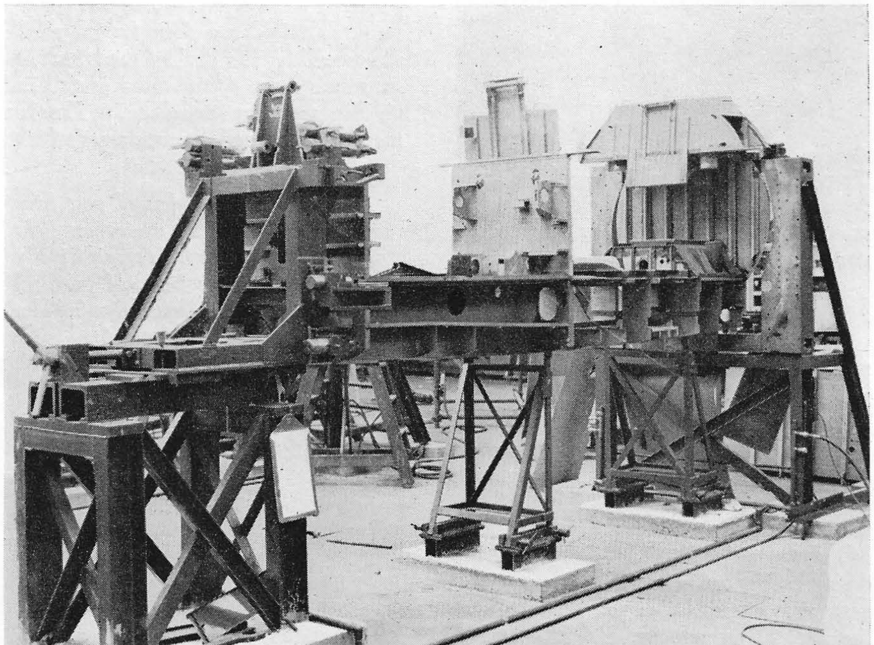
Design Department:
- Chief designer,
- Asst. chief designer (projects),
- Asst. chief designer (technical),
- Chief project designer,
- Chief technical and mechanical engineer.

Other members can be co-opted when necessary for special problems which are their chief concern such as:
- Chief test pilot,
- Weights engineer,
- Transport manager,
- Chief buyer,
- Chief mechanical test engineer,
- Flight shed superintendent and other production personnel.

All aspects of the design and production should be covered by this committee which can be aptly described as the 'steering committee' for the project. The chief designer or the works manager, as convenient, should act as chairman.

The work of this committee can be divided into three distinct phases:
- To work out the best compromises between design requirements and introduction of new processes;
- General responsibility for watching progress and ironing out difficulties;
- To guide the smooth transition from prototypes to full production.

Fig. 6: A further illustration of the application of sub-assembly methods to a fighter fuselage



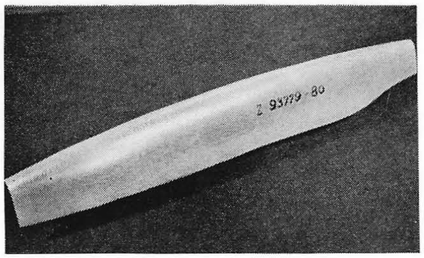


Fig. 7: How refinement of design improves production. The wing tip shown above was originally made in soft aluminium in two halves on a drop hammer and welded together. Fig. 8 illustrates the new method

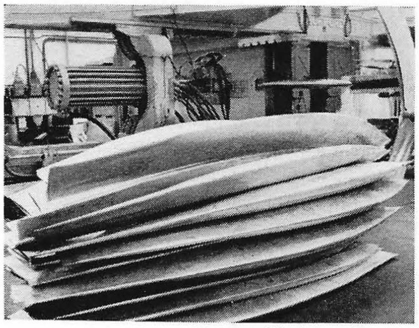
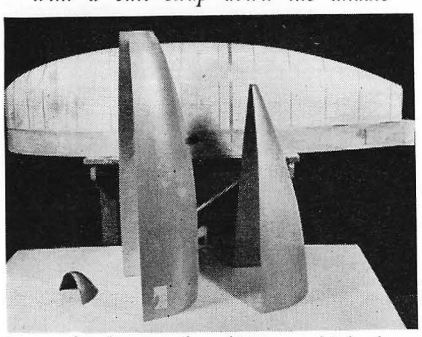


Fig. 8: Using the Hufford machine background parts like the wing tip shown in Fig. 7 can be stretch-formed in aluminium alloy. The resulting job is cheaper and quicker to produce

Fig. 9: These stretch-formed parts were originally designed in two halves with a butt strap down the middle



Two fundamental subjects which have been discussed recently by the development committee and special sub-committees at the author's works are referred to below.

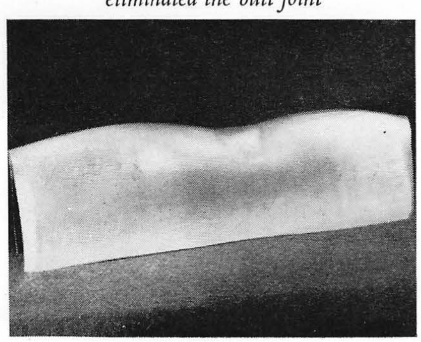
Size of Units

This is the basis of planning. In general the smaller the unit size the better, giving reduction of 'in-jig' times. This may demand the use of joints which might not otherwise have been necessary and design penalties from weight and fatigue must be carefully watched. The S.B.A.C. has issued an excellent pamphlet(1) which is of great value in deciding just how far the design office can meet the shops. This general aspect has been referred to down the ages of aircraft design. The author can well remember Major F. M. Green's slogan in about the late 1920's—'Spend a pound (sterling) to save a pound (weight)'. Things have altered a lot since then and depending on the type of operation the value to a civil airline in annual revenue of saving a pound (weight) is now more like £50. Assuming an eight-year life it has to be demonstrated that a shop's request to throw away one pound of structure weight to ease production should be accompanied by an assurance that the first cost of the aircraft will be reduced by £400. All joints need not, of course, be detachable; advantage can be taken of existing joints in sheets, stringers, etc.

One of the fundamental requirements for efficient production is that the operation cycle times should be as short as possible. The shorter the cycle time the more efficient the operator(s) can become and similarly the organization surrounding the operator becomes more efficient. The operator has less to learn and in consequence ceases to refer to drawings, process instructions, etc., much sooner than he would do with a longer cycle time and, furthermore, achieves a greater manual efficiency, thus reducing costs. Shop supervision is more efficient as it is dealing with several units of manageable proportions instead of one large unit often involving a rather lengthy and involved chain of operations, often inter-related.

In general, the higher the production rate, the greater the amount of sub-assembly required. Ideally, cycle times and jig times should be whole fractions of the shift time. Unfinished cycles at the end of a working day are highly inconvenient and particularly embarrassing in double-shift working. Fig. 4 shows the effect of breaking a fuselage down into components. This shows that in order to achieve a production cycle of one per week two main jigs and four (much smaller) sub-assembly jigs can be used instead of six much more complicated jigs to build up the structure complete. The latter method has several disadvantages which all add up to higher production costs. More floor area would be required. The man-hours expended in productive work and supervisory work would also be greater and the learning period increased owing to greater complication. Access would be greatly inferior and increase the time to get at awkward places inside the structure of the whole assembly, these places would be exposed in the sub-assemblies. Figs. 5 and 6 show how these principles were applied to a fighter fuselage.

Fig. 10: A stretch-formed part from which two (handed) navigation light panels were produced. It was originally designed in two halves and produced by drop hammer. Stretch-forming also eliminated the butt joint



Great advantages accrue from arranging joints in systems, controls, etc., to correspond with unit sizes enabling each unit to be completed, equipped and tested before the final assembly stage. Finally, unit sizes have to be carefully watched, not only from the point of view of major repairs but because they often have to be transported from one factory to another.

Refinement of Design to Improve Production

Machining Limits and Sheet Gauges

This thorny subject probably represents one of the most serious areas of conflict between the prime necessity of saving weight and ease of production whether it be in the machine shop or rolling mill. There can be no relenting here from the design office point of view and the shops must be urged to do the best they possibly can to keep to nominal sizes.

The problem is very largely one of psychology and, recognizing this, much thought has been given to statistical methods of strength assessment whereby the general shop performance is used instead of the most adverse drawing tolerances. Consider a non-fitting part on which the shops usually demand ±.010 in. As the regulations stand at the moment it is mandatory to stress this part to —.010 in. on an outside diameter whereas in the majority of cases the shops produce the part to +.010 in. Assuming an average ruling dimension of 1 in. this represents an excess of weight of 4 per cent. Taking this as a basis and assuming that there are 5 per cent of such parts in the structure weight of an aeroplane a weight penalty of 0.2 per cent ensues or 0.07 per cent increase in take-off weight. Alternatively, this could result in an 0.2 per cent reduction in a payload of a medium size civil aircraft reducing it by 50 lb. in 25,000 lb. causing an annual loss in revenue of £2,500.

This is obviously a very serious matter and a great deal of attention has been paid to this subject by many authorities. One of the most notable papers was by Dr. A. E. Russell(2) and pointed the way to the use of close tolerance sheets now universally adopted by civil aircraft constructors. Potential saving in weight is even more spectacular in this instance amounting to

300 lb. on a 25,000 lb. payload or equivalent to £15,000 per annum in revenue to the airlines.

Much remains to be done in this field, however, and a more vigorous pursuit of statistical methods is plainly indicated plus an intensive educational campaign in the shops. Inspectors too must be urged to play their part and insist at least on the limits being worked to. There is evidence that so long as the part is over nominal size it has to be accepted, however much in excess it may be.

'Handing' of Parts

This is a very fruitful area for easing production costs. Jigs and tools can be significantly cut down if port and starboard parts can be made interchangeable.

Stretch Forming

Fig. 7 shows a wing tip which was originally made in soft aluminium in two halves on a drop hammer and finally welded together. It was later stretch-formed on a Hufford machine as shown in Fig. 8 enabling aluminium alloy to be used. The resulting job was not only cheaper and quicker but was more satisfactory from the strength and particularly the handling point of view before assembly. Fig. 9 also shows some stretch-formed parts originally designed in two halves with a butt strap down the middle, thus saving weight as well as cost and time. Fig. 10 shows a stretch-formed part from which two (handed) navigation light panels were produced. Originally it was designed in two halves and produced by drop hammer. The stretch forming also eliminated the butt strap joint.

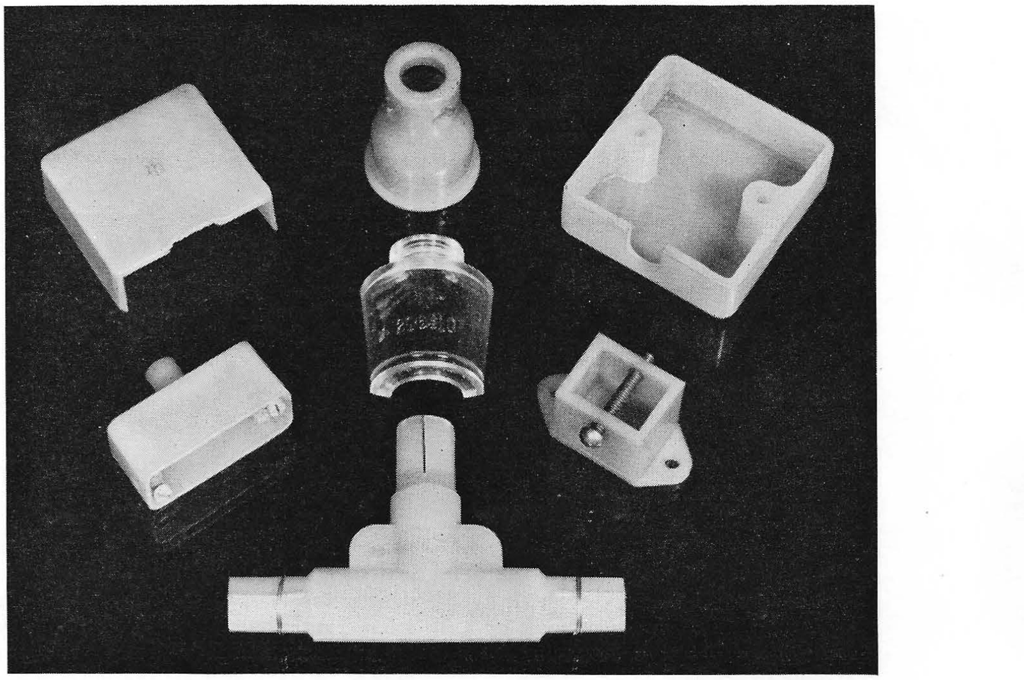


Fig. 11: Injection moulding of plastics (nylon and polystyrene) has proved invaluable for producing special parts for aircraft electrical systems, which would otherwise have been machined from the solid. This photograph shows a selection of parts made in this way

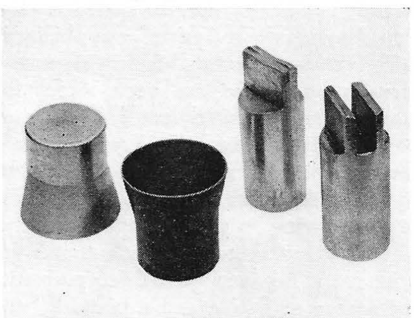
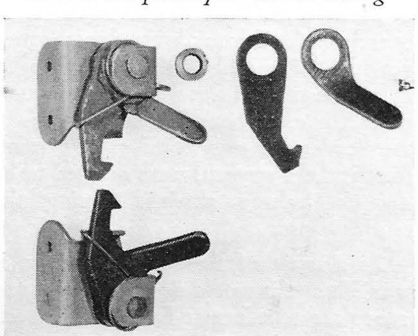


Fig. 12: The components shown above have been manufactured by impact extrusion. Such components have production advantages and better fatigue properties

Fig. 13: Small components can often be integrated, as shown in this illustration. The upper view shows the originally designed catch, consisting of bevel, catch and boss, made from three parts and welded together. The lower view shows the alternative version made in one piece by investment casting



Injection Moulding

Fig. 11 shows a number of parts made by moulding plastics (nylon and polystyrene). This equipment has proved invaluable for producing special parts for aircraft and missile electrical systems which would otherwise have been machined from the solid.

Impact Extrusions

Fig. 12 shows some examples of impact extrusions. On the left is a belled tube normally sealed by a welded plate. As an impact extrusion the part is in one piece saving cost and resulting in a greatly superior article. The male and female sockets on the right have also been made by this method. In addition to the production advantages, improvements in grain flow result giving better fatigue properties. Normally such parts would be machined from bar.

Investment Castings

Much has been written about the integration of structures and the advantages of reducing the number of separate detail parts, particularly for large components. Small components can often be 'integrated' as illustrated in Fig. 13. The upper view shows the originally designed catch consisting of bevel, catch and boss made from three parts and welded together.

The lower view shows the alternative version made in one piece by investment casting. This process produces close tolerance precision castings requiring no machining.

Conclusion

Design for production is a subject which covers a very wide field and can be treated in a variety of ways. This paper has tried to cover the subject broadly, covering the whole process of converting a new design into full production. It emphasizes the importance of early joint planning between the two partners in the enterprise and suggests methods by which this may be done quickly and efficiently. The design office must know intimately the facilities of the workshops. The production departments must be told at the earliest possible stage of new processes essential to the success of the project. When production starts the design office must be willing to consider suggestions by the production departments for improvement. Above all a spirit of mutual co-operation must pervade the whole organization if the desired success is to be achieved.

REFERENCES

(1) The Financial Aspect of Weight Saving. Published by the Society of British Aircraft Constructors.

(2) Journal of the Royal Aeronautical Society, Vol. XLIX, p. 14.

GAS OPERATED RELAYS FOR DETECTING FAULTS IN TRANSFORMERS

E. BIDGOOD, F.R.I.C., A.I.M., *Brush Electrical Engineering Co. Ltd., Loughborough*

THE gas operated relay is one of those items of equipment about which one often hears the term 'fit and forget'. However, under the more popular name of its originator the Bucholz or gas operated relay is a very useful device in that it can give warning of an incipient fault or a trip-out in the event of a major fault occurring on a transformer.

The purpose of this article is to bring some recent operating experience to the notice of works engineers so that although they may not have had experience of the usefulness of these relays, they can judge whether or not a given set of circumstances would make fitting them an advantage.

The operation of these relays depends on the fact that practically every fault which occurs in a transformer is accompanied by the liberation of gas in a more or less appreciable quantity. Thus, if it is possible to indicate at an early date that a little gas is coming off and by this means to operate an alarm at such a time when it is convenient, the unit concerned can be switched out for examination and as mentioned before, if a major fault develops inside the transformer, a violent rush of gas can be used to operate a further device and trip the transformer out.

In general, the relays are fitted only to transformers provided with conservator vessels which means that cost of the conservator has to be taken into account if it would not be normally required on the particular unit under consideration.

Construction of Relays

The relays themselves are very simple, comprising cast housings with one or two hinged floats. The hinged floats are mechanically coupled to a mercury switch, the leads of which are brought out to an external terminal box. It is usual for two petcocks to be provided, one at the top of the relay to permit the release of the collected gas, and the other at the bottom of the relay for testing the continuity of the electrical circuits by releasing the oil internally in the relay. Normally the device is full of oil and is connected in series between the main oil in the transformer and the stored oil in the conservator. When a slight or incipient fault occurs, small bubbles of gas are generated and these, in passing upwards from the transformer tank to the conservator, are trapped in the housing of the relay thereby causing the oil level to drop; the alarm float follows the oil level and when it has loaded sufficiently the contacts in the mercury switch are closed and the alarm circuit is completed.

If an external alarm device is wired in the circuit, this too will operate and indicate that a state of emergency exists. This is one of the particularly valuable features of this relay as there are a number of faults which can occur in transformers which, while they need correction ultimately, do not demand the immediate switching out of circuit of the unit. Thus, by releasing the gas from the top petcock it is possible to establish the rate of evolution of gas and form an opinion as to whether or not, over a period of time, the fault is increasing in magnitude, and suitable arrangements can be made to alert the necessary maintenance facilities to restore the transformer back to its original value. Not only is this fault indication given, but a further interesting feature is that by bleeding off the gas which is evolved under these conditions, it is possible to assess where the fault is likely to have occurred and form an appreciation of its seriousness and the steps which may subsequently be necessary.

The method of bleeding off the gas is quite simple and consists merely of attaching a long length of rubber tube to the gas outgoing petcock on the relay, the other end of the tube being attached to a container, preferably of a type which can be made chemically pure, e.g. glass. This container has stopcocks so arranged that when the whole of the bleed system is filled with oil, it is possible to drain off the oil from the thief, thus drawing the gas in the relay down into the thief vessel when it may be sealed by means of the other gas-tight petcock.

Although the analysis of the gas would present a problem to the electrical engineer, most large works have a chemical laboratory to which this problem is relatively simple, in fact a routine matter. If such a laboratory can be used, it is important to obtain the analysis as soon as possible after a fault has occurred since some of the gases which are evolved under breakdown conditions are soluble in oil and would be lost from the point of view of analysis if a long delay should ensue.

There have been papers prepared, notably by the Electrical Research Association, showing the analysis of gases obtained with various electrical faults in transformers and these are very useful in assessing in the initial stages what may possibly have gone wrong. From a manufacturer's point of view it would seem few opportunities occur to analyse gases in this manner owing to the inherent reliability of the product, but where such cases have occurred it has been possible to pinpoint the source of failure and this has led to considerable savings in time in putting the matter right. For instance, one of the factors that promoted the writing of this article was the Bucholz alarm indication of a 2,500 kVA transformer, which had been installed in a large works for about eighteen months. It was found that the evolution of gas was small but consistent and increased with increased load. Unfortunately, it was of vital importance to this particular customer not to drop the transformer out of commission and an analysis of the gas was made which enabled the opinion to be formed that a breakdown of oil by electric arc was taking place, in other words, a breakdown due to temperature. The analysis showed hydrogen as the main constituent with small amounts of methane, carbon dioxide and carbon monoxide; the two other gases present, nitrogen and oxygen, were deemed to be due to leakage obtained during the sampling process.

As a result of these considerations, it was felt that it would not be necessary to move the transformer from its site back to the works for examination, a rather difficult operation embracing movement over railway lines for a considerable distance. It was thought probable that some fault was taking place whereby an arc was being maintained from metal to metal without insulation being burnt, such arc being a function of the load. With much regret it was concluded that the fault must lie in the tapping switch, notwithstanding the previous good record of the particular type of switch fitted, and arrangements were made to take the cover off the transformer overnight with a view to carrying out any repair necessary. It was found on examination that it was, in fact, a bad contact on a tapping switch, the deduction had been correct and the unit was back in service a matter of three or four hours later.

Before closing the incident, the works engineer concerned examined all important transformers on this particular site with a view to subsequent fitting of gas operated relays because of the fact that it had been possible to detect and put right a fault without a serious interruption to his supply.

If the analysis of gas shows fairly large proportions of carbon dioxide and carbon monoxide, the indication is that there has been an insulation failure, and if additionally, hydrogen and hydrocarbons are present, it almost certainly indicates that an arc has taken place as well as the insulation failure.

These few remarks have been particularly directed at the works engineer because he has, generally speaking, a greater variety of electrical apparatus to cope with than the specialists in the supply authorities and is therefore less able to judge the efficacy of the small pieces of ancillary equipment which are fitted to apparatus from time to time. It is hoped that these words will enable a better assessment of whether or not a relay should be fitted, to be obtained at the time of considering purchasing transformers.

For the interest of those engineers who have access to a chemical laboratory, a few notes on analysis are given below:

Analysis of Gases from Bucholz Relay

The chemical identification and analysis of the gas samples taken from the Bucholz relay does not present any unusual difficulties and the normal apparatus and methods are used. The main constituents, oxygen, hydrogen, carbon dioxide and carbon monoxide, can be easily determined by means of technical Orsat gas analysis equipment. If hydrocarbon gases are also to be determined, a more advanced type of equipment is required and a Precision Orsat assembly is more suitable.

The apparatus used in the Brush Electrical Engineering Company's laboratories is that developed by Sleigh and the complete equipment is shown in the accompanying illustration. With this apparatus only a few c.c. of gas are required for an analysis and the apparatus has an advantage over the Orsat analyser in that the liquids used for absorbing the various gases are introduced into the absorption pipette and are discarded after use, so that fresh solutions can always be used.

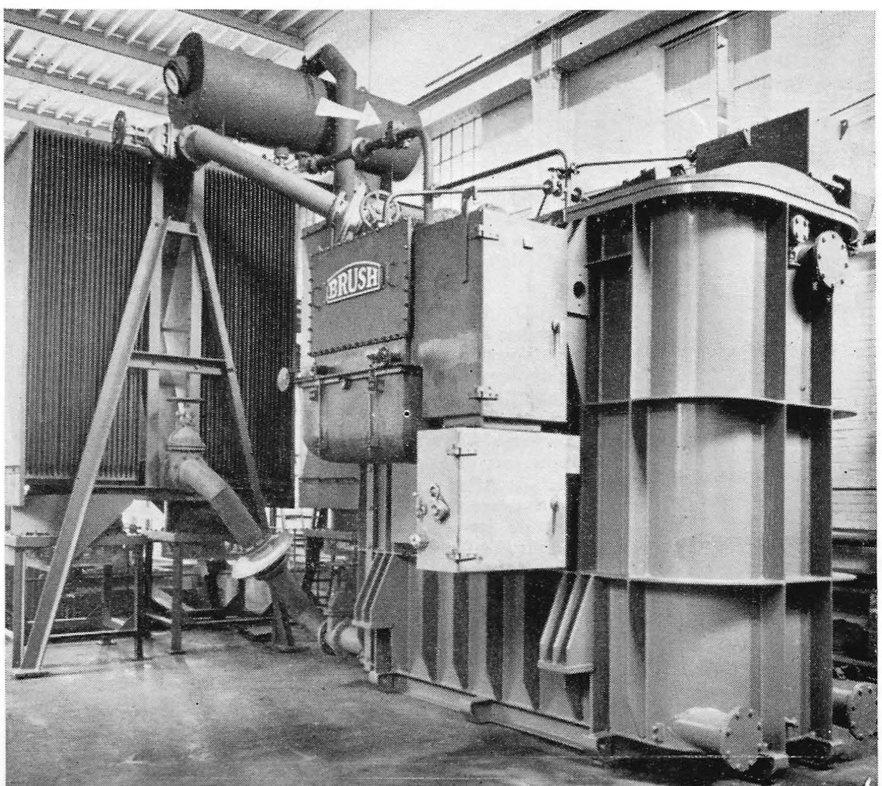
The general procedure adopted is to introduce the gas from the sampling bottle into the measuring burette of the Sleigh apparatus. This sample is adjusted to atmospheric pressure and its volume is measured. The gas is then transferred to the absorption pipette and the various components of the mixture are selectively removed by reagents adapted to the purpose.

Carbon dioxide is first estimated by absorbing it in 36 per cent potassium hydroxide solution. Unsaturated hydrocarbons (ethylene) can be absorbed by a solution of mercuric sulphate in sulphuric acid and acetylene can be absorbed by fuming sulphuric acid or alkaline potassium iodomercurate. Oxygen is then determined using alkaline pyrogallol and then carbon monoxide by ammoniacal cuprous chloride solution. The residual gas will then contain saturated hydrocarbons (ethane), hydrogen and nitrogen. The proportion of ethane and hydrogen are ascertained by mixing the residual gas with a measured excess of oxygen and burning the combustible gases by means of an electrically heated platinum wire. The proportion of carbon dioxide in the gas after combustion and the amount of residual oxygen are estimated as they were in the original sample, then by taking into consideration the volume of oxygen added, the proportions of ethane and hydrogen can be calculated. The residual gas is nitrogen.

The analysis described is time consuming and requires the services of a practised analyst, as a mistake in manipulation at any stage means that the complete operation must be repeated from the beginning.

Nevertheless, it has been our experience that the information gained from the analysis can be of considerable practical application and well merits the effort involved.

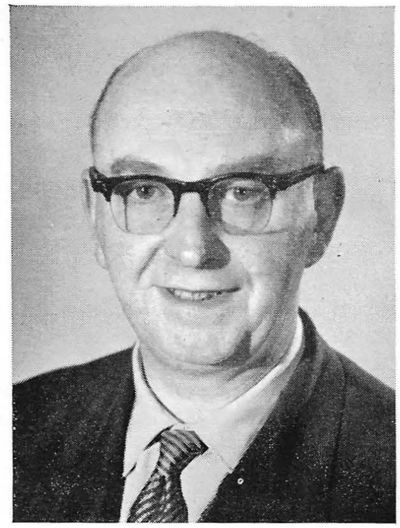
Fig. 1: The gas-operated relay (arrowed), here fitted on a 30,000 kVA Brush transformer, operates by detecting the gases which result from almost every transformer fault. The relay gives warning of incipient faults or, in more serious cases, trips out the transformer. Analysis of the gases evolved can give useful clues to the nature of the fault



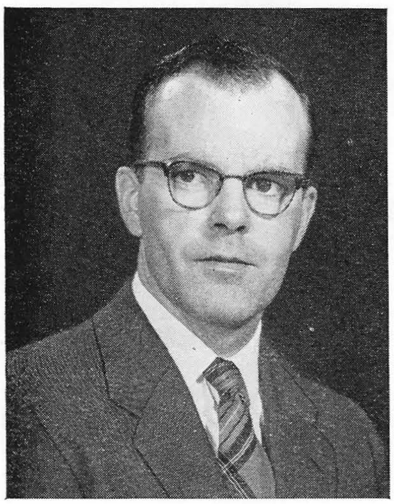
NOTES ABOUT THE AUTHORS

MR. D. H. SMITH, B.Sc. (Eng.), A.M.I.E.E. (pages 48-51), chief engineer of the transformer division of Brush Electrical Engineering Co. Ltd., has a wide experience of transformer engineering going back over 30 years. Educated at Northampton Engineering College, he spent three years with Ferranti Ltd., from which he joined GEC as senior transformer designer in 1929. Mr. Smith was then with Bruce Peebles as chief transformer engineer and deputy manager until 1954 when he joined Brush.

MR. E. D. KEEN, B.Sc., F.R.Ae.S., A.F.I.Ae.S., chief designer (aircraft) of Armstrong Whitworth Aircraft, is probably best known for his paper on integral construction read before the Royal Aeronautical Society in February 1954. He has, however, many other claims to fame in aeronautical circles, having worked on the AW 52 'Flying Wing' and having been associated with the design of the first 'Meteor' jet fighter tailplane to be machined from a solid metal billet. As chief designer of Armstrong Whitworth Aircraft, he has been responsible for the design of the Armstrong Whitworth 'Argosy', the world's first turbo-prop freightercoach.



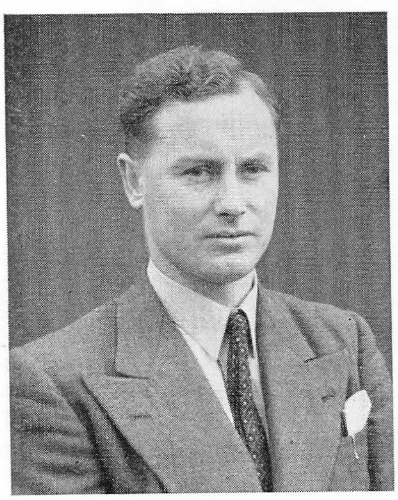
Mr. Keen was educated at the Liverpool Collegiate School and then at the Regent Polytechnic, London. He joined A.W.A. in 1929 as technical assistant to the late Major Wylie.



MR. W. V. O'LEARY, B.Sc.E.E. (pages 52-57), a Canadian, is senior liaison engineer of Canadian Applied Research Ltd. After studying at St. John Radio School, St. John, New Brunswick, he served in the R.C.A.F. and R.A.F. as a radar technician. He graduated B.Sc.E.E. in 1950 at the University of New Brunswick, was assistant chief engineer at the Stark Electronic Instrument Co., Toronto until 1955, then joined the Photographic Survey Corporation, Toronto.

In 1957 Mr. O'Leary came to Canadian Applied Research as project engineer for the airborne profile recorder project. He became senior liaison engineer for aerial survey and associated projects in the following year.

MR. G. J. METCALFE, M.Sc.Tech. (pages 58-59), joined Hawker Siddeley Nuclear Power Co. as chief metallurgist on the company's formation in 1955. He was educated at the Manchester Faculty of Technology, then began his career in 1937 with Rylands Wire Works as junior research metallurgist. From 1938 until 1947 he was in the Civil Service, rising to Technical Officer in the metallurgy department of the Royal Aircraft Establishment, Farnborough. Mr. Metcalfe joined the Fulmer Research Institute as head of the corrosion section, and in 1952 became deputy head of the precious metals laboratory, Mond Nickel Co., a position he held until taking up his present post with Hawker Siddeley Nuclear Power.



MR. R. A. GRIERSON, M.I.E.E., M.I.Prod.E. (pages 66 to 67) was educated at Wolverhampton and Staffordshire Technical College. After his apprenticeship with the Electric Construction Co. Ltd. of Wolverhampton he joined the British Power Transformer Co. of Enfield, first as development engineer, then as contracts engineer. From there he went to Partridge, Wilson & Co. of Leicester and then in 1948 to Brush Electrical Engineering Co., where he is now general works manager, Transformer Division.

RAYMOND WALL, F.L.A. (pages 42-47), librarian of the weapons research division of A. V. Roe and Co., began his library career with the reference library of Manchester Public Libraries. After a number of years there—interrupted by war service with the Royal Air Force—he joined the library department of Imperial Chemical Industries, Dyestuffs Division, as a senior assistant. In 1957 he joined A. V. Roe. His spare-time interests, include water-colour painting, music and astronautics.