26th ANNUAL REPORT OF THE COUNCIL OF THE INSTITUTION

The Council has pleasure in presenting the 26th Annual Report of the Institution which reviews the proceedings for the twelve months ended 31st March, 1952. The Annual General Meeting will be held on Wednesday, October 8th, 1952, at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

INTRODUCTION

Whilst the preparation of an Annual Report is a statutory obligation for the Institution, it has been the practice for many years to give greater detail than a mere summary of events. For this reason, the Report is again presented under the headings of the various Standing Committees who are responsible for the Institution's work under the supervision of the General Council.

The thirteen Section Committees have admirably supported the Council in extending the advantages of membership by meetings and common association. Whilst the Local Committees are primarily concerned with programmes and papers, they are also now making a valuable contribution to the work of examining membership proposals and educational qualifications.

The main brunt of the Institution's work falls upon the seven Standing Committees, who, with the Council, have held a total of 56 meetings during the year. Throughout the General Secretary's absence in India, the administration of the Institution was supervised by a Management Committee under the Chairmanship of the President.

Outstanding in the year's activities was, of course, the 1951 Convention, which can truly be said to have been the largest and most ambitious of its kind ever held in this country. Arranged in support of the Festival of Britain, emphasis was naturally laid on the original contributions made by British scientists and engineers to the development of radio science.

Altogether over 1,000 engineers attended the Convention, and the Council was particularly pleased to welcome both members and visitors from 20 countries outside Great Britain. Both the number of papers presented and the total attendance exceeded those recorded at the 1947 Convention held in Bournemouth.

Once again the Report shows still further increases in membership and examination entries—a most happy augury for the future of the Institution. Increased activity has also been reflected in the larger volume of the Institution's Journal for the past year ; the size of these Proceedings is now only controlled by financial considerations.

Previous Annual Reports have stressed the policy of successive Councils in encouraging the association of electronic engineers throughout the Commonwealth. Second in importance only to the 1951 Convention has been the visit of the General Secretary to India, which has proved a most welcome and positive step in cementing the Institution's Commonwealth relationship.

PROFESSIONAL PURPOSES COMMITTEE

The status and management of the Institution is largely governed by the Constitution as expressed in the Memorandum and Articles of Association.

Since the original Constitution was adopted in 1932, only seven sets of amendments have been required. This, in itself, is a tribute to the foresight and wisdom of the original Committee which drafted the Institution's Constitution. This point is of particular interest in view of the nomination of Mr. W. E. Miller as President-elect of the Institution, for he was one of the signatories to the original Memorandum and Articles of Association.

The regulations required by a professional institution must neither be too rigid nor too elastic; whilst it is necessary from time to time to make amendments, the Constitution to-day retains much of the sound basic structure on which it was founded. There is now, however, a need to amend Article 25, which controls the Constitution of the Council.

According to Article 25, the *immediate* Past-President is the only Past-President who may serve as a member of the Council. It will be obvious, however, that having served the Institution for many years, and reached the high office of President, such a member will have obtained a very great knowledge of the Institution's work and administration. The Committee therefore recommends that the Article be altered to permit the service of the last *three* Past-Presidents.

The Council also approved a recommendation that in the next revision of Article 29 provision be made for the election to the Council of a Companion. Since admission to this class of membership requires a candidate to have attained a high degree of responsibility in the radio industry, the usefulness of such counsel in the affairs of the Institution is obvious.

It is hoped that these recommendations will meet the approval of the membership.

Official negotiations.—Under its Constitution the Institution must bring to the notice of proper authorities ways and means by which engineering knowledge may be used in the service of the community. In fulfilment of this obligation, the Council has need to keep in close touch with governments and government departments, and often to initiate discussions.

The President, President-elect, Mr. L. H. Bedford (Past-President), Mr. J. L. Thompson (Chairman of Council) and Professors H. M. Barlow and E. E. Zepler were, together with the General Secretary, the Institution's representatives in official negotiations. As indicated in previous Reports, the discussions with the Ministry of Labour have been wholly concerned with the compilation of the Technical and Scientific Register. This Register operates under the supervision of an Electrical Engineering Advisory Committee which so far does not include any representatives of the Institution. It is regretted that, notwithstanding further meetings held during the year, little can be added to the report made last year on this subject.

The present staff requirements of the radio and allied industries are apparent from contemporary technical journals and the wide use now made of the Institution's appointments service. Concurrently, there is a marked increase in co-operation between industry and education authorities in making available curricula and training facilities suitable to the further development of industry. These efforts also help to overcome the shortage of suitably trained university graduates.

Nevertheless, education work in the radio and electronics field, as evidenced by results in the Institution's examinations, does not justify complacency; the Council feels bound to support the case for even greater and improved technical training facilities. What is now required is a wide recognition of the urgent needs of a developing industry, seeking professional engineers of specialized training and outlook. A much welcomed step has more recently been taken by the Ministry of Labour in defining a radio technician as "a person who carries out in a responsible manner approved techniques which are either common knowledge amongst those who are technically expert in his branch of industry or specially prescribed by *professional radio engineers*."[1]

Recognition.—In the last Annual Report, reference was made to the Council's policy of devoting increased attention to education, and to the need for obtaining further recognition of the Institution's examinations. In the year under review, it is gratifying to report that recognition has been accorded by two more bodies.

[1] *J.Brit.I.R.E.*, 12, August 1952, p. 418, col. 1.

Firstly, agreement was reached with the Burnham Committee whereby Associate Members engaged in the teaching profession who qualified by passing the Graduateship Examination of the Institution will receive the Graduate allowance payable to university graduates and corporate members of other professional institutions.[2]

Secondly, the British Broadcasting Corporation also announced that the Graduateship Examination would be accepted as an exempting qualification from the Internal Grade "C" examination for promotion from Technical Assistant to Engineer.[3]

Members are aware of the standing arrangements with the Royal Navy and Royal Air Force, and the Council has particular pleasure in reporting that the Indian Army and Indian Air Force[4] now give recognition to membership of the Institution. Similar discussions are also taking place with other Commonwealth government departments.

The policy of the Council over recent years, which has been largely responsible for these achievements, will be continued until universal recognition is attained.

Relationship with other bodies.—For more than a decade the Annual Report has emphasized the Institution's policy in welcoming co-operation with all bodies particularly concerned with radio engineering and those in the wider engineering field. The Institution retains its membership of the Parliamentary and Scientific Committee, also of Advisory Committees of the City and Guilds of London Institute, and representation on various Regional Advisory and Training Committees.[5]

The Institution's support of the work of the British Standards Institution dates back to 1942. For some years the Institution has been represented on two of the B.S.I. Committees and the Committee has particular pleasure in referring to the extension of this representation, as indicated in this report under the heading of Technical Committee.

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[2] J.Brit.I.R.E., 11, July 1951, p. 246.

[3] J.Brit.I.R.E., 11, May 1951, p. 202.

[4] See Indian Air Force Instruction 90/48.

[5] J.Brit.I.R.E., 11, February 1951, p. 74.

Silver Jubilee.—Perhaps the most outstanding feature of the year's activities was the Festival of Britain Convention.

Whilst a full report of the Convention has already appeared in the *Journal*, special reference must be made to the Festival Dinner held in London in June, 1951, to mark the opening of the Institution's contribution to the Festival of Britain. Official representatives from Commonwealth and other countries attended, and the Council and all members appreciated the presence of Admiral the Earl Mountbatten of Burma, K.G., Vice-Patron of the Institution, who presided over the function.

The programme stated:—

"The Convention about to be held is the third of a series and marks not only the Festival of Britain, but also the Silver Jubilee of the Institution. In this Festival Year it is appropriate that the Convention should aim at covering the whole field of electronics, to which the British Commonwealth has made so many important contributions in research and development. In fact, the Convention will be the most comprehensive in its field ever to be held in Great Britain, and the seventy papers to be presented will cover a very wide range of subjects from nuclear physics to audio-frequency engineering."

The proceedings were subsequently televised in the B.B.C. Newsreel.

Whilst there cannot be, at present, any possibility of making conventions an annual occurrence, it is hoped to plan a fourth Convention in the near future.

Commonwealth and oversea relationship.— Reference was made in the last Annual Report to the invitation extended by the Government of India for the General Secretary of the Institution to visit that country. During his four months' tour, Mr. Clifford had full opportunity to meet all the organizations concerned with the development of radio engineering in India. A full report of his work will appear in the *Journal*; most significant, of course, is the establishment of five Indian sections of the Institution.

This extension of Commonwealth sections, in addition to those already existing in South Africa and New Zealand, is a fulfilment of the policy expressed by the Council in post-war years and will undoubtedly be followed by the establishment of yet further sections overseas.

MEMBERSHIP COMMITTEE

The most important part of the Committee's work is the consideration of proposals for election, and transfer to higher grades of membership. Proposals for Student Registration are now determined by compliance with the requirements of the Engineering Joint Examinations Board* or exemption therefrom. In regard to all other grades, attention is once more drawn to the following table which shows in detail

not only the number of proposals considered, but the loss and gain in all grades of membership.

The growing strength of the Institution is indicated by the record number of applications considered by the Committee. These figures do not include a large number of proposals con-

* The Engineering Joint Examinations Board now has the support of most of the engineering institutions, as a means of conducting tests in general education for candidates for Studentship of engineering institutions.

1951/52
Direct Elections

Proposals	Members	Associate Members	Associates	Companions	Graduates	Students	Total
Received ..	18	54	76	1	53	451	653
Accepted ..	12	44	67	1	55†	451	630

Transfers

Proposals		Associate Member to Member	Associate to Associate Member	Graduate to Associate Member	Student to Associate Member	Student to Associate	Student to Graduate	Associate to Graduate	Companion to Associate Member	Total
Applied for	..	15	84	19	23	21	68	3	1	234
Accepted..	..	6	46	10	13	19	77†	7†	1	179

Applications for Reinstatement received and accepted

Member	Associate Member	Associate	Graduate	Student	Total
—	1	2	—	3	6

Removals due to Resignation, Expulsion or Death

Members	Honorary Members	Associate Members	Associates	Companions	Graduates	Students	Total
5	2	24	48	—	1	173	253

† These figures include applicants who subsequently agreed to accept a lower grade of membership than that for which they originally applied.

sidered unsuitable before reaching the Committee stage. Of particular interest are the transfers to higher grades of membership, which justify the policy started by the Council many years ago in encouraging the suitable training of Students.

The last five Annual Reports show that the loss in total membership due to resignations, expulsions, etc., is primarily caused by the termination of Studentship registrations due to inability to meet examination conditions, etc., after the prescribed period of five years. Otherwise, the loss in the higher grades of membership is comparatively small.

The increasing number of entries for the Graduateship Examination, referred to elsewhere in this report, is an especially welcome sign, not only of the Institution's strength but the quality of its membership.

The Council feels, however, that there is still a large number of radio and electronics engineers eligible for election but who have not, for various reasons, yet applied for membership. Obviously, the stronger the Institution, the more easily will further recognition be obtained. There are, of course, difficulties in achieving this, not the least of which is that of making more widely known the Institution's activities. For professional reasons the Institution cannot advertise the value of membership and such work can, indeed, only be done by members themselves.

In the last Annual Report reference was made to the number of enquiries received by the Institution regarding membership. It has been found that over a period of years there is a significant relationship between enquiries and actual proposals received. During the year, 1,703 enquiries were received—160 less than in the preceding year. Against this, however, must be reckoned the increasing co-operation of the overseas and local Sections, the majority of which are now attending to local enquiries regarding membership.

Publication of proposed elections.—As a professional precaution, the method of publishing proposed elections to the various grades of membership has been well justified. The Council proposes to continue this procedure whilst still making maximum use of local Section Committees for opinions on new proposals.

Commonwealth and oversea membership.—In the main, the Institution's professional and academic qualifications for membership are based on British standards. Some years ago, however, the Committee started to view these qualifications on a much broader basis according to the concepts of training overseas, but without in any way lowering what might be considered the minimum requirements.

Academically, the minimum standard may be considered as that required for success in the Graduateship Examination of the Institution. In applying this rule to university and other examinations held overseas, it is necessary to have complete understanding with the Institution's approved representatives. The Committee wishes to record appreciation of the co-operation which has been given by members abroad; this should lead to publication, within the next 12 months, of oversea qualifications which are recognized as satisfying part of the Institution's academic requirements for membership.

For the present, the regulations remain as published in the 19th edition of the Institution's "Membership and Examination Regulations" and any suggestions for amendment are, of course, discussed with the Education and Examinations Committee.

Appointments Registers.—The post-war decision to continue this service to members of the Institution has been amply justified. The shortage of qualified engineers was most marked during the year; but, having regard to the total membership, the Institution has not recorded any considerable movement in the changing of employment.

EDUCATION AND EXAMINATIONS COMMITTEE

The Committee held twelve meetings during the year, under the Chairmanship of Professor E. E. Zepler, who, in addition to attending every meeting of the Committee, has also represented the Institution in meetings with other bodies. During the last few years, Professor Zepler has given considerable time to the educational work of the Institution notwithstanding the additional work in which he had been involved by reason of the University College of Southampton having become a University[6]. His work is widely appreciated and the Committee is especially pleased that Professor Zepler has been nominated for election as a Vice-President.

[6] *J.Brit.I.R.E.*, **12**, May, 1952, p. 305

The Committee have had meetings with representatives of the Electrical and Mechanical Engineering branch of the War Office to discuss the qualifications required for technical personnel serving in the Army and Supplementary Reserve. In basic training Officers are required wholly to concentrate on mechanical and electrical engineering but are later encouraged to specialize. It is in relation to wireless and electronic equipment, as used in the Army, that attention has been given to the requirements of the Institution's membership qualifications.

The Committee wishes to pay particular tribute to the co-operation which the Institution continues to enjoy with the Admiralty and the Air Ministry on training and education matters. In both cases great help has been given in determining the standards of eligibility for membership of commissioned personnel in the radio and electronics branches.

Examination entries.—During the year under review, 799 applications were received for the Graduateship Examination—360 and 439 for the May and November, 1951 examinations respectively. This increase of 21 per cent. over the entries for the previous year maintains the trend of past years and is indicative of the increasing value placed upon the examination both by students and professional engineers.

It is interesting to note that the total number of entries received since registers were first kept is 4,796 and this figure is now increasing at just under 1,000 entries per year.

Recently, there has been a considerable increase in the number of candidates wishing to transfer to a later examination, after arrangements have been completed with the examination centres and the examinee. This practice has involved the Institution in a great deal of extra work and expense and the Council has now decided that in future no entry can be transferred after arrangements have been completed.

Examination Exemption.—The Committee now only deals with applications for exemption not strictly in accordance with the regulations. 186 applications were considered, of which 30 were granted full exemption, 123 exemption from part of the examination, and 33 entirely refused.

Examination Centres.—The 1951 examinations were held at 11 centres in the United Kingdom and 40 overseas. The Committee records appreciation of the accommodation and facilities granted to the Institution by various authorities and in particular the help provided by Service units.

Examiners.—At intervals the Committee appoints new examiners and those now responsible for the various sections of the Graduateship examination are:—

Part I—*Physics*

P. O. Wymer, B.Sc., W. P. Rowley, M.B.E.

Part II—*Principles of Radio Engineering*

K. G. Lockyer, B.Sc.

Part III(a)—*Mathematics*

E. T. A. Rapson, M.Sc.(Eng.), A.C.G.I.

Part III(b)—*Advanced Radio Engineering*

S/Ldr. M. E. Claxton, B.Sc., M.Ed.;
J. R. Miller

Part IV—*Radio Reception (Receiver design and practice)*

H. Stibbe

Part IV—*Radio Transmission*

F. Butler, B.Sc.(Hons.)

Part IV—*Television*

M. Morgan, M.Sc.

Part IV—*Audio Frequency Engineering*

S. Kelly

Part IV—*Electronic Measurements*

S. R. Wilkins

Part IV—*Valve Manufacture and Technology*

S. Rodda, B.Sc.(Hons.)

During the year these examiners prepared 20 question papers and with the continually increasing number of candidates, their duties have become more exacting. Council, therefore, takes this opportunity of expressing to the examiners appreciation of their services to the Institution in this most important work.

Examination Prizes.—The Council has approved the award of prizes for 1951 as follows:

President's Prize and Electronic Measurements Prize

Beswick, George Robert (now an Associate Member)—Birmingham.

Mountbatten Medal

White, Colin James (Graduate Member)
—London.

In the opinion of the Council, no candidate qualified for the S. R. Walker Prize, awarded to the candidate second in the order of merit who passes the examination at one sitting. Similarly, it was also decided to withhold the Audio Frequency Engineering Prize, awarded to the candidate most successful in this optional subject.

Facilities for training.—On a number of occasions the Institution has commented on the lack of suitable training facilities for radio engineering. This has, to a large extent, been responsible for the rather poor results of candidates sitting the Graduateship Examination in recent years, and it is therefore gratifying to record that at least two further technical colleges are starting a full-time course of study covering the syllabus of the Graduateship Examination. These are the Coventry Technical College and the Municipal Technical College, Bolton.

The Radio Industry Council, in conjunction with the Ministry of Education, has also been responsible for the promotion of a number of schemes to increase the supply of qualified engineers to the industry, and in these schemes the Institution's Graduateship Examination figures prominently.

Representation on other Committees.—Through the Education Committee, the Institution is represented on the City and Guilds Advisory Committees on Telecommunications, Radio Service Work, and the Radio Amateurs Examination. The representatives are Professor E. E. Zepler, G. A. Taylor and R. G. Holmes respectively. The Institution is also represented through the Radio Trades Examination Board, on the Co-ordinating Committee for the Radio and Television Servicing Certificate Examinations.

RADIO TRADES EXAMINATION BOARD

The Board reports the resignation, in October last, of Mr. S. A. Hurren, O.B.E., M.C., (Honorary Member), consequent upon his retirement from professional life. Mr. Hurren has been Chairman of the Board since its inception and was in fact instrumental in the foundation of the Board in 1942.

Mr. Hurren was one of the Institution's representatives on the Board and has had much to do with promoting schemes of examination for technicians and mechanics. The Education Committee joins with the Board in hoping that Mr. Hurren will have a long and pleasant retirement.

The Council was pleased to note that Mr. Ernest J. Emery was elected Chairman of the Radio Trades Examination Board, on which he serves as a representative of the Radio Industry Council. Mr. Emery has been a Member of the Institution since 1938 and is also the Chairman of the City and Guilds of London Institute Advisory Committee on radio service work.

Radio Servicing Certificate Examination.— For the May, 1951, examination the Board received entries from 306 candidates, compared with 264 in 1950. Of these, 196 candidates were successful (including 19 who were referred in 1950): 46 were required to take the Practical Test again and 50 failed. The examination was held at 20 centres as far apart as Belfast, Plymouth and Dundee, and the Board wishes to thank the various colleges for the facilities and accommodation granted for the Practical Test.

Television Servicing Certificate Examination.— The second Television Examination was completed in the year under review and for this examination, there were two centres—London and Birmingham. In addition, arrangements were made for a number of candidates in Scotland to take the written papers only; subject to their success in the written papers these candidates will be permitted to sit the Practical Test in 1952.

Of the 84 candidates who entered for the examination, 25 were successful (including 6 who were referred in 1950): 16 were referred in the practical test, and 21 passed the written papers only. 16 candidates failed the entire examination.

It is interesting to note that by the 15th January of this year, the Board had accepted entries from 133 candidates to sit the Television Examination in 1952.

Since its inception, the Board has examined no less than 1,836 candidates, of which 325 sat the Television Examination. When it is remembered that in every case candidates were

subjected to a comprehensive practical test, it will be realized that this is no mean achievement.

These Examinations would not be possible were it not for the support of the industry in lending the receivers. Through the Radio Industry Council, large numbers of radio and television receivers are made available to the Board.

Increased working costs have continued to make it necessary for the constituent bodies to maintain their subsidy. These bodies—the Radio Industry Council, the Radio and Television Retailers' Association, the Scottish Radio Retailers' Association and the Institution— are convinced of the necessity of maintaining and increasing the Board's work to raise the general standard of radio and television servicing in this country. This has become an urgent matter with the enormous growth of television and its increasing complexity.

The Institution has continued to provide secretarial facilities for the Board, in addition to being represented as follows:—

Radio Trades Examination Board

> E. A. W. Spreadbury (Member)
>
> E. J. G. Lewis (Member)
>
> G. A. Taylor (Member)

R.T.E.B. Examinations Committee

> E. J. G. Lewis (Member) *Chairman*
>
> E. A. W. Spreadbury (Member)
>
> W. E. G. Scott (Associate)

Several members have also given assistance by acting as local examiners.

PROGRAMME AND PAPERS COMMITTEE

During the past session, five new members were appointed to the Committee: Mr. E. G. Hamer, B.Sc.(Eng.), (Associate Member), Mr. F. T. Lett (Associate Member), Mr. E. J. G. Lewis (Member), Mr. R. N. Lord, M.A. (Associate Member) and Mr. G. P. Thwaites, B.Sc. (Associate Member). Dr. G. L. Hamburger has continued as Chairman of the Committee.

The 1951 Convention.—Volume XI of the Institution's *Journal* contains full details of the six separate sessions of the 1951 Convention, including abstracts of all the papers read. The programmes as published were all completed

and in addition, the first two Sessions were accompanied by exhibitions of electronic instruments and vacuum equipment. Owing to the illness of Mr. J. W. Ridgeway, the Chairmanship of the session on Valve Technology and Manufacture was undertaken by Mr. J. R. Hughes (Member).

The residential facilities provided at Connaught Hall, University of Southampton (for sessions 3 and 4) and King's College, Cambridge (for session 5) were particularly appreciated. The Cambridge session also marked the inaugural Clerk Maxwell Lecture, which was delivered by Professor G. W. O. Howe, D.Sc., LL.D. The Lecture was actually given in the Maxwell Theatre of the Cavendish Laboratory, established by James Clerk Maxwell, who was the first professor of experimental physics at Cambridge University.

A further outstanding feature of the Television session at Cambridge was the privilege extended to delegates of taking part in a celebration of Evensong in King's College Chapel on the last day of the session, followed by a formal dinner in the Hall of King's College.

The last session, devoted to Audio Frequency Engineering, was held under the Chairmanship of Mr. H. J. Leak (Member) in the Richmond Hall at Earls Court, London, during the period of the 1951 National Radio Exhibition.

Consideration of papers.—The papers read at the Convention were selected after joint consultation between the Papers and Technical Committees. The selection of papers was decided by both Committees, assisted by a number of readers who did not necessarily serve on any committee.

Forty-five industrial firms, government research organizations and University Departments were represented in the authorship of the papers presented.

Due to the demands of the Convention programme, rather fewer papers were submitted for the normal programme. Apart from the Convention papers, the Committee considered 54 contributions, of which only thirty proved suitable for publication in the *Journal*. Previous Annual Reports have expressed the need for all members doing more to procure papers of a sufficiently high standard and interest for read-members, especially new members, in making worthwhile the proceedings of the Institution.

Section meetings.—During the session, the seven sections of the Institution in Great Britain held a record total of 55 meetings. Average attendances tend to increase although in some areas too few members attend regularly in support of their local committee.

The South African section has continued to make progress and held six meetings in Johannesburg. The establishment of sections in Bombay, Calcutta, New Delhi, Madras and Bangalore has further increased the activities of the Institution's overseas membership. The inauguration of these sections has given great satisfaction to local members, and attendances at the first meetings were most encouraging. Many of the papers read are being considered by the Papers Committee in London for publication in the *Journal*, either in full or in condensed form.

Premiums.—The greater size of the 1951 volume of the *Journal* (608 pages) added to the difficulty of adjudicating on the award of the eight premiums offered by the Institution.

For 1951 the Council is able to make the first awards of the Brabazon Premium (for the most outstanding contribution to the Institution's proceedings on electronic or radio aids to aircraft safety), and the Leslie McMichael Premium for the most outstanding paper on the technique of broadcast or television reception.

Council has made the following awards and expresses congratulations to the authors:—

The Clerk Maxwell Premium

H. P. Williams, Ph.D. (Associate Member)

"*Subterranean Communication by Electric Waves*"

(Published in *J. Brit.I.R.E.*, **11**, March 1951, pp. 101-111)

The Heinrich Hertz Premium

R. E. Spencer, B.A.

"*The Detection of Pulse Signals near the Noise Threshold*"

(Published in *J. Brit.I.R.E.*, **11**, October 1951, pp. 435-454)

The Sir Louis Sterling Premium
Emlyn Jones, B.Sc.

Scanning and E.H.T. Circuits for Wide-Angle Picture Tubes

(Published in *J. Brit.I.R.E.*, **12**, January 1952, pp. 23-48)

The Leslie McMichael Premium

R. G. Kitchenn, B.Sc.(Eng.) (Associate Member)

An 8-Channel Transmitter for an Experimental Carrier Wire Broadcasting System (Published in *J. Brit.I.R.E.*, **11**, August 1951, pp. 215-337)

The Brabazon Premium

G. E. Roberts

The Design and Development of the Decca Flight Log

(Published in *J. Brit.I.R.E.*, **12**, February 1952, pp. 117-131.)

The Marconi Premium

E. G. Rowe, M.Sc.

The Technique of Trustworthy Valves (Published in *J. Brit. I.R.E.*, **11**, November 1951, pp. 525-540).

The Dr. Norman Partridge Memorial Award and the Students' Premiums are withheld.

The Journal.—The *Journal* for 1951 (Volume XI) comprised 12 issues and is the largest yearly volume so far published by the Institution. Indeed, it would now seem that the size of each *Journal* will be largely controlled by the recommendations of the Finance Committee. There has been a very considerable increase in publications, reprints, etc., during the year and every member should note the comments of the Finance Committee on this subject.

Since July 1951, one or more Convention papers have been included in each issue of the *Journal* and it is hoped to complete publication of all Convention papers by the end of 1952. Difficulties in paper supply and printing— now fortunately diminishing—have prevented publication in a shorter time, but it is considered that the present rate serves the best interests of the membership in providing a balanced selection of subjects in each issue.

Year Book and Abstracts.—Reference has already been made to printing difficulties experienced during the year. The Institution's staff also had a more than usually heavy burden of work, owing to the Convention arrangements. Nevertheless, the 5th Edition of the Year Book and List of Members was published in November, 1951. With the growth of the Institution, this Edition is the largest so far

issued and a particularly interesting feature is the record it contains of all meetings held and papers read before the Institution since the previous edition.

A third and revised Edition of the Index to principal papers published in the *Journal* was also issued. This Index has proved invaluable for reference and is of particular assistance to prospective authors of papers suitable for publication in the *Journal*. This booklet gives abstracts of all the papers published by the Institution up to July, 1952.

Acknowledgments. — Council wishes to express thanks to all the authors of papers presented at the Convention and Section meetings, and to those who submitted papers for publication in the *Journal*. Several authors rendered particular service to the Institution by reading their papers at more than one Section—a gesture greatly appreciated by members living outside London. Industrial firms and Government establishments are also thanked for their co-operation in making available the services of their staff, and for assisting in the provision of demonstrations.

The Institution's thanks are also due to the various authorities who have provided accommodation for meetings at:

London School of Hygiene and Tropical Medicine,

Institute of Engineers and Shipbuilders, Glasgow,

Engineering Centre, Glasgow,

The College of Technology, Manchester,

The Merseyside and North Wales Electricity Board,

Coventry Technical College,

Winter Gardens, Malvern,

Public Library, Rugby,

Wolverhampton and Staffordshire Technical College,

Institution of Mining and Mechanical Engineers, Newcastle-upon-Tyne,

Department of Natural Philosophy, University of Edinburgh,

and to the various authorities who have provided facilities for the meetings of oversea sections, as well as the Editors of technical and scientific journals who report Institution meetings and activities in their columns.

LIBRARY COMMITTEE

Library services were more widely used by the membership than in any previous year. Means of extending facilities for the loan of books, particularly outside London and abroad, continue to occupy the Committee's attention. From the central library in London over 600 books have been borrowed by members during the year, and some 200 members have availed themselves of the opportunity to read and consult books in the library at 9, Bedford Square.

The principal activity of the Committee is reviewing publishers' lists and members' recommendations in order to select new books for inclusion in the lending section of the library. In general, the Committee's aim has been to widen the selection of works suitable for students taking the Institution's examination, and to include books on subjects which have hitherto been confined to papers in the journals of learned societies. In addition, the Committee has concentrated on the acquisition of reports by University Research Departments and Government Research Departments overseas.

As mentioned in last year's Annual Report, the expense involved in publishing a revised Library Catalogue is not felt to be justified at the present time, and lists of new books available for loan are given in the *Journal* from time to time.

The Library continued to co-operate with other special and Public Libraries to mutual advantage in loans of reference works, etc.

As a result of exchange arrangements with other Societies, the number of other publications received has increased. The Committee arranged to subscribe to several new periodicals which could not be obtained by means of exchange.

The Library staff has continued the indexing of papers and articles appearing in the publications received, and many volumes of various periodicals were bound during the year.

The Institution has also joined ASLIB (The Association of Special Libraries and Information Bureaux).

Gifts.—The Committee is grateful to the many members who have donated books and

copies of technical journals to the Library. Thanks are particularly expressed to Mr. L. W. Meyer (Member), Mr. G. M. Howe, Mr. H. W. Shipton and Dr. C. Susskind (Associate Members); also to Ealing Public Library who have given certain volumes on permanent loan.

As in past years, publishers have supplied copies of new technical books. The majority have been reviewed in the *Journal* and subsequently placed in the Library.

TECHNICAL COMMITTEE

In the last Annual Report mention was made of the latest work of the Technical Committee, namely a report on "Technical Search: Patents and the U.D.C. System." It was hoped that this report would be completed and published in the year under review, but it has proved a rather bigger task than expected, and will not now be published until the October or November, 1952 issue of the *Journal*.

Considerable progress was made and at the end of the year under review the report was in its first draft stage. It has been the work of a number of experts in their own field, and it should prove to be of considerable interest to all members, especially to Graduates and Students. An important change was made in the title which is now "Radio and Electronic Engineering Literature," but it still covers the features detailed in the last Annual Report[7].

The Committee is now discussing preparation of a new report to be entitled "The Use of Primary Materials in the Radio Industry." In this connection it is proposed to appoint a sub-committee on which specialists from the industry will be invited to serve.

British Standards Institution.—The Institution has now been invited to nominate representatives to serve on seven further sub-committees of the British Standards Institution covering the work of the Telecommunications Industry Standards Committee. The names of the representatives have not yet been finally approved and details will be announced in the *Journal*. It is, however, an important step forward in the progress of the Institution that it has now been invited to serve on all the relevant radio committees of the B.S.I.

These committees are in addition to the Nomenclature and Symbols Committee on

[7]*J. Brit.I.R.E.*, 11, September 1951, pp. 353-354.

which since 1947, Mr. G. Wooldridge, B.Sc. (Associate Member)[8] has represented the Institution, and the Radio Interference Committee where since 1948, the representative has been Mr. E. M. Lee, B.Sc. (Member).

1951 Convention.—The Committee took a major part in the organization of the Convention and many of its members served on the Convention Committee.

Much of the detail of the arrangements has already been given elsewhere in this report; the Chairmen of two sessions of the Convention were members of the Committee—Mr. P. Adorian (Radio Communication and Broadcasting) and Mr. H. J. Leak (Audio Frequency Engineering). In addition, the Chairman of the Committee, Mr. E. A. Bowsher, presented a paper on "Television Wire Broadcasting" during the Television Session of the Convention.

Future Work.—In recent years, the Committee has been able usefully to co-operate with other standing committees of the Institution in securing papers, examining the field of membership, etc. With the preparation and publication of special reports,[9] a new phase of the Committee's activities has commenced, which can be of direct and immediate value not only to the profession but also to industry. The report on materials might well be followed by a report on productivity which, in the opinion of many members, is a subject which needs greater attention; indeed, there is much argument for including in the Institution's examination requirements a paper on Industrial Administration.

FINANCE COMMITTEE

Increased income and greatly increased expenditure are shown in the Statement of Accounts for the year ended March 31st, 1952. The Balance Sheet and Auditor's Statement appear on pages 472 and 482-3.

As in previous years, much of the expenditure, apart from salaries and other overhead costs, relates directly to the cost of the *Journal* and

[8]Also a member of Council, see *J. Brit.I.R.E.*, 12, May 1952, p. 270.
[9]For example: "Aerial and earth facilities for the reception of sound broadcasting in prefabricated houses," *J. Brit.I.R.E.*, 5, October 1945, pp. 224-227; "Electronic aids to industry," *J. Brit.I.R.E.*, 9, December 1949, pp. 446-464; "Good engineering practice," *J. Brit.I.R.E.*, 11, January 1951, pp. 25-32.

GENERAL ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1952.

EXPENDITURE

1951 £		£ s. d.	£ s. d.
575	To Examination Expenses including Printing of Papers, Examiners' and Invigilators' Fees and Incidental Expenses		689 2 11
1,907	,, Printing and Publishing Journal, Reports, Regulations and Year Book, *less* Advertising Receipts ..		5,580 4 9
5,165	,, Salaries and State Insurance		5,751 12 2
555	,, Postage and Telephone		690 6 0
	,, Institution Premises:—		
701	Rent, Rates and Insurance ..	1,235 7 1	
133	Lighting and Heating	146 17 5	
203	Office Expenses and Cleaning ..	219 1 6	
233	Repairs	532 17 5	
			2,134 3 5
747	,, Printing and Stationery		863 0 9
776	,, Secretary's and Delegates' Expenses ..		487 11 5
—	,, Contribution to Expenses of Secretary's visit to India		696 0 0
1,025	,, Section Meeting Expenses		1,034 7 4
—	,, Convention Expenses		1,644 13 8
42	,, Audit Fees		52 10 0
177	,, Bank Charges and Cheque Books ..		258 17 4
296	,, Grants to Other Institutions		130 5 0
164	,, Sundry Expenses		283 5 11
—	,, Pension Scheme		378 2 0
116	,, Legal Expenses		— — —
74	,, Premiums and Awards		52 12 6
	,, Depreciation:—		
222	Office Furniture and Fittings ..	216 5 8	
55	Library .. ..:	24 7 9	
			240 13 5
£13,166			**£20,967 8 7**

INCOME

1951 £		£ s. d.
8,710	By Subscriptions including Arrears 10,001 14 10	
108	,, Donations to Building Fund 2,960 0 6	
1,090	,, Examination and Exemption Fees 1,355 9 5	
410	,, Entrance and Transfer Fees 451 13 0	
1,915	,, Sale of Examination Papers, Reprints and Journal 2,780 0 3	
28	,, Interest on Investments (Gross) 28 0 0	
400	,, Radio Trades Examination Board—Secretarial Charges 458 6 8	
505	,, Excess of Expenditure over Income 2,932 3 11	
£13,166		**£20,967 8 7**

Note—The Balance Sheet is printed on pp. 482-3.

meetings. Extension of these essential activities of the Institution must now, however, be limited to available resources. Indeed, if the costs of paper and printing are maintained at last year's figures, the Committee would be compelled to urge drastic pruning of these expenses, even to the extent of reducing the size and frequency of issue of the *Journal*.

It had been hoped that the slight increase in non-corporate member subscriptions—starting in April, 1951—would meet the estimate of increased costs. These were, however, heavier than anticipated, due to the great rise in the basic wage during the year, reflected not so much directly in salaries, as indirectly in payments for services, increased costs of materials, printing and such items as postage. Under the latter item, for example, bulk postal charges on the *Journal* show an increase of 25 per cent. and it seems likely to be still further increased by the contemplated higher postage rates.

Membership subscriptions.—Last year's report referred to the fact that nearly all Institutions have found it necessary to revise subscription rates. Successive Councils of the Brit.I.R.E. have, however, endeavoured to meet rising costs without calling on the membership for a greater individual contribution. Increasing activities and further development in the status of the Institution now demand reconsideration of the justification for a slightly higher individual contribution, and various proposals are at present before the Council. It is hoped to refer to this matter in greater detail at the Annual General Meeting.

Meanwhile, the Committee does appreciate the response of the membership as a whole in meeting their liabilities to the Institution. Arrears of subscriptions have never been so low and in the accounts under review represent slightly less than 6·5 per cent. of the total due.

Building Fund.—Again in the last report, reference was made to the need for the Institution having at least £10,000 invested in a general reserve fund, which might be utilized for the purpose of acquiring the freehold of larger premises. The cost of a suitable building would be in the region of £30-40,000. Although special contributions have been invited since 1944, it is improbable that such an amount could be obtained without considerable support from the industry.

The retiring President has especially applied himself to this problem, and, as indicated in the 1951 report, took steps to secure a greater response to the appeal for contributions to the Building Fund. Hence, this item shows a considerable increase on previous years, due to generous donations by several firms. A full list will be published in the next report.

Even if, for lack of suitable accommodation, etc., the Institution does not take immediate steps towards securing freehold premises, the objective of acquiring a general reserve fund still remains an urgent matter.

Meanwhile, in order to ensure the present tenancy of 9 Bedford Square, a new lease was obtained from the Ministry of Works. Part of the increased rent which the Institution has been obliged to pay is shown under the appropriate item in the expenditure account.

Cost of Library.—Library expenses are still only shown under one item and do not indicate in detail purchases of textbooks, publications and binding charges. Other overhead expenses connected with the Library facilities, such as salaries of the staff, rent of the reading and stack rooms, lighting, stationery, etc., are not itemized in the General Expenditure Account. These charges might now be included under an item "Library Expenses" and general expenditure would be reduced accordingly. This would be in conformity with the practice adopted for showing the net cost of publication of the *Journal*.

Prizes.—The accounts also disclose that the Prize Accounts are not covered by investments, the interest from these being hardly sufficient to cover the value of the prizes.

The excess is a charge against general administration. Here again the Council has agreed that every effort be made to increase the investments of the Institution, so that the interest therefrom will not only defray the present cost of premiums and prizes, but also enable the Institution to add to the present number of awards.

The Staff.—In the 1950 and again in the 25th Annual Reports, the Council stressed the need to commence at an early date a pension scheme to cover permanent members of the staff. These arrangements have now been completed and the first of the contributions is shown in the attached accounts.

General.—The year's working has not, for the reasons stated, maintained the improvement of two years ago. One item of expenditure which exceeded the earlier budget was the Festival of Britain Convention. The Honorary Treasurer draws special attention to this expenditure so that members will be aware of the high costs associated with providing an adequate forum for demonstrating the achievements of the radio and electronic engineer. The Committee agree with the views already expressed in this report that such Conventions are an essential function of the Institution in bringing together members distributed, not only throughout Great Britain, but particularly throughout the Commonwealth. Nevertheless, the cost of such activities should not be borne out of current income, but should be properly provided for by building up reserves.

The benefits of increased membership have been offset by rising costs of materials and services. The continued growth of the Institution should, however, result in more satisfactory Balance Sheets in future years, especially bearing in mind the large expenditure during the past year on non-recurring items and some indication of falling prices, particularly in paper and printing.

CONCLUSION

The Council again desires to express sincere appreciation to all those who have rendered honorary service to the Institution during the past year. Thanks are also expressed for the loyal and skilled service rendered by permanent officers and staff of the Institution.

Particular thanks are accorded to those who have investigated applications of candidates for election to membership, acted as examiners, reviewed theses, adjudicated papers for prizes, reported on papers for publication in the *Journal*, reviewed books received in the Library, and served on committees of the Council.

Much of this work is voluntary and the ordinary members of Council wish to record their appreciation of the example set by the retiring President. Long association with standing committees of the Institution has enabled Mr. Adorian to bring understanding and guidance to the Council in all its problems. He has devoted much time to Institution affairs and during his two years of office has visited all the sections in Great Britain. His retirement from office, after the maximum period he may serve as President, is marked by the sincere thanks and appreciation of his colleagues on the General Council.

Just prior to the end of the Institution's year, Great Britain and the Commonwealth, and indeed the whole world, was shocked by the news of the death of His late Majesty King George VI. Deserved and loyal tribute has been widely expressed, and the Institution had particular reason to be grateful for the encouragement of its work by His late Majesty, who became the first Patron of the Institution.

There is widespread hope that the new reign will mark an era of peace and the greater enjoyment by man of nature's endowment, thus bringing to fruition those high hopes so often expressed by His late Majesty. The Institution is further encouraged to play its part in the achievement of those ideals by now having the honour of the Patronage of Her Majesty Queen Elizabeth II.

The British Institution of Radio Engineers

BENEVOLENT FUND

NOTICE IS HEREBY GIVEN that in accordance with the Rules, the Annual General Meeting of subscribers to the Institution's Benevolent Fund will be held on WEDNESDAY, OCTOBER 8th, 1952, at 7 p.m., at the London School of Hygiene and Tropical Medicine, Keppel Street (Gower Street), London, W.C.1.

AGENDA

(1) To receive the Income and Expenditure Account and the Balance Sheet of the Benevolent Fund of the British Institution of Radio Engineers for the year ended March 31st, 1952.

(2) To receive the Annual Report of the Trustees.

(3) To elect the Trustees for the year 1952/53. The Trustees nominated for election are:—

> The President of the Institution
>
> The Chairman of the General Council
>
> Mr. A. H. Whiteley, M.B.E. (Companion)
>
> Mr. E. J. Emery (Member)
>
> Mr. S. R. Chapman, M.Sc. (Member), (Honorary Treasurer)
>
> Mr. G. D. Clifford (Honorary Secretary)

(4) To elect Honorary Solicitors and Honorary Accountants to the Benevolent Fund. The Trustees recommend the appointment of Messrs. Braund & Hill, 6 Gray's Inn Square, London, W.C.1, as Honorary Solicitors

and

> Mr. R. H. Jenkins, F.C.A., 42 Bedford Avenue, London, W.C.1, as Honorary Accountant.

(5) Any other business.

Annual Report of the Trustees for the Period 1st April, 1951, to 31st March, 1952

The Accounts for the year ended March 31st, 1952, are given on p. 476 and show a further increase in donations. The Trustees express thanks to all members who supported the Fund, and to the two industrial subscribers, Electric and Musical Industries, Ltd., and Whiteley Electrical Radio Co., Ltd., for their further generous contributions.

Members of the Institution and the profession are well represented in the Radio Industries Club. It is, therefore, with a special sense of this membership that the Trustees again record appreciation for the kind thought of the Radio Industries Club of Manchester in making their second generous donation to the Benevolent Fund.

The number of subscribers totalled 784, compared with 568 for the previous year. Omitting the special donations, the average amount per subscriber member was 11s. 5d.—slightly less than for the preceding five years.

From the figures in this and previous reports, it will be seen that only one out of every seven members of the Institution subscribes to the Fund. Bearing in mind that the objects of the Fund* are solely to be of assistance to members and their dependants, the number of subscribers cannot be viewed with satisfaction.

More members have taken advantage of signing a Deed of Covenant with the Institution for seven years, by which the Institution recovers from the Inland Revenue the amount of income tax appropriate to their donation. The Trustees deem it desirable that the income of the Fund be assured by regular covenanted subscriptions, instead of having to rely so much upon appeals and voluntary efforts. It is hoped, therefore, that many more members, especially those making regular annual donations by standing bank order, will complete Deeds of

* Page 11 of the Year Book.

BENEVOLENT FUND

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1952

1951 £		£ s. d.	1951 £		£ s. d.
96	To Grants	188 2 6	574	By Subscriptions and Donations	640 18 9
—	,, Postage and Stationery	20 9 9	70	,, Interest Received (Gross)	102 2 7
	,, Balance being Surplus for year carried to Reserve		—	,, Profit on Redemption of Defence Bonds	1 0 0
548	Account	535 9 1			
£644		£744 1 4	£644		£744 1 4

BALANCE SHEET AS AT 31st MARCH, 1952

£	*Reserve Account:—*	£ s. d.	£ s. d.		*FIXED ASSETS*			
	Balance as at 1st April, 1951 ..	3,464 19 11		£	*Investments at Cost:—*	£ s. d.	£ s. d.	
	Add Surplus for Year	535 9 1			£1,600 2½ per cent. Defence Bonds ..	1,600 0 0		
3,465			4,000 9 0		£900 3 per cent. Defence Bonds ..	900 0 0		
	Current Liabilities:—				£200 3 per cent. Savings Bonds ..	193 17 3		
—	Sundry Creditor		600 0 0		£100 3½ per cent. War Loan ..	104 0 0		
					£684 0s. 6d. 4 per cent. Consolidated			
					Stock	600 0 0		
					£500 5½ per cent. Cumulative Prefer-			
					ence Stock: Jays and Campbells			
				3,152	(Holdings), Ltd.	354 2 0		
							3,751 19 3	
					Current Assets:—			
				168	Due from General and Other Funds	293 11 0		
					Income Tax Repayment Claim on			
				—	Interest	13 1 4		
					Income Tax Repayment Claim on			
				—	Deeds of Covenant	13 7 1		
				145	Cash at Bank	528 10 4		
							848 9 9	
£3,465			£4,600 9 0	£3,465			£4,600 9 0	

Signed {
P. ADORIAN
A. H. WHITELEY } *Trustees.*
J. L. THOMPSON
G. D. CLIFFORD (*Hon. Secretary*).

I have audited the above written Balance Sheet dated 31st March, 1952, in respect of the BENEVOLENT FUND.

I have received all the information and explanations I have required, and in my opinion the Balance Sheet represents the true and accurate state of the BENEVOLENT FUND.

5th August, 1952.   R. H. JENKINS, F.C.A.,
42 Bedford Avenue, W.C.1.   *Honorary Auditor.*

Covenant. For the benefit of new members, and those who may be under the impression that such Covenants must be for large amounts, the Trustees desire to point out that many contributors complete a Deed of Covenant for the few shillings which they donate to the Fund when remitting their annual subscription. The agreement ceases in the event of death and does not involve the executors in any liability.

A further pleasing feature of the Accounts is the increase in the interest received from investments. Although not yet sufficient to meet all the calls for assistance, this additional revenue enables the Trustees to give the maximum assistance, whilst at the same time building up the assets of the Fund.

Subscribers will note that for the first time there is an expenditure item for stationery and postage. Hitherto such costs have been met from the General Fund of the Institution, but the Trustees feel that the Benevolent Fund is now large enough to bear such expenses, without impairing the assistance which must be given to all deserving cases.

The need for limiting expenditure on printing and stationery has, however, prevented publication of a list of subscribers to the Fund, but this will be included in the next issue of the Year Book.

Grants.—It was stated in the last Annual Report that one particular case would be the concern of the Trustees for some time. Subscribers will recall that the case concerns a widow with three young children, and during the year the Fund has continued to give every possible help. The Trustees are still responsible for the maintenance and education of the eldest child in Reed's School and during 1953 it is hoped that the second child will be accepted into the school.

Further help was also extended to an Associate Member whose disabilities consequent upon the effects of being a prisoner of war had caused serious illness. With the help of the Benevolent Fund the member has now been able to clear off all his liabilities and has commenced light employment.

A fresh case during the year concerned that of a member who became partially blind and unable to work. Although he is registered with the National Institute for the Blind, and has been given help from that source, his income was insufficient and an immediate grant was made from the Benevolent Fund.

Another case reviewed by the Trustees was in connection with a Member who died in 1949. His wife was for a time seriously ill and his two children were placed in Reed's School by the Institution. It is particularly pleasing for the Trustees to report on the progress being made by the eldest child, a boy, whose school reports indicate that he is likely to secure a scholarship. The progress of both children has obviously relieved the mother, who is able to undertake employment whilst they are at boarding school.

In recent years the State has accepted some responsibility for the welfare of the needy, sick and aged. A large number of cases still remain, however, for which State assistance is either not forthcoming or is wholly inadequate. For these cases, voluntary help is urgently required and the typical examples which have always been given in these reports confirm how necessary is the Institution's Fund.

So far the Trustees have not had to extend the objects of the Fund to members of the Institution outside Great Britain. This point is being considered, however, especially in the case of members residing in the Commonwealth. The support of the Fund by members overseas is most generous and it is felt that where applicable the Fund should render assistance to all members irrespective of their nationality.

Reed's School.—From the cases mentioned in this and past reports, it will be obvious that the Trustees are especially grateful to the Governors of Reed's School, whose work deserves the greatest possible support. Like so many bodies, the school is experiencing considerable difficulty in raising sufficient funds to meet increased expenditure. It is estimated now that the cost of maintaining each child in the school is at least £210 per year. In order to reduce this cost, the Governors have had to decide that the children's clothing, hitherto supplied by the school, must in future be the responsibility of the parent or guardian. Whilst a scheme for payment has been arranged in order to impose the minimum burden, it is to be expected that in some cases hardship will be experienced. In the case of at least two children placed in the school by the Institution, therefore, this extra cost will be met from the Benevolent Fund. The Trustees feel that all members will support this good work by endeavouring to give as generously as possible to the Fund.

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NOMINATED FOR ELECTION TO COUNCIL

Harold Joseph Leak was born in Hanwell, Middlesex, in 1907 and received his general education at Southall. During the early days of sound films, between 1929 and 1934, he was with British Talking Pictures and The Gaumont British Picture Corporation as an installation engineer of motion picture equipment.

In 1934 Mr. Leak founded his own company for the manufacture of audio-frequency amplifiers and other specialized electronic equipment. He has continued as chief engineer and managing director of the firm, which was made a private limited company in 1941. Whilst connected with Mr. Leak's professional occupation, music reproduction has been his particular interest for many years. He is widely known as a lecturer and demonstrator on this subject and is especially prominent in the field of sound reproduction and public address engineering.

Mr. Leak was elected an Associate Member of the Institution in 1944 and was transferred to full Membership in 1947. He has served on the Technical Committee since January, 1950, and last year he was chairman of the Audio-Frequency Engineering session of the Institution's Festival of Britain Convention.

Major Samuel Reginald Rickman was born at Linton, near Burton-on-Trent, in 1907, and was educated at Sherborne School and Birmingham University. Prior to the war, he was employed in the electrical engineering department of a large Midlands firm.

In 1939, he joined the Royal Corps of Signals and for three years was instructor at the School of Signals. Between 1943 and 1944, he held the appointment of Deputy Assistant Director of Research and Development, Ministry of Supply. In 1944,

Major Rickman became Chief Instructor of the 1st Trades Training Battalion, R. Signals. In 1946 he returned to the School of Signals and was appointed Chief Instructor, Royal Signals Wing, where he was responsible for the higher technical training of officers and senior N.C.O.'s in radio and line communications. He is now Technical Staff Officer to the Headquarters, School of Signals.

Major Rickman was elected an Associate Member of the Institution in 1949 and has presented papers on various aspects of modern communications techniques before the North Eastern Section.

Commander (L) Henry William Young was born in Ireland in 1909 and received his general and technical education in Belfast. In 1935 he was appointed responsible officer for the South Wales Section of the R.N.V.(W.)R. After mobilization as a Section Officer R.N.V.(W.)R. he was first employed in various instructional duties. Later Cmdr. Young was engaged in a Combined Operations Radio Maintenance organization for the maintenance of Radio equipment in Landing Craft, etc., and subsequently as Lieutenant-Commander in Charge of the Combined Operations Signal Maintenance Depot at Ashford. In this latter appointment he was in charge of a mobile quartz crystal production unit.

Cmdr. Young was transferred to the Electrical Branch of the Royal Navy in 1946, and was promoted to Commander (L) in 1947.

Since his transfer to the Royal Navy, Cmdr. Young has been in charge of the training of Radio Maintenance ratings in H.M.S. *Collingwood* and for two years was Electrical Officer, H.M.S. *Illustrious*. He has recently returned from a two-year appointment on the Staff of the British Joint Services Mission in Washington, and is now at the Admiralty Signal and Radar Establishment. Cmdr. Young was elected an Associate Member in 1938 and he has now been nominated to serve on the General Council.

NOTICES

OBITUARIES

Mr. G. M. Jenkins

The Council has learned with great regret of the death of George Mark Jenkins (Member), on September 8th, at the age of 66 years.

Mr. Jenkins, who was elected a Member in 1944, had been associated with the telecommunications industry since its earliest days, and for many years he was with various European subsidiaries of the International Telephone and Telegraph Co.

During the first World War he produced the first practical inter-communication telephone for use in aircraft. Afterwards, he was concerned with the application of electronic techniques to the telephone networks of many European countries. In 1931 he was appointed Chief Engineer of Standard Radio Relay Services, Ltd.

In 1934, Mr. Jenkins relinquished his appointment to become a consulting engineer, occupying himself mainly with electro-medical research. He held over 30 patents in the fields of electro-medical technique, telephony and wire-broadcasting.

Mr. R. F. Sweeney

It is with great regret that the Council has learned of the death of Robert Francis Sweeney, who was elected an Associate of the Institution in 1933. He was 50 years of age, and was managing director of the Birmingham radio business bearing his name which he founded in 1927.

Mr. Sweeney was drowned, together with his wife and two daughters, when his cabin cruiser was wrecked off the Welsh coast; his two sons managed to swim ashore safely.

Mr. E. R. Garnett Passe

The death recently occurred of Mr. E. R. Garnett Passe, F.R.C.S., the well-known surgeon and otologist. He specialized in research into the alleviation of nerve deafness and he was a pioneer in the surgical operation known as fenestration—the cutting of a window in the inner ear to relieve this form of deafness.

Members of the Institution will particularly remember Mr. Passe for the absorbing paper on the Clinical Aspects of Deafness with which he opened the Hearing Aids Symposium before the London Section in 1951 and which was published in the *Journal* for February of that year.

New Section of the U.D.C.

The Universal Decimal Classification System occupies a considerable part of the Technical Committee's report on Technical Information, which, after approval by the General Council, will be published in the *Journal*. Consequently, the recent provisional extension to the U.D.C. which has been issued by the Electrical Engineering Commission of the International Federation for Documentation will be of interest to members.

During recent years it has been realized that the classification of information dealing with electric waves, oscillations and pulses has become somewhat unsatisfactory due to the considerable advances which have taken place in the techniques associated with these subjects. Their classification within the section dealing with telecommunications (621.39) has been found undesirable when, for example, the particular application may have concerned electronics.

The proposal is for the formation of a new section (621.37) which will embrace these important aspects. Also included will be many items concerning circuits for generating and utilizing waves, oscillations and pulses, as, for instance, relaxation oscillators, counting circuits and modulators.

At the moment the scheme, except for one or two minor additions, has secured the agreement of the National Committees of Great Britain, Germany, Denmark, Japan, and the Netherlands. Before its final acceptance, which will involve substantial deletions within the telecommunication group (621.39), comments are invited from interested bodies and persons. Members of the Institution who wish to have an opportunity of making comments may consult a copy of the proposals in the Institution Library.

Ministry of Education Bulletin

Salaries Bulletin No. 9 issued by the Ministry of Education states that the following qualifications entitle a teacher in a primary or secondary school to be classed as a graduate for salary purposes:— Associate Membership by examination of the Institution of Production Engineers and Associate Membership by examination of the British Institution of Radio Engineers.

Mention of this recognition of the graduateship examination was made in the June issue of the *Journal* (page 324).

THE NATIONAL RADIO AND TELEVISION EXHIBITION 1952

This year's Radio Show (the nineteenth) which was opened on August 27th at Earls Court by Lord Burghley, President of the Radio Industry Council, showed an appreciably broader field of interest for the radio engineer than in previous years. Hitherto any exhibits distinct from radio and television sets and associated equipment have been few in number, but the trend, apparent last year, of including exhibits of a general electronics character, was very noticeable. A number of these items were concerned with the rearmament programme, and in his opening address Lord Burghley referred to the fact that the entertainment side, which formed the greater part of the Show, was only a subsidiary part of the radio industry.

The industry's continued efforts to increase exports could be seen throughout the exhibition, a considerable number of special export models being on show, while the component manufacturers' part in this expansion was everywhere apparent. The R.I.C. reported an increased number of overseas visitors—evidence of the Show's new aspect as a "shop window" for buyers outside this country.

Radio in the Services.—The stands of the three Fighting Services were well to the fore in illustrating the ever-increasing applications of electronics. The Royal Navy showed an anti-aircraft gun and its director together with the associated electronic equipment; there were also working models of simple electronic computors of the servo-mechanism type for multiplication of numbers and the calculation of the trajectory of a projectile. In the latter, a ball bearing was dropped on to a plate and, irrespective of the height through which the ball fell, it always bounced into a container whose position was determined by a servo-mechanism.

The Regular Army exhibit also demonstrated the working of anti-aircraft guns, in this case controlled by radar through a predictor, and an instructional exhibit to demonstrate the working of P.P.I. radar by means of ultrasonic waves in water. Communication equipment of a considerable variety of types and covering the whole range from the medium waves to microwaves were also shown, and here a portable centimetric telephone link for working over optical paths of up to 20 miles was of particular interest.

Radar equipment was also to be seen on the Royal Air Force stand, on which a most noticeable exhibit was a radio-controlled model aircraft in which undercarriage and bomb-doors were opened by radio. The training of aircraft apprentices formed an important feature of the stand, which included, amongst the "static" exhibits, examples of modern techniques in miniaturization and "packaged" circuits.

Advances in Electronics.—The hardening of steel by radio frequency heating was an interesting exhibit in which a billet was placed in the centre of a coil and brought to red heat by eddy currents. At the end of the heating cycle water automatically quenched both billet and coil. The great advantage of R.F. heating is to enable heat to be applied to small, selective areas.

A demonstration of underwater television attracted considerable attention*; models submerged in a tank were observed by an underwater camera and the scene presented on nearby screens.

Other instances of the applications of television apart from entertainment were demonstrated: these were a "TV telephone" and an aid to microscopy. In the former, two television camera/receiver chains were added to normal telephone equipment; such a system, although very costly, may have a number of applications in the commercial world. There are obviously considerable educational possibilities in enabling numbers of students to view microscope images simultaneously and several firms have developed similar apparatus.†

On view at this exhibition for the first time was the image converter tube which has many applications in the field of optics—it can be used for image magnification, or intensification, for conversion of infra-red to visible light, as well as in a high speed camera where it acts as an electronic shutter.‡

New Television and Radio Receivers.—Prices of domestic radio and television equipment which were rather lower than last year, were considered to be at their minimum having regard to industrial conditions in the foreseeable future. Most sets

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* See also, for instance, "Underwater Television," *J. Brit. I.R.E.* 12, No. 4, April, 1952, p. 266.

† See, for instance, "Physical Society's Exhibition," *J. Brit. I.R.E.* 12, No. 5, May, 1952, p. 277.

‡ J. A. Jenkins and R. A. Chippendale, "The Applications of Image Converters to High Speed Photography." *J. Brit. I.R.E.*, 11, No. 11, November, 1952, pp. 505-517.

incorporated devices for improving reception in fringe and other difficult areas and there were simplifications apparent both in users' controls and in the channel-changing adjustments for the service engineer. A number of new television models were smaller in physical size while incorporating larger screens—in nearly all cases at least 12 in. in diameter (the largest directly-viewed screen was 21 in. in diameter). As far as picture quality was concerned there seemed to be little difference between sets of different makes, although the increased number of projection receivers did show an appreciable improvement as compared with last year; this was due mainly to improvements both in tube screen material and in E.H.T. circuits. Wall projection types were to be seen on several manufacturers' stands.

Radio receiver developments, which were, in general, less striking, were mainly aimed at greater portability, and included portable radiogramophones; many radiogramophones incorporated three-speed turntables. The makers of many sets stressed improvements in the audio-frequency circuits, notably in larger loudspeakers. Although not strictly speaking concerned with the ordinary radio or television receiver, a demonstration of two-channel stereophonic reproduction attracted attention and will recall to members the paper presented at the A.F. Engineering Session of the Convention held during last year's Show.§

Several manufacturers' stands featured what might be termed factory exhibits—in which products were seen actually in process of manufacture. These included construction of television camera units, and one of the stages in the fabrication of filaments for hearing-aid valves. The automatic testing of capacitors for insulation resistance, voltage proof value, and capacitance, and the subsequent grading into tolerance grades was also demonstrated.

The B.B.C.—The contribution made by the B.B.C. has always been an important feature of the Show, particularly for the layman, and this year was no exception. A large and well-equipped studio for television and sound performances was able to accommodate audiences of nearly 1,000, and 53 rehearsals and 11 finished performances were held during the 10 days of the Show. The Corporation's exhibit also included outside broadcast equipment, and sound effects apparatus.

§ J. Moir and J. A. Leslie, "The Stereophonic Reproduction of Speech and Music. *J. Brit. I.R.E.*, 12, No. 6, June, 1952, pp. 360-366.

Technical Training.—A completely new departure, and one in which the Institution has particular interest, was the Technical Training exhibit. Reference was made to this in the August issue of the *Journal* (pp. 417-8), and it was welcome evidence of the way in which the Radio Industry Council is facing the pressing problem of shortage of technical personnel, by encouragement of suitable technical courses.

Experimental equipment used in laboratories was shown by the radio and electronics departments of Northampton Polytechnic, Norwood Technical Institute, Imperial College of Science and Technology, E.M.I. Institutes, the Marconi College and the College of Aeronautics, and representatives of these colleges were present to give information and advice on opportunities in the industry. One of the exhibits was a diagram showing technical training courses covering various examinations, including the requirements of the Grad. Brit. I.R.E. examination.

Award for Technical Writing.—The first award of a Radio Industry Council premium for technical writing was made during the course of the Show to Mr. J. R. Acton, B.Sc. (Graduate), of the Ericsson Research Laboratories, Nottingham. The

award was for an article on "The Single-Pulse Dekatron" which was published in *Electronic Engineering* in February of this year.

Mr. Acton, who lives at Bunny, Nottinghamshire, is 31 years of age, and was educated at St. Edmund's School, Canterbury. He took external honours in science at London University and was elected a Graduate of the Institution in 1944. During the early years of the war he was on the technical staff of A. C. Cossor, Ltd., later transferring to the research department. In 1948 he joined the research department of Ericsson Telephones, Ltd., who were just starting comprehensive research into cold cathode tubes and he now has charge of research in this particular field. Mr. Acton is also conducting an independent research (sponsored by Ericssons) in the Physics Department at Nottingham University on collision cross-sections of metastable atoms.

1951									£	s.	d.	£	s.	d.
£	*RESERVES*													
500	Library Reserve Account	..	..	..	..	..	..	..				500	0	0

CURRENT LIABILITIES

1,830	Sundry Creditors	..	..	..	..	..	..	..	..	.. 6,277	2	1			
1,098	Subscriptions and Examination Fees in Advance				..	..	..	.. 1,944	9	7			
5,229	Bank Overdraft	..	..	..	..	..	..	..	.. 6,186	3	5			
											14,407	15	1

> NOTE: With regard to money held in India on behalf of the
> Institution, the Rupee is taken at the Exchange Rate
> of 1s. 6d.

Signed

P. ADORIAN (*President*).

J. L. THOMPSON (*Chairman, Finance Committee*).

S. R. CHAPMAN (*Honorary Treasurer*).

G. D. CLIFFORD (*General Secretary*).

£8,657   £14,907 15 1

We have obtained all the information and explanations which to the best of our knowledge and belief were neces
appears from our examination of those books.

We have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreer
to us, the said accounts give the information required by the Companies Act, 1948, in the manner so required.
Expenditure Account gives a true and fair view of the Excess of Expenditure over Income for the year ended on that
15*th August*, 1952.
    42 Bedford Avenue, London, W.C.1.

1951		£	s.	d.	£	s.	d.	£	s.	d.
£	*FIXED ASSETS*									
	Office Furniture and Fittings at Cost				3,318	10	4			
	Less Depreciation to date				1,365	10	4			
1,996								1,953	0	0
	The *Louis Sterling* Library at Cost				874	19	1			
	Less Depreciation to date				374	19	1			
500								500	0	0
	Investments at Cost :—									
	President's Prize Fund									
	£200 3% Savings Bonds (Market Value £168)				200	0	0			
	£50 3% Defence Bonds				50	0	0			
					250	0	0			
	Dr. Norman Partridge Memorial Fund									
	£200 3% Defence Bonds				200	0	0			
	S. R. Walker Prize Fund									
	£100 2½% Defence Bonds				100	0	0			
	Leslie McMichael Premium Fund									
	£300 3% Defence Bonds				300	0	0			
950								850	0	0
3,446								3,303	0	0

CURRENT ASSETS

1951		£	s.	d.	£	s.	d.
2,317	Stock of Stationery, Journals and Examination Papers at Cost ..	2,413	12	11			
1,518	Sundry Debtors and Payments in Advance including Subscriptions in arrear	2,216	17	7			
54	Balance at Bank, No. 3 Account (Building Fund)	2,890	12	2			
7	Balance at Bank, *Norman Partridge Memorial Fund*	7	6	5			
300	Balance at Bank, *Leslie McMichael Premium Fund*	—	—	—			
29	Sections—Balances at Banks and in Hand	105	2	7			
11	Cash in Hand	6	5	5			
					7,639	17	1

RESERVE ACCOUNT

1951		£	s.	d.	£	s.	d.	£	s.	d.
	Balances as at 1st April, 1951:—									
	General Fund				1,912	8	6			
	Less President's Prize Fund	.. 256	9	11						
	Dr. Norman Partridge Memorial Fund	.. 220	16	5						
	S. R. Walker Prize Fund	.. 102	8	1						
	Leslie McMichael Premium Fund	.. 300	0	0						
					879	14	5			
					1,032	14	1			
1,033	*Add* Excess of Expenditure over Income for the Year				2,932	3	11			
								3,964	18	0
£8,657								£14,907	15	1

e purposes of our audit. In our opinion proper books of account have been kept by the Institution so far as

he books of account. In our opinion and to the best of our information and according to the explanations given
e Sheet gives a true and fair view of the state of the Institution's affairs as at 31st March, 1952, and the Income and

GLADSTONE, JENKINS & CO.,
Auditors.

GRADUATESHIP EXAMINATION MAY 1952

SECOND PASS LIST (*Overseas Candidates*)

This list contains the results of the remaining oversea candidates not included in the first Pass List published on p.419 of the August *Journal*. A total of 516 candidates entered for the examination.

Eligible for Transfer or Election to Graduateship or Higher Grade of Membership

(These candidates have now satisfied the Examiners in all subjects of the examination)

ACHARYA, Ganesh Narayan. *Poona, India.*

BALAGANGADHARA RAO T. K. (S) *North Arcott, India*
BELLARE, Chandrakant Vasudeo. (S) *Bombay.*
BHATNAGAR, Brijnandan Saroop. (S) *Lucknow.*

CHIMNI, Ranjit Singh. (S) *Dehra Dun, India.*
CHOPRA, Prem Nath. (S) *Simla, India.*

DEODHAR, Ganesh Shakar. (S) *Bombay.*

GODBOLE, Diwakar Mahadeo. (S) *Poona, India.*
GOVINDARAGHAVAN, Doraiswamy. (S) *Calicut, India.*
GUNDU RAO, G. S. (S) *Bombay.*

JAISWAL, Hari Prasad. (S) *Dehra Dun, India.*

KOTCHAH, Ramnath Anantakrishna. (S) *Bombay.*

LEAN, James Leslie. (S) *Townsville, Australia.*

MASILLAMANI, Joseph Jeyapalan. (S) *Bombay.*
MHATRA, Paramanand Balaram. (S) *Bombay.*

NAGESWARAN, S. (S) *Bombay*
NARAYAN, Shankar. *Kanpur, India.*

PATANKAR, Arvind Vishnu. (S) *Bombay.*

RAGHANAN NAIR, Chalayikara. (S) *New Delhi*
RAICHAND, Suraj Kumar. (S) *Bombay.*
ROZENSTEIN, Solomon. (S) *Haifa, Israel.*

SOBTI, Baij Nath. (S) *New Delhi.*
SOMANATHAN, C. S. (S) *Bombay.*
SURI, S. K. (S) *New Delhi.*

The following candidates were successful only in the Part or Parts indicated

AHMED, Nazir. (S) *Rawalpindi, Pakistan.* (IIIa)
AHMED, Syed Maqbool. (S) *Lahore, Pakistan.* (I, II, IIIa)
AHUJA, Gajindar Singh. (S) *Dehra Dun, India.* (IIIa)
ANANTHARAMIAH, A. V. (S) *Bangalore.* (IIIb)

BALARAMAN, Venkataraman. (S) *Chakulia, India.* (II)
BHASIN, Chaman Lal. (S) *Delhi.* (IIIa)
BHATIA, Tilak Raj. (S) *New Delhi.* (I)
BHATT, Rajanikant Jatashanker. (S) *Madras.* (IIIa)
BHOLA, Ram Avtar. (S) *Poona, India.* (I, II, IIIa)
BHONSLE, Rajarum Vishnu. (S) *Poona, India.* (IV)
BRADING, Donald Hugh. (S) *Sydney.* (II)

CAMERON, Archibald. (S) *Palmerston, New Zealand.* (IIIa)
CASEY, Alvin Melbourne. (S) *Peterboro, Ontario.* (I)
CHANDRA, Jagdish. (S) *Saharanpur, India.* (II)
CHATTERJI, Amritendra Nath. (S) *Cuttack, India.* (IIIa)
CHIMNI, Inderjit Singh. (S) *Poona, India.* (IIIa)

DHAR, Makhan Lal. (S) *Agra, India.* (IIIa)
DUGGAL, Jagmohan Sarup. (S) *Bombay.* (IIIa)

FISHER, Jack Edward. (S) *Bangalore.* (I, II, IIIa).
FISHMAN, David H. (S) *Haifa, Israel.* (I, II, IIIa, IV)

GHUMAN, Surjit Singh. (S) *Dehra Dun, India.* (IIIa)
GILL, Santakk Singh. (S) *Poona, India.* (II, IIIa)
GITTINS, Leonard. (S) *Lahore, Pakistan.* (I)
GOEL, Surajmal. (S) *New Delhi.* (IIIb)
GUPTA, Roshan Lal. (S) *Delhi.* (II)

HORNE, Jerome. (S) *East London, South Africa.* (II)

JAHANGIR, Mohd Afza. (S) *Peshawar, Pakistan.* (I)
JAWA, Balraj. (S) *New Delhi.* (IV)

KALYANA, Sundarah Ragangam. (S) *New Delhi.* (IV)
KANOJIAH, Babubhai Ramprasad. (S) *Kothi, India.* (IIIa)
KHAMBATY, Moiz Badrudin. (S) *Bombay.* (II, IIIa)
KIRK, Joseph. (S) *Dodoma, Tanganyika.* (II)
KOTWAL, Wasudeo Deokrishna. (S) *Bombay* (I, II)
KUNDU, Mukul Ranjan. (S) *Calcutta.* (IIIb)

LAL, Brij Behari. (S) *New Delhi.* (IIIa)
LAXMIKANTHAN, Namakkar Rajarao. (S) *New Delhi.* (II)

MADON, Karkhushru Rustomji. (S) *Bombay.* (I, II, IIIa)
MALHOTRA, Bahri Jag Mohanlal. (S) *Amritsar.* (IIIa)
MATHURE, Sudhaker Balkrishna. (S) *Bombay.* (IIIb)
MELHOTRA, Asharaya Lal. (S) *Agra, India.* (I, II, IIIa)
MONGA, Bansi Dhar. (S) *Madari, India.* (IIIa)
MUKHTAR SINGH. (S) *Jullundur, India.* (II, IIIa)

NAYAK, Nagar Atmarama. *Bombay.* (IV)
NIWAZ, Haq (S) *Rawalpindi, Pakistan.* (II, IIIa)

PONKSHE, Madhav Ramchandra. (S) *Bombay.* (IIIb)
PRABHAKARA RAO, Gadiyar. (S) *Poona, India.* (IIIb)

RAI, Ram Mohan. (S) *Bhopal, India.* (IIIb)
RAMABHADRAN, Srinivasa. (S) *Poona, India.* (IIIb)
RAMANATHAN, P. V. N. (S) *Calcutta.* (IV)
RAMARAO, Penukonda Narasingarao. (S) *Bombay.* (II, IIIb)
RAMASWAMY, Subbarao. (S) *Bombay.* (IV)
RAMPAL, Mulkh Raj Sharma. (S) *Amritsar.* (IIIb)
RAMULOO, Dhulipudi. (S) *Secunderabad, India.* (IIIa)
RAO, Kateel Sanjeeva. (S) *Bombay.* (I, II, IIIa)
ROY, Rajit Kuman. (S) *New Delhi.* (IIIa)

SARDESAI, Damodar Balkrishna. (S) *Poona, India.* (IIIa).
SIDHU, Niranjan Singh. (S) *Ferozepur, Punjab.* (I, II)
SINGH, Gurbach Sachdev. (S) *Simla, India.* (IIIa)
SIVASUBRAMANIAN, Kalathur Ponnappachary. (S) *Madras.* (I)
SONI, Jitender Nath. (S) *Dehra Dun, India.* (IIIa)
STUUT, Frederick Derk. (S) *Perth, Western Australia.* (IIIa)
SUBRAMANIAN, Parachuram. (S) *Bombay.* (II)
SWAMINATHAN, Mayaram Sundarsan. (S) *Madras.* (IIIb)
SWAROOP, Jagdish. (S) *Bombay.* (IV)

TAN KAY BOH. (S) *Penang, Malaya.* (II, IIIa)
TEJUJA, Mohanlal M. (S) *Bombay.* (I)

VAIDYANATHAN, G. (S) *Madras.* (II, IIIa)
VARADARAJAN, R. S. (S) *Madras.* (II)
VARGHESE, Samuel. (S) *Kandy, Ceylon.* (I)
VARMA, Roop Kishore. *New Delhi.* (IIIa)
VASWANI, Herkishen Bulchand. (S) *Bombay.* (II, IV)

WADHWA, Balwant Singh. (S) *New Delhi.* (IIIa)
WOOLFSON, Joshua Cyril. (S) *Johannesburg.* (II, IIIa)

(S) denotes a Registered Student.

OBJECTIVE TESTING OF PICK-UPS AND LOUDSPEAKERS*

by

K. R. McLachlan† and R. Yorke, B.Sc., B.Eng.†

A Paper presented at the Sixth Session of the 1951 *Radio Convention on September 6th at Earls Court, London*

SUMMARY

The paper describes some of the analytical and experimental techniques used in an objective assessment of the performance of the transducers in a gramophone reproduction system, namely the pick-up and loudspeaker.

It is shown that analysis by dynamical analogies provides a means whereby a general mathematical solution for their performance may be reached.

Apparatus used to determine the steady state and transient response is described and examples of typical tests are given to show the value of these techniques.

Details are included of methods used to indicate and record, together with other relevant information, the mechanical vibrations set up in these transducers.

1. Introduction

When the characteristics of any system show unexpected deviations from the normal, a scheme involving controlled experiments and hypotheses must form the main equipment in determining the reasons for these deviations. However, this approach only allows deductions concerning the particular to be made, and a mathematical approach is essential in order to extend to the general. The more complex the system being investigated, the more necessary does a rigorous adherence to this procedure become.

In particular, conclusions arrived at after investigating transducer performance experimentally may be extended to include all transducers of a similar form by mathematical analysis. Clearly, for a satisfactory determination of the characteristics of pick-ups and loudspeakers, these methods must be employed. The experimental and analytical work here described has arisen from such an approach.

2. Pick-ups

In an electromechanical transducer of this type, consideration must be given to both the mechanical and electrical aspects of the system and their effect one on the other. In a unit of the type shown in Fig. 1, the relative movement between the needle and the head should be a copy of the groove modulation. However, owing to spurious vibrations set up in other parts of the mechanical system this is not always the case, this undesired effect being greatest when a condition of resonance is reached. The electrical response curves of this unit show deviations which other tests had shown were attributable to one or more of the following types of mechanical vibration.
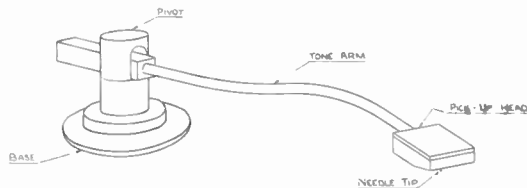
Fig. 1.—Typical pick-up.

Firstly, pivotal resonance, in which the whole mass system resonates with the needle support compliance. Secondly, lateral resonance, in which the tone arm vibrates laterally as a beam, the distributed mass and compliance forming the resonant elements. Thirdly, torsional resonance, in which the pick-up head resonates with the torsional compliance of the tone arm about its own axis. And fourthly, needle resonance, in which the needle mass resonates with the record groove compliance.

2.1. *Analysis*

Although the necessary analysis of this system could be carried out in purely mechanical terms, it is helpful to translate the system into its electrical equivalent using the direct dynamical analogy. In this analogy, mass is supposed equivalent to inductance, compliance to capacitance, velocity to current and force to e.m.f. Applying the analogy to the pick-up of Fig. 1, we arrive at the equivalent circuit which is shown in Fig. 2.
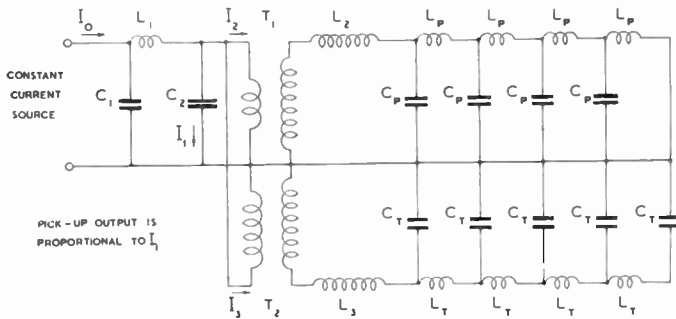

Fig. 2.—Equivalent circuit of a pick-up.

L_1 represents the mass of the needle and C_1 and C_2 the compliance of the record groove and of the needle support respectively. L_2 and L_3 represent respectively the moment of inertia of the head about the pivot and its polar moment of inertia about the tone arm axis. Since the arm possesses distributed mass and compliance, it may be represented by a transmission line consisting of elements L_P and C_P. For the lateral and pivotal vibrations, the elements represent distributed moment of inertia about the pivot and distributed rotational compliance, respectively. The line is short-circuited at the end representing the pivot since at this termination rotational velocity may occur without torque. The torsional constants of the arm may be similarly represented, forming another transmission line consisting of elements L_T and C_T. These are equivalent, respectively, to polar moment of inertia and torsional compliance of the arm. In this case the line is open-circuited since at the pivot no torsional velocity can take place though torque may exist. Each of these lines is fed by a transformer. T_1 has a step-up ratio equal to the ratio of torque at the needle support to that at the head (about the pivot),

and T_2 has a ratio equal to torque at the needle support to that at the head about the tone arm axis. The electrical output of the pick-up is proportional to I_1. Supplying the whole circuit is a constant current generator representing the record groove.

In forming this equivalent circuit, several approximations have been made; for example, the termination of the line composed of elements L_P and C_P has been shown as a short circuit, whereas in fact a small amount of resistance exists. Again, the needle should be represented as a transmission line since it has small distributed mass and compliance. However, the errors introduced are small, and are in magnitude, not in form.

It is clear from the circuit that a number of resonances can take place which will affect the current flowing in C_2, which, as stated, represents the pick-up output.

At some low frequency the reactance effects of C_1, L_1 and C_P are negligible and a parallel resonant circuit is formed by C_2 and L_2 and the line inductances L_P. This corresponds to the pivotal resonance described earlier. At higher frequencies the transmission lines become resonant and their input impedances change in both magnitude and sign over quite a small frequency range. Since the input is a constant current, the difference current through C_2 is an inverse function of the transmission line current and an "N" curve is formed in the electrical characteristic. Several of these "N" curves may appear since there are two lines and each can resonate at a number of frequencies. At some high frequency corresponding to needle resonance the parallel circuit formed of L_1 and C_1 will resonate and a large current will flow in C_2. It must be remembered that as the frequency increases, the reactance of C_2 decreases and that of L_2 and L_3 increases until the resonant lines have no effect on the current in C_2. The force exerted by the needle is proportional to the p.d. appearing at the input terminals.

A mathematical analysis of this circuit is given in Appendix 1 and it is seen that a response curve similar to that observed experimentally is obtained.

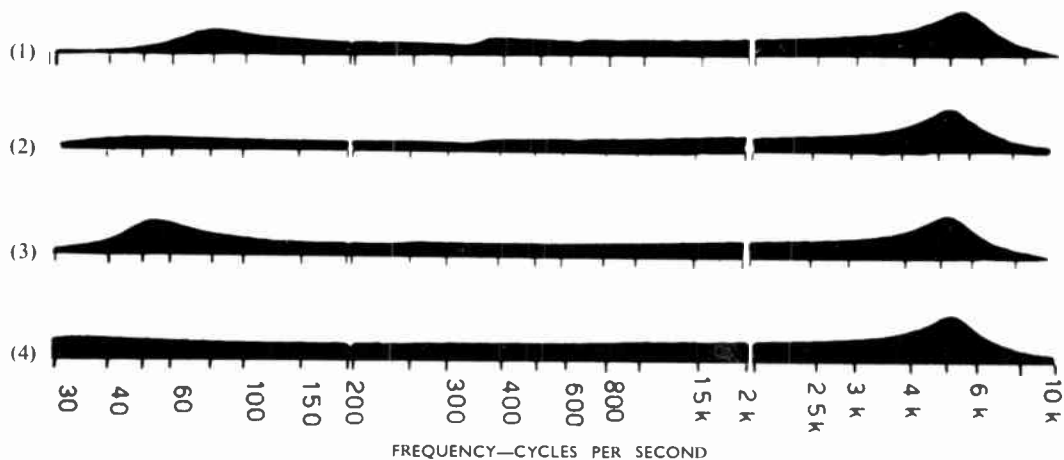There are two main advantages of this type of analysis: firstly the existing electric circuit

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(1)

(2)

(3)

(4)

30 40 60 100 150 200 300 400 600 800 1.5 k 2 k 2.5 k 3 k 4 k 6 k 10 k

FREQUENCY—CYCLES PER SECOND

Fig. 3.—Response curves for pick-up taken by an analogue computor.

theory, which owing to the use of complex notation has reached a more advanced state than the corresponding mechanical theory, may be utilized with little modification; secondly the electric circuit may be set up and used as an analogue computor.

Figure 3 shows some response curves taken on such a computor. In this case only the line representing the lateral vibration conditions was used. The effects of pivotal and needle resonances and of line impedance changes giving rise to "N" curves may clearly be seen. The four curves show the effect of a variation in the values of L_2 and C_2, in the following manner.

			C_2		L_2
Curve 1	..	..	$5 \mu F$	..	210 mH
Curve 2	..	..	$20 \mu F$	..	210 mH
Curve 3	..	..	$5 \mu F$	..	1200 mH
Curve 4	..	..	$20 \mu F$	..	1200 mH

It is clear from these that an increase in the value of C_2 lowers the pivotal resonant frequency and to some extent reduces the effect of arm resonances (but does not alter their frequency), whereas an increase in the value of L_2 again lowers the pivotal resonance, but to a smaller extent, but has considerable effect on both magnitude and frequency of the arm resonances. The needle resonance remains unaffected by these changes.

These curves show that it is possible to predict the performance of a pick-up without actually making it.

2.2. Experimental Work

As already mentioned, the deviations noticed in the electrical response curves of a system of this kind are due mainly to mechanical resonances which, as is well known, may be of exceedingly high "Q." Some of these deviations, therefore, occur over a very small frequency range, and any method of plotting the frequency response characteristic must be capable of dealing with these very abrupt changes. The more usual point by point method is clearly unsatisfactory and a method of continuous plotting must be used.

The method adopted is to supply the pick-up with a signal from a gliding frequency record whose range extends from 10 c/s to 14,000 c/s. The electrical output is amplified and displayed as a vertical line on a cathode ray tube, and this is photographed by means of a rotating drum camera. The axis of rotation of the drum is parallel to the display and provides a film speed of nearly 1 in/min, this speed being chosen to give a well-proportioned diagram. The record driving motor and the camera drum motor are synchronously interlocked thus providing the required fixed relationship between time and frequency at the film.

Figure 4 shows an example of the type of record obtained by the use of this method. The top curve (*a*) shows a frequency response characteristic of the pick-up of Fig. 1. It shows all the effects of resonance mentioned: pivotal, arm, and in this case two small effects due to
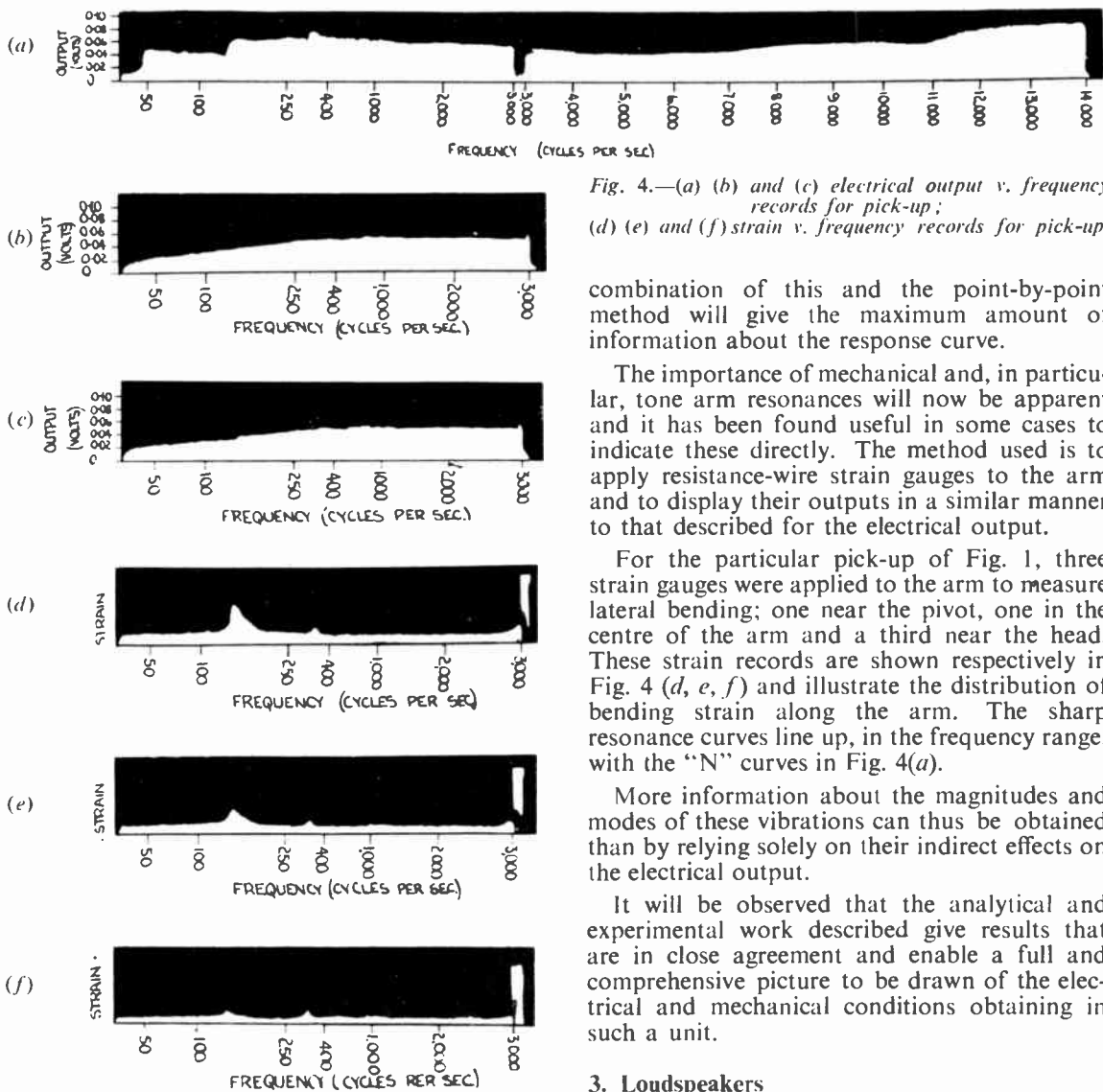
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combination of this and the point-by-point method will give the maximum amount of information about the response curve.

The importance of mechanical and, in particular, tone arm resonances will now be apparent and it has been found useful in some cases to indicate these directly. The method used is to apply resistance-wire strain gauges to the arm and to display their outputs in a similar manner to that described for the electrical output.

For the particular pick-up of Fig. 1, three strain gauges were applied to the arm to measure lateral bending; one near the pivot, one in the centre of the arm and a third near the head. These strain records are shown respectively in Fig. 4 (d, e, f) and illustrate the distribution of bending strain along the arm. The sharp resonance curves line up, in the frequency range, with the "N" curves in Fig. 4(a).

More information about the magnitudes and modes of these vibrations can thus be obtained than by relying solely on their indirect effects on the electrical output.

It will be observed that the analytical and experimental work described give results that are in close agreement and enable a full and comprehensive picture to be drawn of the electrical and mechanical conditions obtaining in such a unit.

3. Loudspeakers

The moving-coil loudspeaker may be subjected to the same type of analysis as was used for the pick-up, with the same dynamical analogy. In this case, however, since there is much closer coupling between the electrical and mechanical circuits, the performance of the unit is much more dependent on the load connected to the electrical terminals than in the case of the pick-up. As a result the electromagnetic transducing element must be included in the equivalent circuit diagram.

sub-harmonic excitation of needle resonance, this being outside the frequency range covered by the record.

Curves (b) and (c) illustrate the effect of a greatly increased needle support compliance, and show the result to be in accordance with the effect of increasing C_2 in the electrical analogue.

Although the accuracy of this method of curve plotting is not of an extremely high order, a

3.1. *Analysis*

Figure 5(*a*) shows the equivalent circuit diagram representing the electrical and mechanical conditions and including the electromechanical transducing element. R and L represent respectively the resistance and inductance of the voice coil; M and C_D the mass of the voice coil and the compliance of its supporting spider. The cone itself having distributed mass and compliance, is represented as the transmission line comprising elements m and C_C, which is terminated by the capacitance C_S representing the compliance of the surround.

The circuit as drawn is rather unwieldy, since it includes a transducing element, the characteristic of which is that a current in the electrical side produces a force, i.e. in our analogy an e.m.f., on the mechanical side. This makes analysis, and a clear appreciation of the action of the circuit, difficult.

It is convenient to eliminate the complications introduced by this transducing element by transferring the whole of the electrical equivalent of the mechanical circuit over to the electrical side. Appendix 2 shows the relationship between elements so transferred and demonstrates that, for example, a series inductance element on the mechanical side appears on the electrical side as a shunt capacitance element, and so on.

Figure 5(*b*) shows the complete electrical equivalent of Fig. 5(*a*) when the transducing element has been removed in this manner. This represents the loudspeaker as a mechanical device (no account is taken at this stage of air loading and for simplicity, resistive losses have been ignored).

The loudspeaker is normally connected to a signal source of low impedance, and when the frequency of this source is varied over a wide range, several resonance effects take place. At low frequencies the reactance effects of l are negligible and the circuit reduces to a simple parallel LC circuit. The resonant frequency of this circuit is usually termed the fundamental resonance. At higher frequencies the transmission line comes into resonance since it is incorrectly terminated, and the standing waves set up mean that the cone may no longer be considered as a rigid piston.
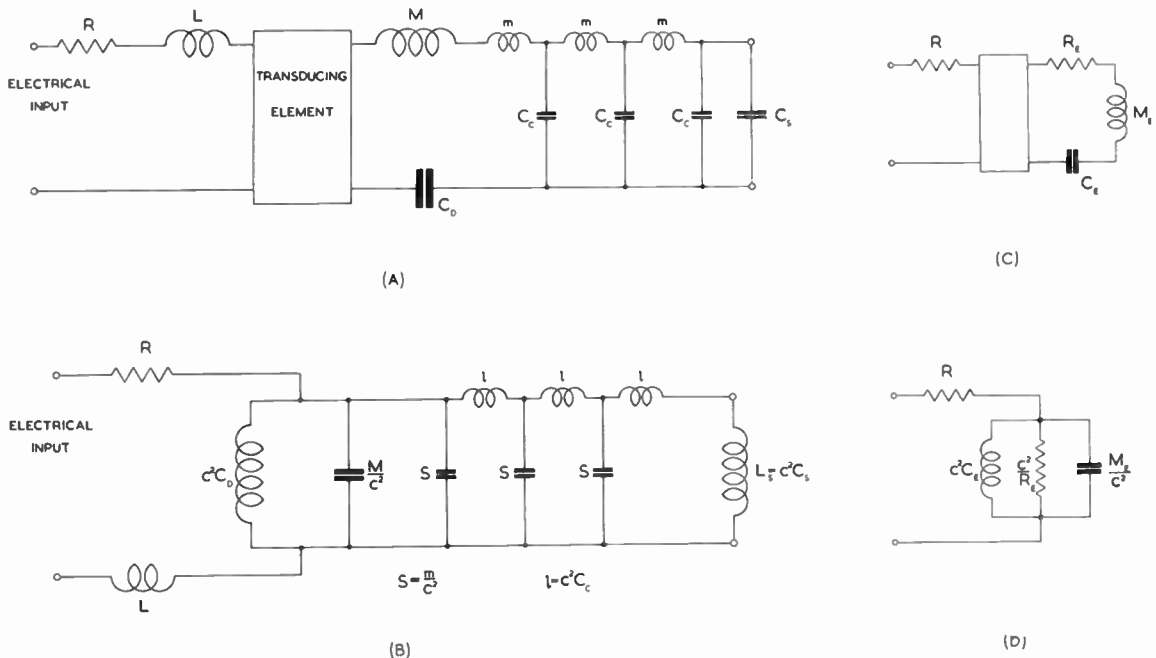
Fig. 5.—(*a*) Equivalent circuit for a loudspeaker; (*b*) As (*a*) but transducing element represented electrically; (*c*) and (*d*) As (*a*) and (*b*) respectively but simplified for low frequencies only.

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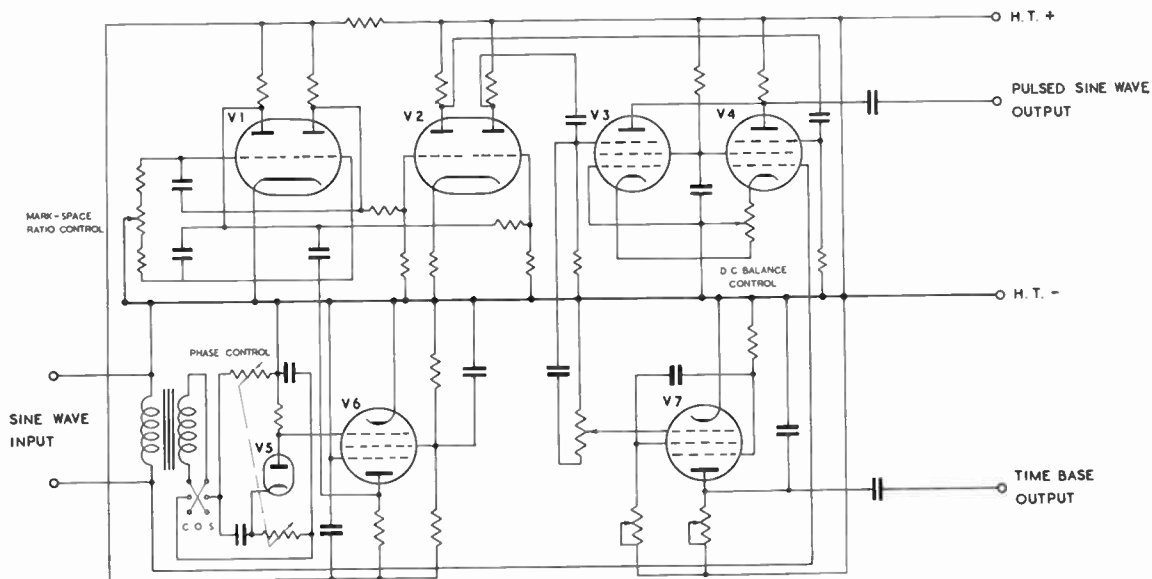
Fig. 6.—Circuit of a transient signal generator.

Much other useful information could be obtained from this diagram, but sufficient has been said to show the value of this dynamical analogy.

In normal operation the speaker is called upon to deal with transient signals as well as with steady tones, and for best response to both types of signal any resonances in the system should be well outside the required frequency range. However, it is not always possible to lower the frequency of fundamental resonance beyond the audio frequency range, but within this limitation the optimum condition is obtained when the circuit is critically damped.

The simplified equivalent circuits Figs. 5(c) and 5(d), true only at low frequencies, have been included to show clearly the damping effect of generator source impedance. For this purpose the resistance of the mechanical circuit, denoted by R_E, has been included since it does provide in itself some damping of the resonant circuit. In practice the value of this resistance is too low to provide critical damping of the mechanical circuit. In Fig. 5(d) this means that the reflected resistance C^2/R_E is too high to achieve this condition, and it is clear from this diagram that critical damping conditions may be reached by a suitable choice of $(R + R_o)$, where R_o is the generator output impedance. It is also clear from Fig. 5(b) that this particular choice of

$(R + R_o)$ will not prevent standing waves being set up in the line and hence is only valuable in improving low frequency performance.

Depending on the value of the voice coil resistance, negative values of R_o may be necessary to achieve the desired critical damping conditions in the low frequency resonant circuit.

3.2. Experimental Work

In order to carry out tests on the low frequency transient response of loudspeakers it is clear from the foregoing remarks that an amplifier whose output impedance can be easily varied must be provided. Such an amplifier was designed in which a combination of positive current and negative voltage feedbacks gave an output impedance range of from $+ 20 \,\Omega$ to $- 10 \,\Omega$, continuously variable. Details of this amplifier have appeared elsewhere.*

Two convenient forms of transient testing signal are possible, a square wave or a pulsed sine wave, and the repetition frequency of the chosen type must be sufficiently low to allow steady state conditions in the resonant circuit to be reached in between each transient. The tests described in this paper were performed

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* McLachlan, K. R. and Yorke, R. "An Amplifier of Variable Output Impedance." *Wireless Engineer*, **28**, July 1951, pp. 222-225.

with the pulsed sine wave method since at these low frequencies it allowed considerable simplification of the test apparatus to be effected.

For satisfactory testing with this method it must be possible to vary the frequency of the sine wave over a suitable range, and to control the starting and stopping points of the square wave envelope with respect to the sine wave.

Figure 6 shows the circuit of a transient signal generator which meets these requirements. V1 is a self-running multivibrator the natural frequency of which is about 1·5 c/s. The two anti-phase outputs ·from this multivibrator are amplified and squared in V2. The signal amplitude appearing at the anodes of V2 is sufficiently large to cut off the anode currents of V3 and V4 alternately. Hence with correct adjustment of the d.c. bias conditions in these two valves, since they have a common anode load, no square wave signal appears at the output terminal. When a sine wave signal is injected into the control grid of V4 only, it appears at the common anode load when V4 is switched on, but not in the other half cycle when V3 is switched on. The instant of starting is controlled by synchronizing the multivibrator at a definite point on the incoming sine wave. This is effected by V5 and V6 which together square the sine wave which after differentiation provides a synchronizing pulse. The exact point on the sine wave at which synchronization takes place is adjusted by the phase control, which together with the change-over switch allows a range greater than $\pm$ 90 deg to be obtained. The instant of stopping is controlled by variation of the mark/space ratio of the multivibrator.

A simple and effective way of producing a continuous c.r.t. display is to incorporate into the unit a synchronized time base running at half the repetition frequency of the multivibrator. This ensures that one complete cycle of events is easily visible on the tube, and V7 generates this time base.

The output from this unit is fed via the variable output impedance amplifier mentioned above to provide the testing transient for the loudspeaker.

The performance of the loudspeaker under these conditions was investigated in two distinct stages: first the determination of the mechanical movement of the cone, and second of its acoustic output.

To detect and display the movement of the

cone a method must be used which does not interfere in any way with this movement. Its frequency and transient response must be very good and its amplitude distortion negligible.
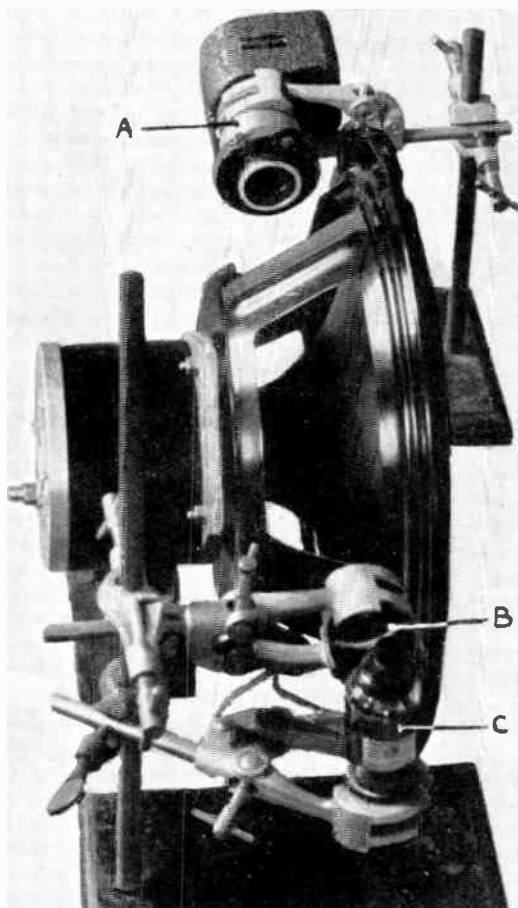

Fig. 7.—Experimental arrangement for displaying cone movement by means of a light-beam and photo-electric cell.

(a) Light source ; (b) Condensing lens ; (c) Photoelectric cell.

Figure 7 illustrates the disposition of the components of the apparatus used, which conforms to the above requirements. The light source and lens system throws part of the real image of a slit on to the cone, the rest of the image falling on a second lens system which focuses it on to a photo-electric cell. The major axis of the image is parallel to the direction of the cone's movement, and hence the amount of light falling on the cell is a linear function of the
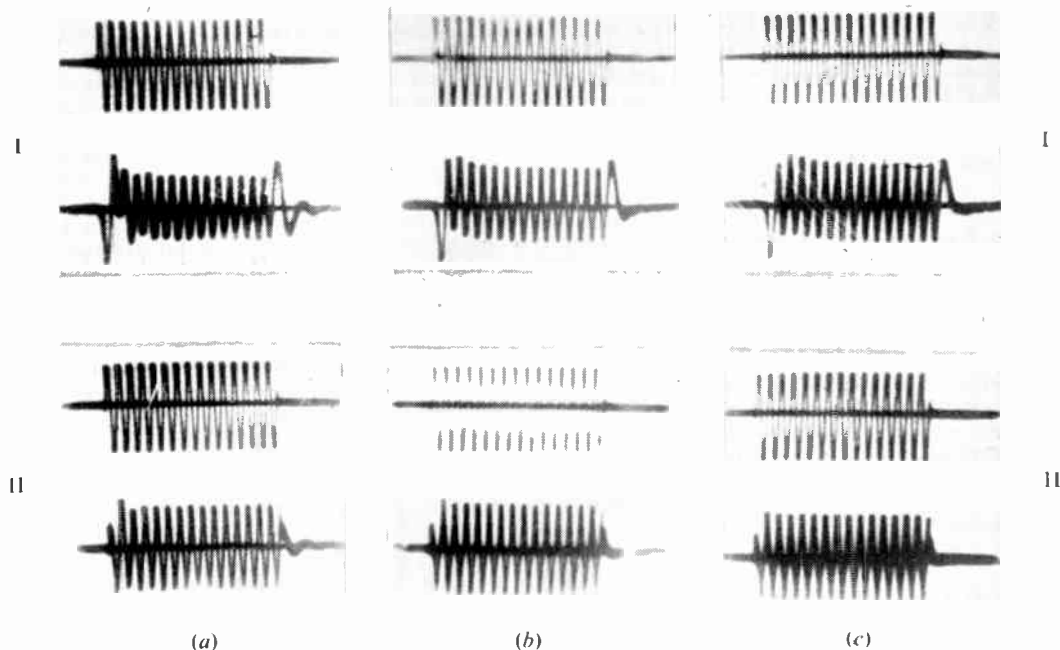
Fig. 8.—Records of following loudspeaker characteristics:—

I. *Input waveform and mechanical movement;* II. *Input waveform and acoustic output. These are shown for the following values of output impedance of the driving amplifier:* (a) $+ 20\Omega$; (b) *zero;* (c) $- 5\Omega$.

position of the cone. The voltage output from the cell, after suitable amplification, may be used to plot the movement of the cone on a c.r.t., the input waveform being displayed simultaneously on the second beam of the double-beam tube.

At low frequencies, at least, the mechanical movement of the cone gives a fair idea of the speaker's performance, and in any case gives useful experimental data to correlate with the equivalent circuit diagram. In addition, the method allows the motion of any portion of the cone to be indicated with ease, this being valuable for quantitative measurements on cone break-up.

To measure the acoustic output of the speaker a crystal microphone was used having a substantially flat frequency response characteristic over the required test range. Its output was fed via a high-gain linear amplifier to the c.r.t. and as before was compared with the input waveform.

Figure 8 shows examples of the kind of records obtained by the use of these methods. Reading vertically from top to bottom the four

sets give: input waveform, mechanical movement; input waveform, acoustic output. These are arranged in three columns representing three different output impedance settings of the driving amplifier.

It is not the purpose of this paper to interpret these results, but it is of interest to note that shown clearly on these records is the beating of the transient component of the speaker's response with the impressed signal, and the decay oscillation after the signal has stopped.

4. Conclusion

The analytical work carried out on the pick-up is capable of explaining all the phenomena observed experimentally, and therefore provides a general solution for this type of transducer.

As the work on loudspeakers is still in its initial stages, a similar general solution has not yet been reached.

However, good agreement is shown between the analytical and experimental work which these general principles have dictated.

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5. Acknowledgment

The authors would like to thank Mr. J. McKenzie, a student in the Engineering Department of University College, Southampton, for his invaluable help in the considerable photographic work involved.

6. Appendix 1

Demonstration of the Form of the Pick-up Characteristic

Note.—Vector and complex quantities are shown throughout by bold type.

The purpose of this analysis is to show that resonant peaks and "N" curves exist in the frequency response characteristic of a pick-up for which the equivalent electric circuit is as shown in Fig. 2. It demonstrates that the former are due to straightforward resonant effects, and that the latter are due to transmission line input impedance changes.

It is permissible, in this analysis, to ignore the transformers T_1 and T_2 since they alter only the magnitude and not the form of the effects.

Similarly to simplify the analysis, only one line, that consisting of L_P, C_P, will be considered. Fig. 9(a) shows the equivalent circuit of Fig. 2. simplified in this way; and Fig. 9(b) a generalization. As shown, z_3 is the input impedance of the short-circuited transmission line.

A measure of the output of the pick-up can be obtained from the value of I_1/I_0;

From Fig. 9(b)

$$\frac{I_3}{I_4} = z_4 + \left(\frac{z_1(z_2+z_3)}{z_1+z_2+z_3}\right)\bigg/z_5$$

and since $I_3 = I_0 - I_4$

$$\frac{I_0-I_4}{I_4} = \frac{z_4(z_1+z_2+z_3)+z_2z_1+z_3z_1}{z_5(z_1+z_2+z_3)}.$$

Similarly

$$I_1 = I_4\left[\frac{z_2+z_3}{z_1+z_2+z_3}\right]$$
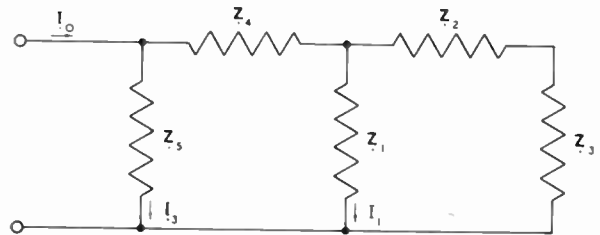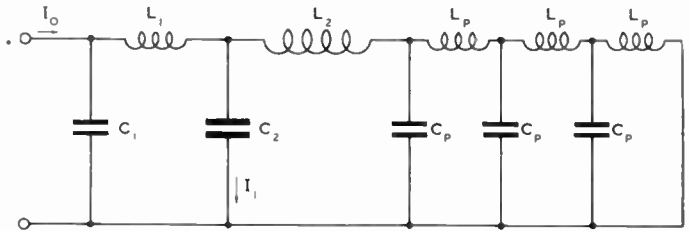
Fig. 9.—(a) Simplification of Fig. 2 for analysis of the pick-up. (b) Generalized form of (a).

or $I_4 = I_1\left[\frac{z_1+z_2+z_3}{z_2+z_3}\right]$

So that

$$\frac{I_0}{I_4} = 1 + \frac{z_4(z_1+z_2+z_3)+z_2z_1+z_3z_1}{z_5(z_1+z_2+z_3)}$$

or

$$\frac{I_0}{I_1\left[\dfrac{z_1+z_2+z_3}{z_2+z_3}\right]}$$

$$= \frac{(z_4+z_5)(z_1+z_2+z_3)+z_1(z_2+z_3)}{z_5(z_1+z_2+z_3)}$$

or $\dfrac{I_1}{I_0} = \dfrac{z_5(z_2+z_3)}{z_1(z_2+z_3)+(z_4+z_5)(z_1+z_2+z_3)}$

$$\dots\dots\dots\dots(1)$$

In this case:—$z_1 = \dfrac{-j}{\omega C_2}$; $z_2 = j\omega L_2$;

$z_3 = j\sqrt{L_p/C_p}\tan\omega\sqrt{L_pC_p}$;

$z_4 = j\omega L_1$ and $z_5 = \dfrac{-j}{\omega C_1}$

Substituting these values into equation (1)

$$\frac{I_1}{I_0} = \frac{\dfrac{-1}{\omega C_1}\left(\omega L_2 + \sqrt{\dfrac{L_p}{C_p}}\tan\omega\sqrt{L_pC_p}\right)}{\left(\dfrac{-1}{\omega C_2}\right)\left(\omega L_2+\sqrt{\dfrac{L_p}{C_p}}\tan\omega\sqrt{L_pC_p}\right)+\left(\omega L_1-\dfrac{1}{\omega C_1}\right)\left(\omega L_2-\dfrac{1}{\omega C_2}+\sqrt{\dfrac{L_p}{C_p}}\tan\omega\sqrt{L_pC_p}\right)}$$

$$\dots\dots\dots\dots(2)$$

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The form of Equation (2) could be obtained by plotting out in full. However, due to the large number of terms involving ω, this would be a long and tedious process and a good idea of the salient features of the curve may be obtained by inspection.

Remembering that $1/\omega C_2$ will be very small at all but the lowest frequencies; that ωL_2 will be quite large down to low frequencies, and that $\sqrt{L_p/C_p} \tan \omega \sqrt{L_p C_p}$ will alternate between $\pm \infty$ passing through zero, several effects become apparent.

(i) When

$(\omega L_2 - 1/\omega C_2 + \sqrt{L_p/C_p} \tan \omega \sqrt{L_p C_p}) = 0$,
Equn. (2) reduces to $\mathbf{I}_1/\mathbf{I}_0 = C_2/C_1$.

This occurs at several frequencies:—

(a) When $\sqrt{L_p/C_p} \tan \omega \sqrt{L_p C_p}$ is positive and equal numerically to $(1/\omega C_2 - \omega L_2)$. This occurs at one frequency only and corresponds to pivotal resonance.

(b) At a whole range of frequencies when $\sqrt{L_p/C_p} \tan \omega \sqrt{L_p C_p}$ is negative and equal numerically to $(\omega L_2 - 1/\omega C_2)$, these corresponding to arm resonances.

The lowest of these occurs at a higher frequency than pivotal resonance since $\omega L_2 > 1/\omega C_2$. The others occur at frequencies of 3, 5, 7, - - - etc., times that of the lowest arm resonance.

(ii) When $(\omega L_2 + \sqrt{L_p/C_p} \tan \omega \sqrt{L_p C_p}) = 0$ Equn. (2) reduces to $\mathbf{I}_1/\mathbf{I}_0 = 0$. This, of course, occurs when $\sqrt{L_p/C_p} \tan \omega \sqrt{L_p C_p}$ is negative, and equal to ωL_2 numerically. These zero points occur, therefore, always slightly lower in frequency than the $\mathbf{I}_1/\mathbf{I}_0 = C_2/C_1$ points of (i)(b) above. The combination of these factors therefore gives rise to a series of "N" curves in the frequency characteristic.

(iii) Needle resonance is easily seen when equation (1) is rewritten as follows:—

$$\frac{\mathbf{I}_1}{\mathbf{I}_0} = \frac{\mathbf{z}_5 (\mathbf{z}_2 + \mathbf{z}_3)}{(\mathbf{z}_1 + \mathbf{z}_2 + \mathbf{z}_3)\left[\mathbf{z}_4 + \mathbf{z}_5 + \dfrac{\mathbf{z}_1(\mathbf{z}_2 + \mathbf{z}_3)}{\mathbf{z}_1 + \mathbf{z}_2 + \mathbf{z}_3}\right]}$$

$$\dots\dots\dots\dots\dots(3)$$

for when $\left[\mathbf{z}_4 + \mathbf{z}_5 + \dfrac{\mathbf{z}_1(\mathbf{z}_2 + \mathbf{z}_3)}{\mathbf{z}_1 + \mathbf{z}_2 + \mathbf{z}_3}\right] = 0$, this reduces to $\mathbf{I}_1/\mathbf{I}_0 = \infty$ which gives needle resonance. Since $\mathbf{z}_2$ is very large at frequencies near needle

resonance, the expression $\dfrac{\mathbf{z}_1(\mathbf{z}_2 + \mathbf{z}_3)}{\mathbf{z}_1 + \mathbf{z}_2 + \mathbf{z}_3}$ tends to be equal to $\mathbf{z}_1$ which is very small and has negligible effect on the frequency of needle resonance.

(iv) At all other frequencies in the mid-range, i.e. above pivotal resonance but below needle resonance, equation (2) reduces approximately to $\mathbf{I}_1/\mathbf{I}_0 = 1$ since the first term in the denominator is much less than all other terms, $(\omega L_1 - 1/\omega C_1) \simeq - 1/\omega C_1$, and $1/\omega C_2$ is very small at frequencies appreciably above pivotal resonance.

Practical Considerations

The theoretical analysis given above is highly idealized in that it neglects the effects of resistance losses. In practice, however, resistance in the line elements will cause the line input impedance to change between two finite limits (positive and negative reactances) instead of increasing to $\pm \infty$. In addition the input impedance will be partly resistive instead of purely reactive as formerly assumed.

The combined effects of these modifications to the theory will be: (i) to cause the "N" curves to appear less and less marked as the frequency increases, (ii) to eliminate all but the first few (perhaps only two or three) "N" curves altogether.

The explanation of case (i) is that, at the point of resonance between the line input impedance (when capacitive reactive) and L_2, the circuit thus formed will still possess some resistance and therefore will not shunt C_2 so effectively, especially at high frequencies when $1/\omega C_2$ is small. Neither will the peak of the resonance curve rise so high as the frequency increases for, even at the parallel resonant frequency of L_2, C_2 and the line input impedance, there will still be resistance in the circuit.

The fact that the line input impedance rises to finite values only, accounts for the disappearance of all but the first few "N" curves. As the frequency increases ωL_2 will become very large, and the line input impedance, when capacitive reactive, will not be large enough to resonate with it. Hence, no resonant points are reached when the frequency is high.

The above analysis therefore accounts adequately for all the phenomena noticed. The electrical circuit of Fig. 2 can be considered then as a true analogue of the mechanical device of Fig. 1.

7. Appendix 2

Demonstration of the Properties of the Electromagnetic Transducing Element

It is proposed to show in this analysis, by taking three typical examples of its properties, the characteristics of the electromagnetic transducing element represented by a coil oscillating in a uniform magnetic field.
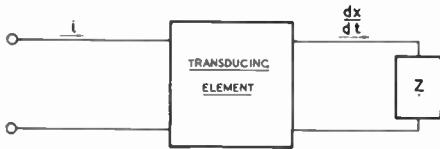

Fig. 10. Equivalent circuit of an electromagnetic transducer.

Figure 10 represents, diagrammatically, this element. Let it consist of a coil of N turns, of diameter d cm. situated in a magnetic field of strength B gauss. The circuit to the left is purely electrical and that to the right is the electrical equivalent of the mechanical circuit. The resistance and inductance of the coil will be neglected.

The force exerted by this coil when carrying a current i amperes $= F$ dynes

    where $F = B\pi N d i \, 10^{-1}$ dynes

    or $F = ci$ dynes.

c will be called the transducing constant. Let this force, assumed here to be sinusoidal, act upon a mechanical impedance $\mathbf{Z}$ mech.ohms, as shown in Fig. 10.

Then $ci = \mathbf{Z} \, dx/dt$, where x represents the deflection from the "at rest" position.

The equivalent electrical impedance $\mathbf{Z}_e$ of this mechanical impedance $\mathbf{Z}$ is given by:

$$\mathbf{Z}_e = \frac{E}{I} \quad \text{where} \quad E = c\frac{dx}{dt}$$

Hence $\quad \dfrac{dx}{dt} = \dfrac{c}{\mathbf{Z}} i \;$ and $\; e = \dfrac{c^2}{\mathbf{Z}} i$

So that $\mathbf{Z}_e = \dfrac{e}{i} = \dfrac{c^2}{\mathbf{Z}} \;$ or $\; \mathbf{Y}_e = \dfrac{i}{e} = \dfrac{1}{c^2}\mathbf{Z}$

Example 1: Suppose $\mathbf{Z} = \rho + j\omega M$ mechanical ohms, i.e. a series circuit consisting of a mechanical resistance ρ ohms and a mass M gms.

then $\mathbf{Y}_e = \rho/c^2 + j\omega \, M/c^2$ mhos and this is the admittance of a circuit consisting of a resistance R' ohms and a capacitance C' farads in parallel, where $R' = c^2/\rho$ and $C' = M/c^2$.

Checking these results dimensionally: in the electromagnetic system of units, flux density B has the dimensions $M^{\frac{1}{2}} L^{-\frac{1}{2}} T^{-1} \mu^{\frac{1}{2}}$.

$\therefore c$ has the dimensions $L \cdot L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1} \mu^{\frac{1}{2}}$
$$= M^{\frac{1}{2}} L^{\frac{1}{2}} T^{-1} \mu^{\frac{1}{2}}$$

$\therefore c^2$ has the dimensions $MLT^{-2} \mu$
ρ has the dimensions

$$\frac{\text{FORCE}}{\text{VELOCITY}} = \frac{MLT^{-2}}{LT^{-1}} = MT^{-1}$$

$$\therefore R' = \frac{c^2}{\rho} = \frac{MLT^{-2}\mu}{MT^{-1}} = LT^{-1}\mu$$

which are the dimensions of an electrical resistance in the electromagnetic system of units.

Similarly C' has the dimensions $M/MLT^{-2}\mu = L^{-1}T^2\mu^{-1}$, which are the dimensions of a capacitance in the electromagnetic system of units.

Example 2: Suppose $\mathbf{Z} = \rho - j/\omega K$ mechanical ohms where K represents compliance.

Then $\mathbf{Y}_e = \rho/c^2 - j/\omega c^2 K = \rho/c^2 + 1/j\omega c^2 K$ and this is the admittance of a circuit consisting of a resistance R' ohms and an inductance L' Henries in parallel; where $R' = c^2/\rho$ and $L' = c^2K$. These may be checked dimensionally as before:

thus, K has the dimensions $L/MLT^{-2} = M^{-1}T^2$
$\therefore L'$ has the dimensions $MLT^{-2}\mu \, M^{-1}T^2 = L\mu$. Similarly it may be shown that a circuit consisting of M, K and ρ in series reduces to a parallel L', C', R' circuit on the electrical side, where $L' = c^2K$; $C' = M/c^2$ and $R' = c^2/\rho$.

Example 3: Consider a transmission line such as the one shown in Fig. 5 (a) consisting of the elements m and C_c and terminated in the capacitance C_s.

It is shown in elementary transmission line theory that the input impedance of this line $\mathbf{Z}_s$ is given by:—

$$\mathbf{Z}_s = \mathbf{z}_0 \left[\frac{\mathbf{z}_r \cosh \sqrt{\mathbf{yz}} + \mathbf{z}_0 \sinh \sqrt{\mathbf{yz}}}{\mathbf{z}_0 \cosh \sqrt{\mathbf{yz}} + \mathbf{z}_r \sinh \sqrt{\mathbf{yz}}} \right] \quad ..(4)$$

Where $\mathbf{z}_0$ is the characteristic impedance of the

line $= \sqrt{\dfrac{m}{C_c}}$ in this case ;

$\sqrt{\mathbf{yz}} = j\omega\sqrt{mC_c}$, in this case, and

$\quad \mathbf{z}_r =$ terminating impedance
$$= \frac{-j}{\omega C_s} \text{ in this case.}$$

Let the input impedance Z_s of this line be the impedance Z above. Hence, the electrical input impedance $= c^2/Z = Z_e$

or $$Z_e = \frac{c^2}{z_0} \left[\frac{z_0 \cosh \sqrt{yz} + z_r \sinh \sqrt{yz}}{z_r \cosh \sqrt{yz} + z_0 \sinh \sqrt{yz}} \right]$$

$$= c^2 \sqrt{\frac{C_c}{m}} \left[\frac{\sqrt{\frac{m}{C_c}} \cosh j\omega \sqrt{mC_c} - \frac{j}{\omega C_s} \sinh j\omega \sqrt{mC_c}}{\frac{-j}{\omega C_s} \cosh j\omega \sqrt{mC_c} + \sqrt{\frac{m}{C_c}} \sinh j\omega \sqrt{mC_c}} \right]$$

$$= c^2 \sqrt{\frac{C_c}{m}} \left[\frac{\sqrt{\frac{m}{C_c}} \cos \omega \sqrt{mC_c} + \frac{1}{\omega C_s} \sin \omega \sqrt{mC_c}}{\frac{1}{j\omega C_s} \cos \omega \sqrt{mC_c} + j \sqrt{\frac{m}{C_c}} \sin \omega \sqrt{mC_c}} \right] \dots \dots (5)$$

since $\cosh jx = \cos x$ and $\sinh jx = j \sin x$.

This is equal to the input impedance of a transmission line whose elements consist of series inductances $l = c^2 C_c$ and of shunt capacitances $s = m/c^2$, and terminated in an inductance $L_s = c^2 C_s$.

For in this case

$$z_0 = \sqrt{\frac{l}{s}}$$

$$= \sqrt{\frac{c^2 C_c c^2}{m}}$$

$$= c^2 \sqrt{\frac{C_c}{m}}$$

and

$$\sqrt{yz} = \sqrt{j\omega l j\omega s} = j\omega \sqrt{ls}$$

$$= j\omega \sqrt{c^2 C_s \frac{m}{c^2}}$$

$$= j\omega \sqrt{mC_c}$$

and

$$z_r = j\omega L_s = j\omega c^2 C_s$$

From Equation (4):

$$Z_e = c^2 \sqrt{\frac{C_c}{m}} \left[\frac{j\omega c^2 C_s \cosh j\omega \sqrt{C_c m} + c^2 \sqrt{\frac{C_c}{m}} \sinh j\omega \sqrt{C_c m}}{c^2 \sqrt{\frac{C_c}{m}} \cosh j\omega \sqrt{C_c m} + j\omega c^2 C_s \sinh j\omega \sqrt{C_c m}} \right]$$

i.e.

$$Z_e = c^2 \sqrt{\frac{C_c}{m}} \left[\frac{j\omega c^2 C_s \cos \omega \sqrt{C_c m} + jc^2 \sqrt{\frac{C_c}{m}} \sin \omega \sqrt{C_c m}}{c^2 \sqrt{\frac{C_c}{m}} \cos \omega \sqrt{C_c m} - \omega c^2 C_s \sin \omega \sqrt{C_c m}} \right]$$

$$= c^2 \sqrt{\frac{C_c}{m}} \left[\frac{\sqrt{\frac{m}{C_c}} \cos \omega \sqrt{C_c m} + \frac{1}{\omega C_s} \sin \omega \sqrt{C_c m}}{\frac{1}{j\omega C_s} \cos \omega \sqrt{C_c m} + j \sqrt{\frac{m}{C_s}} \sin \omega \sqrt{C_c m}} \right]$$

which is the same as equation (5). Hence the electrical equivalent circuit of Fig. 5(b) represents precisely the electrical equivalent of the mechanical circuit of Fig. 5(a).

NEW TRIGGER CIRCUITS FOR USE WITH COLD CATHODE COUNTING TUBES*

by

J. L. W. Churchill, B.Sc.†

SUMMARY

The paper describes several new trigger circuits which have been devised for use in conjunction with cold cathode, gas discharge counting tubes. By means of these circuits a scaling unit, which can subtract as well as add, may be constructed. A brief consideration of the counting losses of such a circuit on random input pulses is given.

1. Introduction

The advent of multi-electrode, gas discharge tubes promises new developments in the field of electronic counting. These tubes have been described by Bacon and Pollard[1] and by Hough and Ridler.[2] The cold cathode counting tubes at present available have a lower maximum counting speed than the conventional circuits using thermionic tubes. However, due to the simplification allowed, the new tubes may well replace the conventional circuits, except for applications where minimum resolving time is essential. A recent survey of counting circuits by Cooke-Yarborough[3] pointed out the advantages of the cold cathode counting tube, and also indicated some possible circuit arrangements for straightforward scalers employing them. Barnes, Cooke-Yarborough and Thomas[4] have described an interesting application of these tubes as the storage elements of an electronic digital computor.

The various types of these tubes differ mainly in the method by which the discharge is transferred from one cathode to the next, but this paper is particularly concerned with the one described by Bacon and Pollard,[1] i.e. the "Dekatron," developed and manufactured by Ericsson Telephones, Ltd. This tube contains an anode in the form of a disc around which is an array of thirty similar wires which are at right angles to the plane of the disc. Ten of these wires are used as cathodes while the remaining twenty are transfer electrodes. The arrangement is shown diagrammatically in Fig. 1, where K1, K2—K0 are the cathode wires and the

wires labelled A and B are the transfer electrodes. It will be seen that there is one A and one B electrode between each pair of cathodes, and that all the A's are connected together and similarly all the B's. In the quiescent state a discharge passes between the anode and one of the cathodes, e.g. K1, while the transfer electrodes are returned to a potential positive with respect to the cathodes so that very little current flows to them. If now the A transfer electrodes are taken down to a potential more negative than
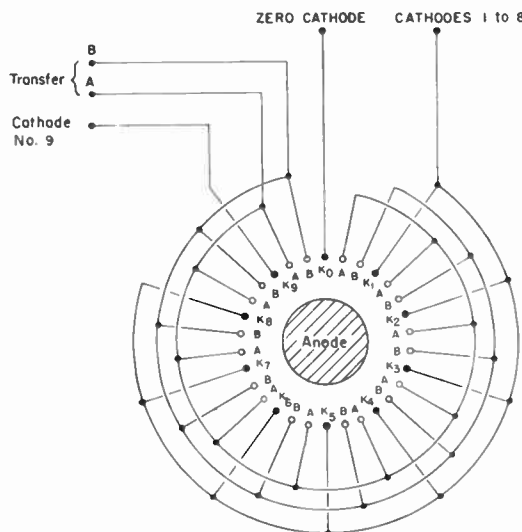

Fig. 1.—Electrode arrangement in the counting tube.

the cathodes, the discharge will leave K1 and pass to the nearest A electrode, and will remain there until this electrode is returned to its positive bias. When this occurs the discharge moves back on to the cathode it has just left, unless the B electrodes are made negative at the same time as the A electrodes become positive, in which case the discharge moves from the A

on to the nearest B electrode. As before it will remain there until the B electrode is brought back positive again. This time, due to the fact that the A electrodes are more positive than the cathodes, the glow instead of moving back on to the A it has just left moves forward on to the next cathode, i.e. K2. Thus it will be seen that in order to advance the discharge from one cathode to the next, the two sets of transfer electrodes must be driven successively to a potential more negative than the cathodes. By inserting resistances in series with the cathode leads output voltage pulses are developed across them which may be used to operate a coupling circuit to drive the next decade.

Suitable values for the Ericsson tube type GC10A would be a bias of + 60 volts for the transfer electrodes and transfer pulses of 120 volts amplitude and a minimum width of 500 microseconds.

The direction of transfer of the discharge is determined by the order of arrival of the transfer pulses, i.e. the discharge will advance by one cathode if a pulse is applied to transfer electrode A before the pulse on B, and it will move back by one cathode if a pulse is applied to B transfer electrode before the pulse on A. Very little attention appears to have been paid to this reversible property of these counting tubes, but it makes possible a scaling circuit which will subtract as well as add. Such a circuit is of use, for example, in counting the net number of revolutions of a shaft which may reverse as in the case of the velocity servo type of integrator,[5] and possibly for use in electronic digital computors. A third suggested use is in the counting of nuclear disintegrations when the counting rate is very slow and one wishes to subtract the spurious background counts, in which case one would have a Geiger counter registering background counts only, and would wish to subtract its counts from those of another counter which was registering background counts plus required counts.

The trigger circuits now to be described were originally designed for use with cold cathode counting tubes, but they may be of use in other applications.

2. Paired-Pulse Generators

The circuit of Fig. 2 produces two successive square pulses, at separate output points, suitable for driving a cold cathode counting tube.[6] The circuit may be made self-running or triggered and is shown in the latter form. Three pentodes are employed and should preferably be of the short suppressor base variety, e.g. Mazda 6F33, which also has an internal diode which limits positive excursions of the suppressor. Each anode is directly coupled to the suppressor grid of the preceding valve and capacitively coupled to the control grid of the following valve. The screen grids may be connected together and returned to a positive supply.
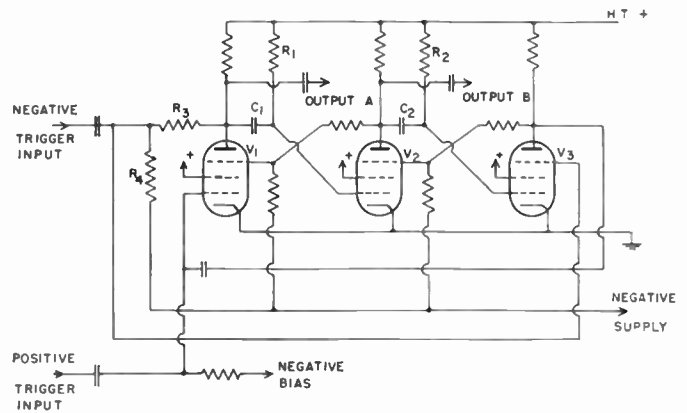

Fig. 2.—*Paired pulse generator.*

The potential divider formed by resistors R3 R4 is arranged such that when V1 is conducting, the suppressor grid of V3 is held at a potential sufficiently negative to cut off current to the anode of V3, but when V1 is cut off and its anode rises nearly to the H.T. potential, then the suppressor grid of V3 is brought slightly positive with respect to earth potential and allows V3 to conduct. Similarly for the other suppressor grid circuits. In the case of the triggered circuit, V1 is held cut off on its control grid by virtue of its grid leak being returned to a negative supply. Hence V3 is conducting. V2 is conducting to its screen but not to its anode, since its suppressor is cut off by the potential drop across the anode load of V3.

The circuit is triggered by injecting a negative pulse on to the suppressor of V3. The anode of
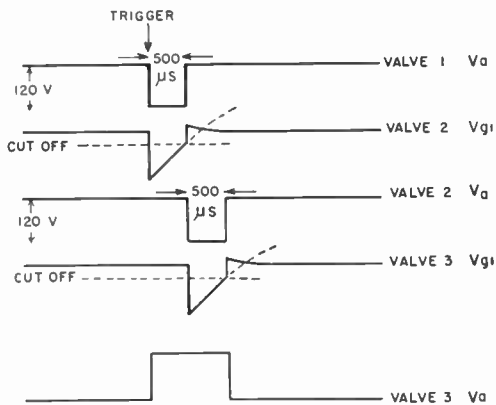
Fig. 3.—*Waveforms of the circuit of Fig. 2.*

V3 rises in potential bringing the grid of V1 with it and causing V1 to conduct. This in turn causes the suppressor of V3 to drop further, giving rise to a regenerative action in which V3 is turned off and V1 turned on.

During this process V2 remains cut off to its anode. When V3 is cut off the potential of the suppressor of V2 is raised, but at the same time the control grid of V2 is cut off by the drop in potential of V1 anode. V2 control grid now starts to leak back towards the positive supply potential at the time constant of R1.C1 and when it rises above cut-off, V2 starts to conduct and a regenerative action similar to that which occurred between V3 and V1 now occurs between V2 and V1. At the end of it V2 is conducting, V3 is cut off on its control grid and V1 is cut off on its suppressor.

The grid of V3 now leaks back with a time constant C2.R2 until V3 starts to conduct and the regenerative action takes place once more, leaving V3 conducting. Here the process stops, since the grid of V1 is held below cut-off by the negative bias supply. The circuit may also be triggered by a positive pulse on the control grid of V1 and may be made self-running by returning the grid leak of V1 to the same positive supply as those of V2 and V3. The relevant waveforms are shown in Fig. 3.

An alternative method of generating these successive pulses is to employ two flip-flop circuits coupled together, such that the second one is triggered over when the first one triggers

back into its stable state. When counting random events, however, the circuit of Fig. 2 is preferable, since it has a known dead time. A second trigger pulse, which arrives before the circuit has completed its cycle of operation, has no effect, since V3 is cut off until the cycle is complete. In the case of the double flip-flop arrangement a second trigger pulse could trigger the first flip-flop over again before the second one had resumed its stable state. This would lead to uncertain operation when used to drive a counting tube.

In order to exploit the reversible nature of the counting tube it is necessary to be able to reverse the order of arrival of the pulses at the transfer electrodes. The simplest way, of course, is to reverse the connections to the transfer electrodes
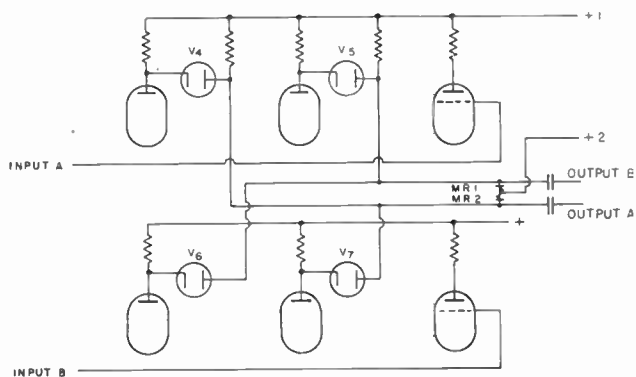

Fig. 4.—*Method of interconnection of two circuits of Fig. 2 to form a reversible paired pulse generator.*

by a relay circuit, but this suffers from the disadvantage of being slow and further circuits are necessary to change the relay over from its add to its subtract position at the appropriate moment. Another method is to use two circuits similar to that of Fig. 2 interconnected as shown in Fig. 4. It will be seen that the first valve of the upper circuit is cross-connected to the second valve of the lower circuit and vice-versa. The diodes V4, 5, 6, 7 are incorporated to prevent the operation of one circuit triggering the other and the germanium rectifiers MR1 and MR2 limit the pulse amplitude in the event of both circuits being triggered together. Then a trigger pulse at input A produces an output pulse at output A followed by a pulse at output B, while a trigger at input B produces a pulse first at output B and then one at output A.
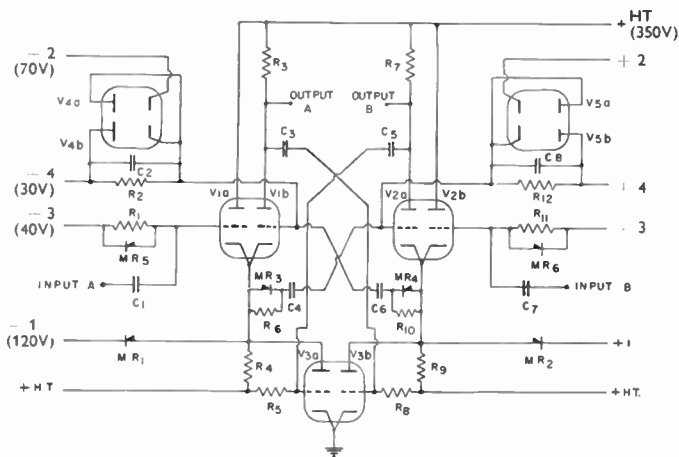
499

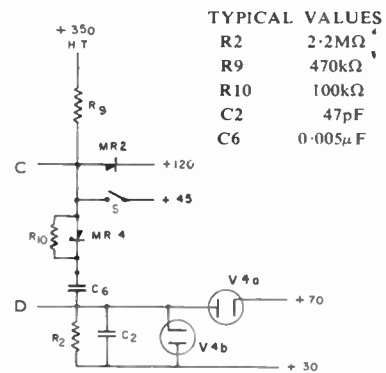Fig. 5.—Reversible paired pulse generator.

Fig. 6.—Detail of Fig. 5.

A more elegant method of performing this operation is by means of the circuit of Fig. 5.[7] Here again, there are two input points and two output points, and the order in which the pulses are generated at the output points depends on which input point receives the trigger pulse.

The waveforms relevant to the circuit of Fig. 5 are shown in Fig. 7, but before going into the details of the circuit a brief description of the mode of operation is worth while.

The circuit starts with V1a, V3a, V2b and V3b all conducting. A trigger pulse at input A causes the anode current of V1a to be diverted through V1b and the potential drop at its anode cuts off V3b. The grid of V3b leaks back and, when the valve conducts, its anode current passes through V2a and the drop in potential at the anode of the latter cuts off V3a. Its grid then leaks back and when V3a conducts again its anode current passes through V1a and at the same time V2a is cut off, causing V2b to conduct. The circuit is then back in its original state.

In the description to follow, reference is made to various clamping potentials, and for clarity the actual values used in a design are quoted. These values are by no means critical and may vary between one design and another.

In more detail the circuit operation is as follows:—

The grid of V1a is returned to a more positive potential than the grid of V1b so that when the circuit is in its normal state V1a conducts and V1b is cut off. Hence current flows through
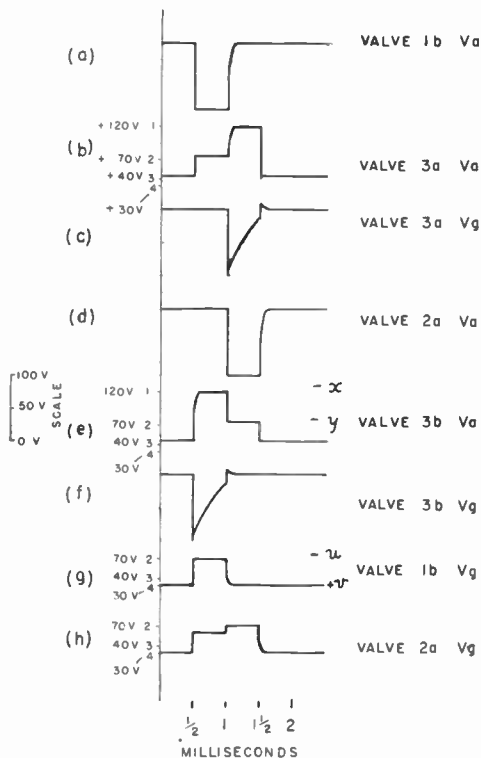

Fig. 7.—Waveforms of the circuit of Fig. 5.

V1a and V3a in series. Similarly, current flows through V2b and V3b in series. The operation of the circuit will be described for the case of a trigger pulse applied to input A, but the circuit

is perfectly symmetrical and the operation is similar for input B with the functions of V1 and V2 and of V3a and V3b interchanged.

When a negative pulse is applied to the grid of V1a this valve is cut off and its anode current diverted through V1b, producing a drop in the potential of its anode. This drop is coupled via C3 to the grid of V3b causing this valve to cut off. The anode of V3b is connected via R9 to the H.T. line so its potential tends to rise towards the H.T. potential. In order to ascertain the nature of this rise, the relevant part of Fig. 5 has been separated for clarity and is shown in Fig. 6. The switch S represents the valve V3b and while it is conducting the point C is held at a few volts above the grid potential of V2b. When the switch S is opened the potential of points C and D would, in the absence of C2, rise instantaneously to potentials determined by the relative values of R9 and R2 and, with the values shown in Fig. 6, point D would rise from 30 volts to approximately 280 volts. During this phase the germanium crystal rectifier MR4 is conducting in its forward direction and can be regarded as a short circuit. However, the presence of C2 (which is much smaller than C6) delays this initial rise slightly and, in fact, this rise has a time constant given by C2 and R9 and R2 in parallel. When point D reaches a potential of +70 volts it is caught by the diode V4a and from then on the potential of point C rises with a time constant of R9 C6 towards the H.T. potential until it is caught by the germanium crystal MR2 at +120 volts. The potential of point D then starts to decay exponentially towards +30 volts with a time constant given by R2 C6 but this is chosen to be large compared with the period of operation of the whole trigger circuit. These rises in potentials of the anode of V3b and the grid of V1b are shown in Fig. 7e and g.

This rise in the grid potential of V1b to above the +40 bias potential of the grid of V1a gives the necessary trigger action. Further, the cathodes of V1, and therefore the anode of V3a, rise to a potential a volt or two above the +70 clamping potential of the grid of V1b. This rise is transmitted via C4 to the grid of V2a, bringing it up to a potential decidedly more positive than the +40 grid return of V2b.

The grid potential of V3b rises exponentially towards H.T. potential with a time constant of R8.C3, and this is the time constant which

determines the width of the pulse from output A. When V3b starts to conduct, its anode drops from its clamping potential of +120 volts to a volt or two above the grid potential of V2a. It is essential to the operation of the circuit that this drop is not transmitted instantaneously to the grid of V1b and thence back via C4 to the grid of V2a, otherwise a trigger back action occurs and the grid of V2a is brought down below the grid of V2b. To obviate this, capacitor C2 and germanium crystal rectifier MR4 have been included. The drop in potential of the anode of V3b cuts off MR4 so that there is now the resistance of R10 in series with C6. Hence the grid of V1b drops with a time constant of R2, R10 and C2 in parallel. This gives time for V2a to conduct and the drop of potential at its anode to cut off V3a and V1b. The anode potential of V3a rises, rapidly at first until the grid of V2a has been carried up to its clamping potential of +70, and then more slowly until it is caught by MR1 at +120 volts (see Fig. 7b). Meanwhile, the potential of the grid of V1b has dropped to its lower clamping potential of +30 volts and has been caught there by diode V4b. Hence, when V3a starts to conduct again its anode current will pass through V1a.

The grid potential of V3a rises exponentially towards H.T. potential with a time constant of R5.C5, which is the one which governs the width of the pulse from output B. When V3a starts to conduct its anode potential drops from +120 volts to a volt or two above the +40 return of the grid of V1a. This drop is transmitted to the grid of V2a, causing V2a to cut off. Its anode current is diverted through V2b and the grid of V2a is caught at its initial potential of +30 by V5b diode.

The circuit is now back in its original condition, having delivered a negative-going square pulse from output A, followed by a similar pulse from output B. A trigger pulse on input B would, by a similar process, produce a pulse at output B, followed by one at output A.

The germanium crystal rectifiers MR5 and MR6 are included to prevent positive overshoot in the triggering waveform triggering the circuit back prematurely.

The choice of values for the clamping potentials +1, +2, +3 and +4 is governed by the following considerations: +3 should be sufficiently positive with respect to +4 that valves V1b and

V2a are completely cut off when the circuit is in its quiescent state. Potentials $+1$ and $+2$ are so chosen that the drop $x \rightarrow y$ in the anode potential of V3b (see Fig. 7e) is more than sufficient to carry the grid of V1b from its upper clamping potential $+2$ to its lower clamping potential $+4$, i.e. $u \rightarrow v$ in Fig. 7g.

When the two inputs to the circuit are trains of randomly occurring pulses, then some counting losses are involved, due to the dead time of the circuit. The magnitude of these losses cannot be estimated unless one has a knowledge of the sum of the mean pulse rates of the two inputs, as will be seen from the following argument.
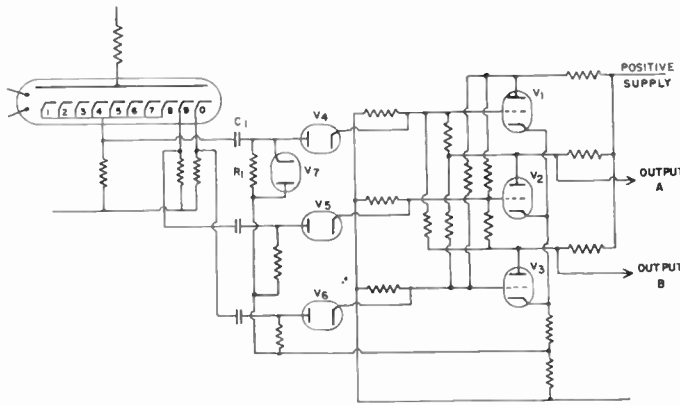

Fig. 8.—Hard valve reversible coupling circuit.

If N_1 and N_2 represent the mean numbers of counts per second actually registered at the two inputs, while N_{1r} and N_{2r} are the corresponding counts per second which would be registered in the absence of losses, then:—

The total dead time per second $= (N_1 + N_2) T$ where T secs $=$ circuit dead time per count,

then loss at input 1 $= N_{1r} (N_1 + N_2) T$ per sec
$$\dots \dots \dots \dots (1)$$

and loss at input 2 $= N_{2r} (N_1 + N_2) T$ per sec
$$\dots \dots \dots \dots (2)$$

whence $\quad N_1 = N_{1r} [1 - (N_1 + N_2) T]$
$$\dots \dots \dots \dots (3)$$

and $\quad N_2 = N_{2r} [1 - (N_1 + N_2) T]$
$$\dots \dots \dots \dots (4)$$

From equations (1) and (2) it follows that the

error in the difference is $(N_{1r} - N_{2r})(N_1 + N_2) T$. Then substituting for N_{1r} and N_{2r} from equations (3) and (4) we obtain:—

The error in the difference $=$

$$(N_1 - N_2) \frac{(N_1 + N_2) T}{1 - (N_1 + N_2) T} \text{ counts per sec.} \dots (5)$$

For slow counting rates when $(N_1 + N_2) T \ll 1$, equation (5) reduces to:—

Error $= (N_1 - N_2)(N_1 + N_2) T$ counts per sec.

3. Reversible Coupling Circuits

A complete scaling circuit normally consists of more than one decade, which means that if it is required to subtract as well as to add, then an interstage coupling circuit is necessary, which will transfer the sense of the arithmetical operation from the preceding decade to the following one. A circuit which achieves this is shown in Fig. 8. It is shown as used in conjunction with a cold cathode counting tube in which cathodes 1 to 8 are connected together internally and brought out to a common base pin and cathodes 9 and 0 each have their own pin. Signals are taken from all three cathode pins. The nature of the output signals during addition will be a succession of eight positive-going pulses from cathodes 1 to 8, followed by one pulse from cathode 9, and then one from cathode 0. During subtraction the pulse from cathode 0 will precede that from cathode 9. The coupling circuit of Fig. 8 will be seen to be a modified form of a ring-of-three scaling circuit. Every anode is d.c.-coupled to the grids of both of the other valves, and the three triodes have a common cathode resistor. The circuit is in a stable condition with any one valve conducting and the other two cut off, since the conducting valve has its grid d.c.-coupled to the anodes of two cut-off valves and it is, therefore, more positive than the grid of a cut-off valve which is d.c.-coupled to the anode of one conducting valve and one cut-off valve.

If the circuit starts with V1 conducting, either of the other two valves may be made to conduct by momentarily raising its grid to a potential more positive than the grid of V1. A cumulative action takes place and the change-over is rapid. The diodes V4, V5 and V6 are inserted to
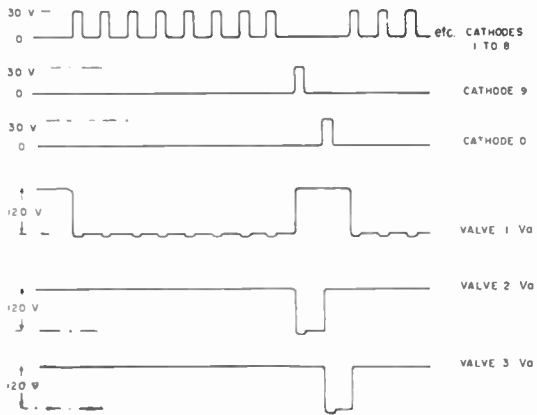
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Fig. 9.—Waveforms of the circuit of Fig. 8.

prevent the trailing edges of the triggering pulses from triggering the circuit in the reverse direction. The anodes of these diodes are returned to a potential below the grid cut-off potential of valves V1, V2 and V3.

Diode V7 is to provide d.c. restoration on the rapidly occurring pulses at that input.

The transfer electrodes of the following counting tube are d.c. coupled to the anodes of V2 and V3. It will be noticed that, while a count of 9 is registered on the first decade, the glow of the second will rest on transfer electrode 1. Similarly, the glow of the second will rest on transfer electrode 2 when a count of 0 is registered on the first decade, and the glow comes to rest on a cathode in the second decade when the count has reached 1 or 8 in the first, depending on whether the circuit is adding or subtracting. This, however, does not lead to any ambiguity in reading the count. The relevant waveforms are shown in Fig. 9.

Another circuit which fulfils the same function as the one of Fig. 8 is shown in Fig. 10.[8] Of the two, the latter is to be preferred, since apart from being simpler the values of its circuit components are far less critical. The valves V1, V2 and V3 are gas-filled cold-cathode trigger valves. For clarity the connections to the priming gaps and shield electrodes have been omitted from the figure.

The mode of operation of the circuit may be best followed by starting with the assumption that V1 is glowing and that V2 and V3 are

extinguished. Then V2 may be struck by applying a positive pulse to its trigger electrode. When this occurs the anode of V2 is held instantaneously at H.T. potential by the action of the capacitor C2 and hence the potential of the common cathode line rises in order to maintain the volt drop across the valve at the value for glow conditions. This raising by V2 of the cathode potential of V1 causes the latter to extinguish since the anode of V1 cannot rise instantaneously because of the presence of C1 and the anode-cathode voltage of V1 is brought below its glow maintaining value. The anode potential of V2 then falls exponentially with a time constant determined by C2 and the parallel combination of R2 and R4. The cathode line potential drops at the same rate to its original value.* In a similar way a pulse on the trigger electrode of V3 will cause it to strike and in doing so to extinguish V2. When a valve is extinguished its anode potential rises exponentially to H.T. potential with the time constant of the anode circuit (R1.C1 in the case of V1).
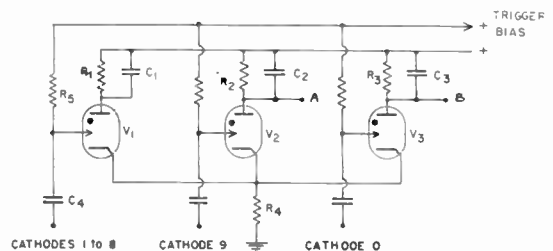

Fig. 10.—Reversible coupling circuit employing gas discharge trigger valves.

The diodes V4, V5 and V6 shown in Fig. 8 are not necessary in this circuit, since the gas filled trigger valves cannot be quenched by a negative pulse on the trigger electrode. In this case, in order to employ a diode across R5 for d.c. restoration, a resistance must be inserted between the trigger electrode and the junction of R5 and C4, since without it, once the trigger gap has struck, sufficient current to maintain it will then pass through the diode from the trigger bias supply and the result is that V1 cannot be quenched. However, with this circuit it is quite adequate simply to choose the time constant of the coupling circuit C4.R5 to be about equal to the period between output pulses generated by
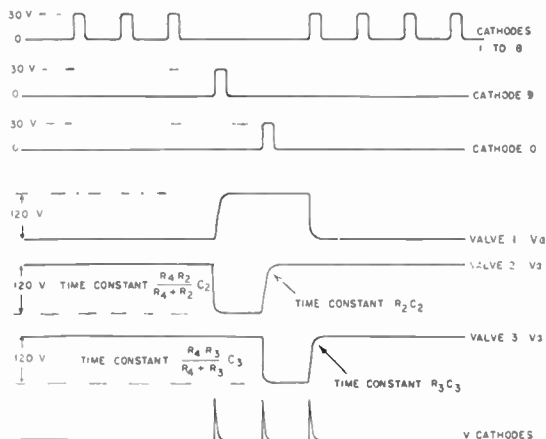
*Only if R1 = R3 = R2.

Fig. 11.—*Waveforms of the circuit of Fig.* 10.

the preceeding counting tube. With this value the leading edge of the first pulse of the train is transmitted to the trigger electrode with negligible attenuation and further the coupling capacitor C4 will discharge substantially during the period in which the glow of the counting tube is on cathode 9 or 0. The relevant waveforms are shown in Fig. 11.

This circuit could be extended for other applications to include any number of valves any one of which could be made to conduct, at the same time extinguishing a valve which is already glowing.

4. Conclusions

Trigger circuits have been described which can be used to drive multi-electrode cold cathode counting tubes of the variety which have two transfer electrodes between successive cathodes. These circuit arrangements have the special property of being able to drive the counting

tube both in the forward and in the reverse direction, allowing for the construction of a scaling circuit which can both add and subtract and some applications of such a circuit are suggested.

5. Acknowledgments

6. References

1. Bacon, R. C. and Pollard, J. R. "The Dekatron." *Electronic Engng*, **22**, May 1950, pp. 173-177.

2. Hough, G. H. and Ridler, D. S. "Multi-cathode gas-tube counters." *Elec. Commun.*, **27**, Sept. 1950, pp. 214-226.

3. Cooke-Yarborough, E. H. "The counting of random pulses." *J.Brit.I.R.E.*, **11**, Sept. 1951, pp. 367-381.

4. Barnes, R. C. M., Cooke-Yarborough, E. H. and Thomas, D. G. A. "An electronic digital computor using cold cathode counting tubes for storage." *Electronic Engng*, **23**, Aug. and Sept. 1951, pp. 286-291, 341-343.

5. Williams, F. C. and Uttley, A. M. "The Velodyne." *J. Instn Elect. Engrs*, **93**, Part IIIA, 1946, pp. 1256-1274.

6. Churchill J. L. W., British Patent Application No. 7122/52.

7. Churchill, J. L. W., British Patent Application No. 7120/52.

8. Churchill, J. L. W., British Patent Application No. 7121/52.