THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

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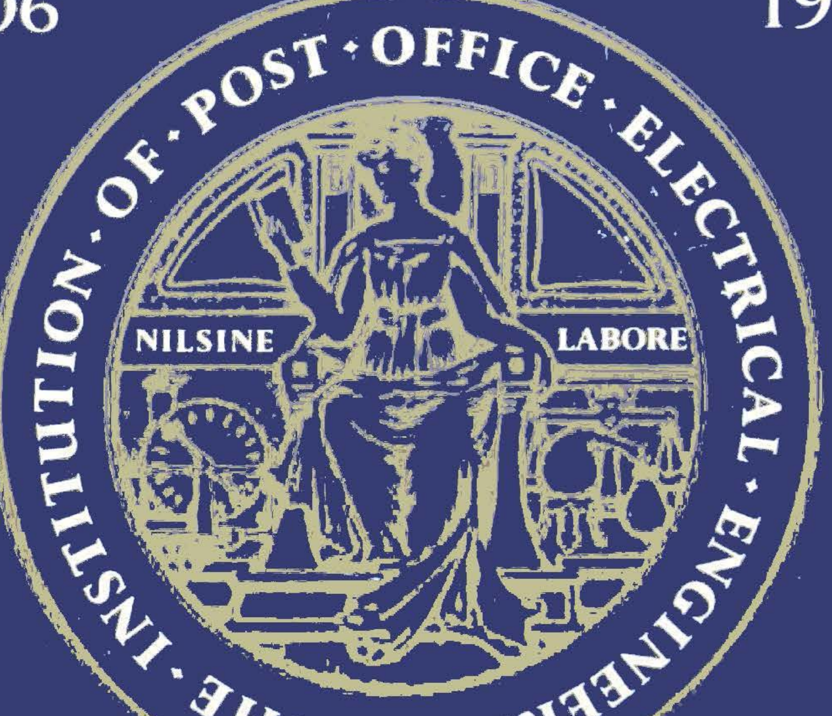
1906 1956



50TH ANNIVERSARY

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 49 October 1956 Part 3

JUBILEE NUMBER

COMMEMORATING THE 50TH ANNIVERSARY OF FOUNDATION OF THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

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SIR JOHN GAVEY, C.B., M.I.E.E.
First President of the
Institution of Post Office
Electrical Engineers
1906

Brig. L. H. HARRIS,
C.B.E., T.D., M.Sc., F.C.G.I.,
M.I.E.E.
President of the
Institution of Post Office
Electrical Engineers
1956

FOREWORD

On the occasion of its Jubilee I wish to congratulate the Institution of Post Office Electrical Engineers on the achievements of the past 50 years and to thank all who have contributed to this success. The cumulative value of its work and meetings at the various centres must now be very great, both to the Post Office and to the membership.

The Journal has proved its value as an interesting educational medium and provides a detailed history of the engineering development of the Post Office over nearly 50 years. Throughout we have enjoyed the support and friendliness of our Administration and of Industry.

Your first president, Sir John Gavey, C.B., would indeed be proud of the stature the Institution has reached and he too would have wished me to thank the many thousands who have contributed to the fulfilment of his hopes.

The Jubilee occurs at an appropriate time in the history and progress of telecommunications; world cable telephony, subscriber trunk dialling, automatic telex, electronic switching and the mechanization of office processes are all in various stages of implementation, and offer stimulating problems to the members of the Institution at the commencement of its second half-century.

We begin this phase without misgivings and confident that the Institution will continue to fill its role in the widening interests of the Post Office and also in the progress of what many of us consider to be the most interesting branch of the most interesting of professions.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

1906-1956

PRESIDENT

1906-07	Sir John Gavey C.B., M.I.E.E.
1907-12	Major W. A. J. O'Meara C.M.G., M.INST.C.E., M.I.E.E.
1912-19	Sir Wm. Slingo M.I.E.E.
1919-22	Sir Wm. Noble M.I.E.E.
1922-32	Col. Sir Thomas Fortune Purves O.B.E., M.I.E.E.
1932-39	Sir George Lee O.B.E., M.C., B.SC., M.I.E.E.
1939-46	Col. Sir Stanley Angwin K.B.E., D.S.O., M.C., T.D., M.I.E.E.
1946-51	Sir Archibald J. Gill B.SC.(ENG.), M.I.E.E., F.I.R.E.
1951-54	Sir W. Gordon Radley K.C.B., C.B.E., PH.D.(ENG.), M.I.E.E.
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1911-12	Sir Wm. Slingo M.I.E.E.
1912-13	H. R. Kempe M.INST.C.E., M.I.E.E.
1913-15	Sir Wm. Noble M.I.E.E.
1915-21	A. J. Stubbs M.INST.C.E., M.I.E.E.
1921-22	Col. Sir Thomas Fortune Purves O.B.E., M.I.E.E.
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1929-31	E. H. Shaughnessey O.B.E., M.I.E.E., M.I.R.E.
1931-32	Sir George Lee O.B.E., M.C., B.SC., M.I.E.E.
1932-35	Major H. Brown O.B.E., M.I.E.E.
1935-39	Col. Sir Stanley Angwin K.B.E., D.S.O., M.C., T.D., M.I.E.E.
1939-42	P. J. Ridd C.B.E., M.I.E.E.
1942-46	Sir Archibald J. Gill B.SC.(ENG.), M.I.E.E., F.I.R.E.
1946-54	H. Faulkner C.M.G., B.SC.(ENG.), M.I.E.E., F.I.R.E.
1954-55	Col. J. Reading M.B.E., E.R.D., B.SC.(ENG.), M.I.E.E.
1955-	D. A. Barron M.SC., M.I.E.E.

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1908-10	J. M. Crawford
1910-11	J. H. Bell
1911-23	T. Smerdon A.M.I.E.E.
1923-29	R. V. Hansford D.SC., M.I.E.E.
1929-31	P. G. Hay M.I.E.E., F.S.I.
1931-35	J. Innes C.B., B.SC., M.I.E.E.
1935-51	Col. J. Reading M.B.E., E.R.D., B.SC.(ENG.), M.I.E.E.
1951-	H. E. Wilcockson A.M.I.E.E.

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1907-09	D. H. Kennedy A.M.I.E.E.
1909-12	H. R. Kempe M.INST.C.E., M.I.E.E.
1912-19	J. W. Atkinson I.S.O., M.I.E.E.
1919-22	A. O. Gibbon M.I.E.E.
1922-25	E. H. Shaughnessey O.B.E., M.I.E.E., M.I.R.E.
1925-28	B. O. Anson O.B.E., M.I.E.E.
1928-31	C. J. Mercer M.I.E.E., M.I.R.E.
1931-34	B. O. Anson O.B.E., M.I.E.E.
1934-36	P. J. Ridd C.B.E., M.I.E.E.
1936-39	R. M. Chamney B.SC., A.M.INST.C.E., A.M.I.E.E.
1939-40	G. F. O'Dell B.SC., M.I.E.E.
1940-46	R. M. Chamney B.SC., A.M.INST.C.E., A.M.I.E.E.
1946-49	C. W. Brown M.I.E.E.
1949-51	W. T. Gemmell B.SC.(ENG.), A.C.G.I., M.I.MECH.E., A.M.I.E.E.
1951-55	D. A. Barron M.SC., M.I.E.E.
1955-	R. E. Jones M.B.E., M.SC., D.I.C., A.C.G.I., M.I.E.E.

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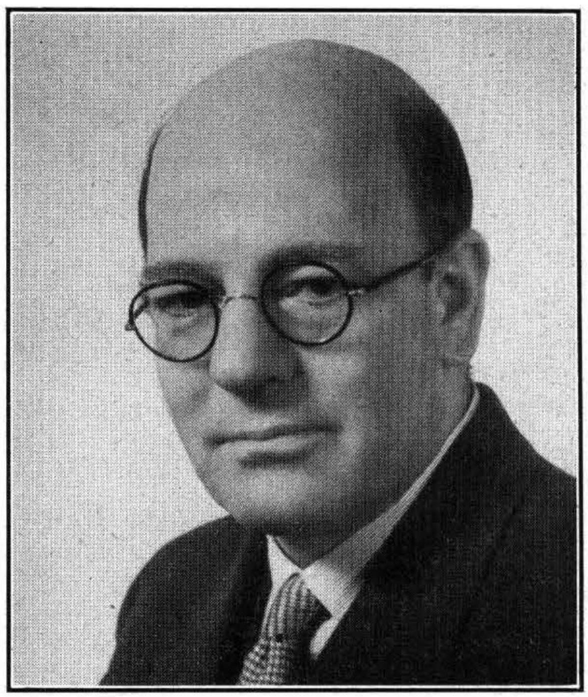
	Secretary	W. H. Fox, A.M.I.E.E.
EASTERN CENTRE	*Chairman*	W. E. Hudson, B.SC.(ENG.), WHIT. SCH., A.C.G.I.
	Secretary	G. A. Huke
SOUTH-MIDLAND CENTRE	*Chairman*	W. E. Hudson, B.SC.(ENG.), WHIT. SCH., A.C.G.I.
	Secretary	S. D. Pendry, M.B.E., A.M.I.E.E.
NORTH-EASTERN CENTRE	*Chairman*	Lt.-Col. J. Baines, O.B.E., T.D.
	Secretary	T. E. Walker
NORTHERN CENTRE	*Chairman*	Lt.-Col. J. Baines, O.B.E., T.D.
	Secretary	J. F. Chapman
BIRMINGHAM CENTRE	*Chairman*	L. L. Tolley, B.SC., M.I.E.E.
	Secretary	C. H. Painter, A.M.I.E.E.
NOTTINGHAM CENTRE	*Chairman*	L. L. Tolley, B.SC., M.I.E.E.
	Secretary	T. A. Bish
STONE-STOKE CENTRE	*Chairman*	H. R. Harbottle, O.B.E., B.SC., D.F.H., M.I.E.E.
	Secretary	T. O. Robinson, GRADUATE I.E.E.
MANCHESTER & LIVERPOOL CENTRE	*Chairman*	H. G. Davis, O.B.E., B.SC.(ENG.), M.I.E.E.
	Secretary	W. Davies, F.R.D.
PRESTON CENTRE	*Chairman*	H. G. Davis, O.B.E., B.SC.(ENG.), M.I.E.E.
	Secretary	J. W. Gould
WALES & BORDER COUNTIES CENTRE	*Chairman*	C. E. Moffatt, WHIT. EX., A.C.G.I., A.M.I.E.E.
	Secretary	J. R. Young, A.M.I.E.E.
SOUTH-WESTERN CENTRE	*Chairman*	A. E. Morrill, B.SC., A.C.G.I., A.M.I.E.E.
	Secretary	L. R. Hargrave
SCOTLAND EAST CENTRE	*Chairman*	R. J. Hines, B.SC.(ENG.), M.I.E.E.
	Secretary	J. W. Rance, B.SC.(ENG.), A.M.I.E.E.
SCOTLAND WEST CENTRE	*Chairman*	R. J. Hines, B.SC.(ENG.), M.I.E.E.
	Secretary	C. G. Davis, A.M.I.E.E.
NORTHERN IRELAND CENTRE	*Chairman*	P. L. Barker, B.SC., M.I.E.E.
	Secretary	A. E. Connelly, A.M.I.E.E.

D. A. BARRON,
M.Sc., M.I.E.E.
Chairman of Council of the Institution of Post Office Electrical Engineers

H. E. WILCOCKSON,
A.M.I.E.E.
Secretary of the Institution of Post Office Electrical Engineers



Fifty Years of the Institution of Post Office Electrical Engineers

The Institution of Post Office Electrical Engineers was founded in 1906 "to promote the general advancement of electrical and telegraphic science and its applications, and to facilitate the exchange of information and ideas on these subjects amongst the members of the Institution, and for this purpose:—

(a) To hold meetings for reading and discussing communications,
(b) To print and circulate among the members such communications as the Council may deem worthy,
and (c) To form a Library of books, publications and manuscripts . . ."

The present Rules contain some amplification of the terms employed in 1906, but the essential principles have remained unchanged throughout the lifetime of the Institution.

In an endeavour to do justice to the many aspects of the Institution's work, this article has been divided into self-contained sections dealing with specific activities, preceded by notes concerning the foundation period, and containing some details concerning organization and membership.

The Foundation Years

The Historical Background.

THE circumstances attending the establishment of the Institution are summarized in a paragraph of the first Annual Report of Council, as follows:—

> "In April 1905, the Engineers, realizing that the time had come when individual study should be assisted by a co-operative movement, formed the 'Society of Post Office Engineers,' by means of which facilities were (to be) provided not only for the purchase of standard electrical works, but also for the discussion of the various problems which arise in connexion with the work of the Post Office Engineering Department. A circular, indicating the aims and objects of the Society, was issued and at once arrested the attention of the (Headquarters) Department, with the result that a liberal grant-in-aid was secured from the Treasury, and, with an enlarged membership and somewhat wider scope, the present Institution was established."

It is clear from the Draft Rules (May 1905) of the Society of Post Office Engineers that great interest was focused by the members on the technical aspect of that Society, since the objects outlined included provision for the holding of meetings for reading and discussing papers bearing on telegraphy and telephony, printing and publication of reports of the proceedings, and the establishment of a library on electrical telegraph or telephone science. The fact that the Society of Post Office Engineers proposed to have two sides to its organization, one educational and the other as advisory on all matters relating to staff welfare, was clearly a source of concern to the Department, who considered that technical matters and matters involving conditions of service should be separated. Sir John Gavey, C.B., Engineer-in-Chief to the Post Office, put this view to representatives of the Society on 17th May, 1905, and at the same time outlined a tentative scheme for organizing the technical side on much more comprehensive lines than the Society could hope to achieve, in which the Department, with the assistance of the staff, would organize a purely technical society. A capital sum of not less than £500 would be made available immediately for a technical library, and an annual sum of £250 for technical journals and other expenses. These proposals were favourably received, and at a further meeting of London and Provincial Engineers, on 9th June, 1905, Sir John Gavey announced that the Postmaster-General had approved the establishment of a Technical Institution, and that the Treasury had sanctioned the financial proposals outlined earlier. The delegates present then suggested that the staff should be allowed to augment, by subscription, the funds provided by the Department, a proposal which was welcomed by Sir John Gavey. On the same evening, at a well-attended meeting of London staff and Provincial delegates, the proposals regarding the Technical Institution were cordially accepted, as was a motion that the staff should contribute to the funds. Representatives were also elected to serve on an Organizing Committee to be set up to "take in hand the organization of the proposed Technical Institution and the formulation of Rules."

In the event, therefore, the Society of Post Office Engineers never actually developed its proposed technical side, and at no time has the Institution been controlled by the Department, since it was established during the deliberations of the Organizing Committee, in a note from Sir John Gavey, that "it is intended that the Institution as a whole should be absolutely self-governed." In the early years the annual grant-in-aid of £250 received by the Institution from the Department was about equal to the sum raised from members' subscriptions, but by 1952 this grant represented only one-seventeenth of the subscription income. The increased grant of £1,000 received since 1953 now represents about one-fifth of members' subscriptions.

The Organizing Committee (sometimes referred to as the Formation Committee) held its first meeting on 10th October, 1905, and comprised a Chairman (Mr. G. M. Carr, Superintending Engineer, nominated by the Engineer-in-Chief) and eight members elected by and from the staff concerned (four from London, four from the provincial districts). Further meetings were held in January and February 1906, and in March 1906 a comprehensive memorandum describing the aims and objects of the proposed Institution, and draft rules, were distributed to the potential members, together with application forms for membership of the Institution, and nomination forms for the election of Members of Council, Local Committees, and Treasurer and Secretary.

The final meeting of the Formation Committee was held on 6th June, 1906, and the first formal Council Meeting followed.

The Inaugural Session.

The records held by the Institution indicate that, whilst the Organizing Committee, which established so well the foundations upon which the Institution has since grown, began its labours in October 1905, it was not until 6th June, 1906, that the first formally constituted Council Meeting was held. At this meeting the President, Sir John Gavey, C.B., took the chair for the first item on the agenda, namely, "Formal Inauguration of the Institution by the President." Subsequently the chair was taken by Mr. G. M. Carr, first Chairman of Council, who had previously acted in the capacity of Chairman of the Organizing Committee.

The scope of the Institution's activities in its first year of operation was remarkably extensive. The Central Lending Library came into effective operation in July, 1906, when an initial catalogue was circulated, and 800 issues had been made by the end of the session. Sixteen reference libraries were established under the supervision of Local Centre Secretaries, and circulation of technical periodicals commenced. Furthermore, no less than 40 meetings were held at 12 Local Centres, at which papers were read and discussed, including six at the London (then Metropolitan) Centre. At the first London Centre meeting, on 8th October, 1906, Mr. R. McIlroy presented a paper on "The Telegraph Acts." The membership at the end of the session totalled **755**.

It is in the light of the above summary that the following remarks by Sir John Gavey at the first Annual General Meeting, after the presentation of the first Annual Report of Council, should be read:—

"I congratulate most heartily the Institution of Post Office Electrical Engineers on the excellent results of their work, first as to the numbers of members enrolled, and next as to the excellence and the great variety of papers that have been read. I think that for a new Institution, scattered as are its members over the whole of the United Kingdom, the result of your work is little short of marvellous. I think I may say that when the original Society of Telegraph Engineers was established in the year 1871—a Society that was supported by all the leading electrical engineers of those days, a Society that had the advantages of having all its members gathered in the Metropolis—I think I am right in saying that they did not do such good work in their first year as you and your colleagues in the first year of this Institution."

Organization

An outline follows of the basic organization of the Institution, with brief reference to the major changes that have occurred.

Officers and Council.

The affairs of the Institution are conducted by a Council, of which the Chairman and Vice-Chairman are nominated by the President of the Institution (the Engineer-in-Chief of the Post Office) and the other officers, including the Honorary Treasurer, are nominated and elected by the members; representation is by Departmental grades, and is to some extent territorial. The Secretary, the Librarian, and their assistants are nominated by Council.

At its inception the Council numbered 14, including 10 elected members. The number has been increased from time to time, to ensure adequate representation, and is now 22, including 19 elected members.

Local Centres and Committees.

From the beginning, Local Centres have been established to conduct the executive work of the Institution; responsibility being vested in the Local Committees for the working of each such Centre, for all arrangements connected with the preparation of the annual program of meetings, and for the observance of the rules of the Institution.

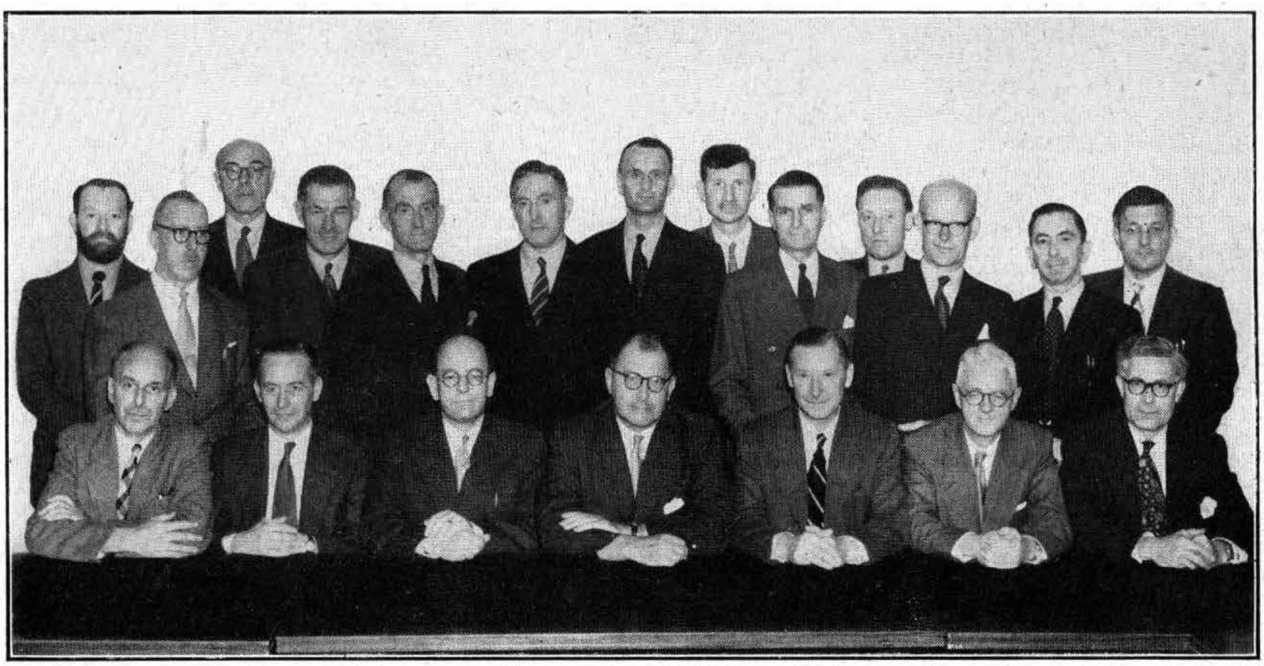
London Centre.

The London Centre initially served "the staff of the Engineer-in-Chief's Office, and the Metropolitan Engineering Districts (including the Southern District of England)." The Local Committee consisted of a Chairman and Vice-Chairman, nominated annually by the Engineer-in-Chief, and 10 elected members, from whom the Honorary Local Secretary was elected by the Committee.

To-day the London Centre serves members in the same geographical area, but to take account of Regionalization and other changes in Post Office organization it is now defined as follows:—"Members of the Engineering Department, the External Telecommunications Executive, the London Regions, and members from the Brighton, Tunbridge Wells and Canterbury Areas of the Home Counties Region, known as the 'South Eastern Group'." To provide adequate representation for the vastly increased membership, the Committee now consists of a Chairman and Vice-Chairman, nominated annually by the Engineer-in-Chief; an Honorary Local Secretary, with a minimum of three assistants, elected by the members; and **14** elected members of committee.

Provincial Centres.

In **1906** a Local Centre was established in each Provincial Engineering District, the Committee consisting in each instance of the Superintending Engineer and Assistant Superintending Engineer, as Chairman and Vice-Chairman, respectively, supported by four elected members, from whom the Honorary Local Secretary was elected by the Committee. In the inaugural session **13** such centres were formed, and the Provincial organization remained in general



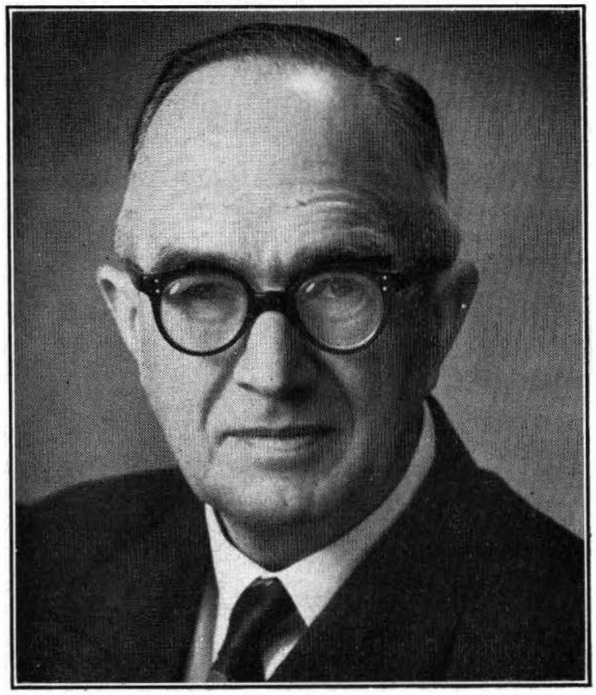
Standing:—G. Turner, L. R. Hargrave, W. R. Wickens, G. A. Probert, W. H. Fox, F. W. J. Webber, B. R. Horsfield, R. H. de Wardt, R. F. Waldegrave, J. Bass, T. A. Waight, A. H. C. Knox and K. W. Dutton.

Seated:—R. W. Palmer, A. F. Sturges, H. E. Wilcockson (Secretary), D. A. Barron (Chairman), R. E. Jones, M.B.E. (Honorary Treasurer), G. S. Berkeley and H. M. Turner.

Officers and Members of Council, 1956-57.

on a District basis until the experimental regionalization of the Post Office services was introduced. As a consequence, it was necessary in 1935 to reframe the Rules, primarily to safeguard the membership rights of those employed on the Engineering side of the Regional organization. The existing local-centre organization was, however, retained as far as practicable, and Regional Co-ordinating Committees were set up in those Regions containing more than one Provincial Centre (e.g. in the North-Eastern Region, which incorporated, broadly, the original Northern and North-Eastern Centres). This process of adjustment was repeated in the early war years, when regionalization of the Post Office was brought into full effect, and in the 1940-41 Annual Report it is recorded that "rearrangements of Centres where necessary to conform with the Regional organization have been completed." The number of such Local Centres was then 15, and has remained unchanged.

In 1922, following the admission of Inspectors and Established Draughtsmen to Institution Corporate Membership, the number of elected members in each Local Centre Committee was increased from four to five, and a further increase from five to six was made in 1926, when these grades were given separate representation. To-day each Committee consists of a Chairman and Vice-Chairman (the Chief Regional Engineer and a Regional Engineer, respectively); an Honorary Local Secretary (with assistants as necessary), elected by the members; and six elected members of Committee.



Sir W. Gordon Radley, K.C.B., C.B.E., Ph.D.(Eng.), M.I.E.E., Director-General of the Post Office—President of the Institution, 1951-54.

Membership of the Institution

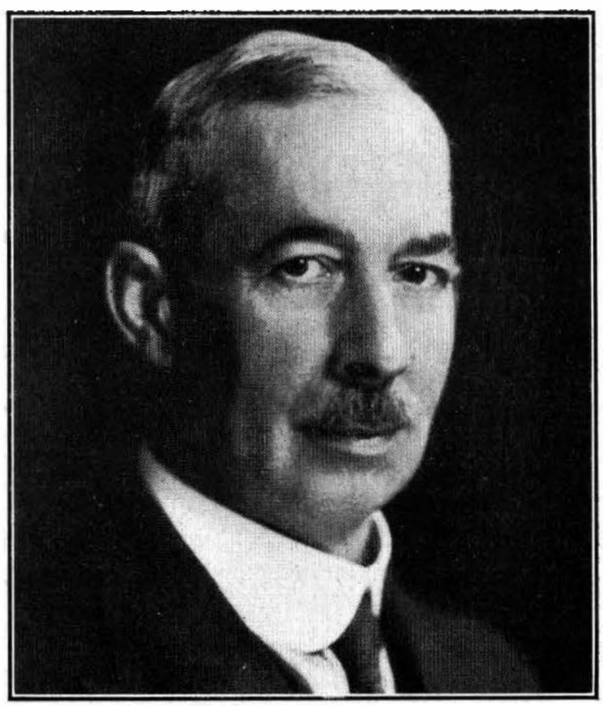
Conditions of Membership.

At the time of its foundation the Institution was "open to all officers of the Engineering Department of the Post Office, from the Engineer-in-Chief to Sub-Engineers and Clerks." Revision of the rules has been necessary from time to time to take account of expansion of the Post Office, the creation of new engineering grades, regionalization of Post Office services, and latterly the inclusion of certain staffs of the Factories and Contracts Departments of the Post Office. Membership is now open to all engineering, technical and scientific officers in the Engineering, Factories and Contracts Establishments of the Post Office of and above stated ranks (which, as a generalization, can be equated to the Inspector grade of the Engineering Establishment), and to Higher Clerical Officers (or Executive Officers) and above, who are employed in the Engineering Department, in the Engineering Branch of Regional Headquarters, or on the engineering side of the Clerical Divisions of Telephone Areas.

Honorary Membership.

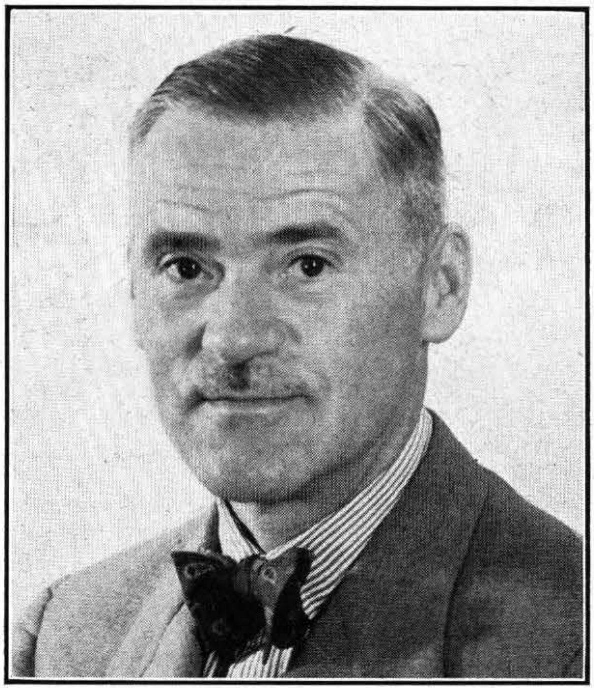
In 1908 the Council "deemed it desirable that there should exist some means whereby officers retiring from the Service may, at the discretion of the Council, be enabled to continue in touch with the Institution and its work. Sir John Gavey, C.B., and A. W. Heaviside, Esq., I.S.O., have accordingly been elected Honorary Members." In 1910, G. M. Carr, Esq., M.I.E.E., was elected an Honorary Member for his valuable services to the Institution, particularly as Chairman of the Formation Committee of the Institution.

The current Rule (established in 1922, at which date there were six Honorary Members) reads—"The Council may elect a limited number of Honorary Members from among persons whose services to the Institution have been of an exceptional character." The present number of such members is 14, among them Sir W. Gordon Radley, K.C.B., C.B.E., Ph.D.(Eng.), M.I.E.E., a past-President of the Institution, and now the Director-General of the Post Office. Another Honorary Member, elected in 1944, is Mr. J. W. Atkinson, I.S.O., M.I.E.E., who represents a link with the past. He was closely associated with all the activities leading to the formation of the Organizing Committee, on which he also served as Secretary; he then served as Secretary of the Institution from its foundation until the end of the 1907-08 session, and afterwards as member of Council, member of the Board of Editors of the *P.O.E.E. Journal*, and as Honorary Treasurer.



J. W. Atkinson, I.S.O., M.I.E.E.—First Secretary of the Institution, 1906-08.

Included also is the last officer to relinquish the post of Secretary of the Institution, Col. J. Reading, M.B.E., E.R.D., B.Sc.(Eng.), M.I.E.E., who held this office from 1935 to 1951. He also served as Managing Editor of the *P.O.E.E. Journal*, Chairman of Council and Chairman of the Board of Editors of the *P.O.E.E. Journal*.



COL. J. READING, M.B.E., E.R.D., B.SC.(ENG.), M.I.E.E.—SECRETARY OF THE INSTITUTION, 1935-51; CHAIRMAN OF COUNCIL, 1954-55.

Corresponding Members.

In 1908 the rules were extended as follows:—"Officers of Colonial and Foreign Telegraph and Telephone Administrations who are engaged in Electrical Engineering work may be admitted as Colonial and Foreign Corresponding Members, respectively, after application." By 1914, 80 such members had been enrolled. The conditions for corresponding membership were revised in 1924, substantially to the following form:—

Application for corresponding membership may be made by the following:

(a) By former corporate members of the Institution who have left the service of the Post Office and are engaged on any responsible work connected with electrical communications.

(b) By officers engaged on electrical engineering work of a responsible character, either in connexion with a telecommunications service in the Commonwealth countries or Colonial Territories, or in connexion with telecommunications which are controlled by any British Government Department other than the Post Office.

(c) By officers engaged in electrical engineering work of a responsible character in connexion with a foreign telegraph or telephone service.

The power to grant or terminate Corresponding Membership may be exercised by the Chairman on behalf of Council.

Every Corresponding Member is supplied with a copy of the *Post Office Electrical Engineers' Journal*, and of each unrestricted issue of the Printed Papers of the Institution, made during the Institution year.

Membership Figures.

There were 755 members when the Institution was founded in 1906; to-day there are 6,120.

An important criterion of the success of an organization of the character of the Institution is the proportion of eligible staff which it attracts as members, for only by reaching a high proportion of such staff can it serve appropriately their ever-growing and changing technical needs. At its formation the membership represented 70 per cent of those eligible, which is recorded as "exceeding the sanguine expectation of the Organizing Committee." The present membership of 6,120 represents 74 per cent of the eligible staff, and the Council is hopeful of achieving some further increase, even in this very satisfactory performance.

The acquisition of the National Telephone Company's System, and the consequent transfer of staff to the Post Office Engineering Department in the autumn of 1912, was followed by an increase in membership from 854 to 940. A still larger increase, to 1,336, in the following year was attributable to the continuing enrolment of ex-N.T.C. staff, and to the extension of membership to include the grades of Senior Inspector, Inspector and probationary sub-Engineer.

The outbreak of the First World War curbed the activities of the Institution and the growth in membership, but by the 1920-21 session a membership total of 1,469 was reached.

The continued growth of the Engineering Department in the period between the two World Wars was reflected in the growth in membership to 4,400 at 31st March, 1939. The highest yearly increase (526) occurred in 1937-38.

A further break in the expansion of the Institution occurred during the Second World War, but in the last decade the membership has increased steadily from 4,985 to 6,120.

INSTITUTION MEETINGS

The most important of the activities of the Institution is the holding of meetings, normally seven in each session, at each Local Centre. Papers are presented, mainly by members of the Institution, on scientific, technical and allied matters associated with the activities of the Post Office, and opportunities are given for discussion. By these meetings the Institution is able to give its members interesting and valuable information of progress in the telecommunications field.

The sessions of the Institution during which papers are presented commence about 1st October and terminate about 30th April in each year. Council noted with satisfaction in 1909 that the number of meetings in successive sessions showed a steady rise from 40 in the first year, to 52 in the second, and to 56 in the session 1908-09, "a number within measurable distance of that which would be given were monthly meetings held throughout the session in each of the twelve centres." By 1913-14 a notable increase, to 76 meetings during the session, had taken place.

By 1922-23—after a period of curtailment due to the war—the programs of meetings arranged by all centres had reached almost pre-war proportions, with a total of 70 meetings. In 1926-27 the London Centre successfully introduced a program of informal meetings, which still remain a notable feature of the Centre's activities. In the last full session before the outbreak of the Second World War the number of meetings at the 14 Local Centres concerned had increased to 88.

The records for 1939-40 show that once again the impact of war had its effect on the Institution's activities, for "in general, conditions throughout the country made the holding of Centre meetings impracticable." Subsequently the abnormal conditions were alleviated by holding meetings on an Area basis, and 100 meetings were held in 1943-44, including seven informal meetings of the London Centre.

In the immediate post-war years full programs of Centre meetings were quickly re-established, and by the 1946-47 session there were 140 meetings at the 14 Centres and 20 sub-Centres then functioning. The number of main Centres has now increased to 15, with the amalgamation of the Stoke & Stone sub-Centres, and the number of sub-Centres has decreased to six. In recent sessions, with the smaller number of sub-Centres, the number of meetings held has been about 120.

The number of meetings held, and papers presented, is not, of course, the sole criterion of the value of each session's proceedings. The range of the subject matter covered (a matter for selection by Local Centre Committees) and the standard of the contributions (recognized by Council in selection of papers for printing, and allocation of medal awards) are of equal if not greater importance. Council are, however, satisfied that the quotation below, extracted from the first Annual Report, has been applicable throughout the intervening years: "The proceedings in every instance have attained a high level of excellence, not only as regards the papers themselves, but also the discussions thereon. The experience already gained shows that no difficulty need be anticipated in obtaining contributions of high quality, nor does there appear to be a likelihood that papers will be confined to any particular class of subject."

Institution Printed Papers

A further important function of the Institution is the publication of papers selected from those read before the Centres. By this means the more important contributions are not only made available as works of reference to the entire membership, but also to all those interested in the design, provision and operation of telecommunications equipment and systems, including subscribers from the Commonwealth and Dependencies, Foreign Administrations and Industry.

At the first Annual General Meeting of the Institution it was recorded "that many of the papers have reached such a standard of excellence as, in the opinion of local committees, to warrant their being printed and distributed to members . . . three of these are still before the Council, but the printing of the remaining five has been authorized." By the date of the second Annual General Meeting, no fewer than 13 papers had been distributed, with a further three papers approved for printing. The Council was also able to record "The benefits accruing from the publication of selected papers . . . are very considerable, and it is worthy of note that an increasingly large number of orders is being received from non-members, including officers of other Administrations and many of the prominent electrical manufacturing firms."

These Printed Papers have undoubtedly been maintained at a high standard throughout the life of the Institution. At the end of the 1955-56 session the total number issued was 206.

Library Facilities

Central (Lending) Library.

The Central (Lending) Library came into effective operation early in July 1906, when an initial catalogue listing the books then available was circulated to the members. The formation of a Technical Library was one of the essential facilities whereby the objects of the Institution were to be achieved, and for which the Departmental Capital Grant of £500 had been made available.

During the first session a separate "Library Committee" was set up and this important Committee has functioned continuously since then.

By the end of the second session the Library Committee was able to announce that an adequate selection of standard works had been included in the Library, which had increased to 680 volumes, and that further additions must come from new publications. The demand for issues continued to be heavy and it was proposed that an additional post of Librarian should be created. This post was accepted by Mr. J. Smerdon in the 1908-09 session, and held by him until his retirement in 1933, by which time the number of books in the Library had increased to 1,161. Of the 2,300 issues in the 1932-33 session, 800 were to members of the newly formed Junior Section, which had been inaugurated in the previous session, and to whose 2,100 members the Institution's Library facilities were available.

By 1908-09 the Department's initial grant was exhausted, and thereafter all books added were purchased out of revenue. During the First World War library facilities remained available to members on Active Service and, as a result, it is recorded that "there is reason to fear that some of these volumes have been buried in the trenches and dug-outs in the French battlefields."

During the 1931-32 session the scope of the Library was extended by subscribing to Messrs. Lewis's Technical and Scientific Library. Some 60 books were obtained on loan from this source during that session, and 90 in the following session; more recent figures being 122 in 1951-52 and 224 in 1952-53. This method of meeting occasional demands shows considerable economies compared with increasing the number of books held in the Library.

The Library Committee, as well as examining new works and new editions with a view to adding them to the Library, also keeps under continuous review the need for retaining the older works. In the last three years 420 new books and 45 new editions have been examined, and 246 new books, 29 new editions and 11 additional copies of books already in the Library have been purchased. In the same period, a review of 260 books published in 1935 or earlier resulted in 29 being withdrawn.

During 1955-56, 4,449 books were issued, 648 to Associate (formerly Junior) Section members. Demands on Lewis's Library totalled 224. The number of volumes held in the Lending Library was about 2,500. These figures amply justify the active and progressive policy adopted by the Library Committee.

Technical Periodicals.

At the foundation of the Institution, arrangements were made for the general circulation to all members of any or all of the four technical journals approved by Council, the period of retention not to exceed four days. The experience of the first year demonstrated, however, that this basis of provision did not meet the requirements, which demanded both a wider range of choice and the opportunity for retaining the periodicals for longer than originally allowed. A number of arrangements were in force from time to time, and in October 1911 a scheme came into operation under which each member was entitled to select only one periodical. This basis of distribution has remained in force until the present day.

The selection of periodicals for circulation, and the circulation arrangements, are under the control of the Library Committee. The choice of periodicals offered to members in 1955-56 was five weeklies, six monthlies, and three quarterlies; 13,532 copies were purchased for circulation to 5,016 members, representing 88 per cent of the total membership, at a cost of £859.

Reference Libraries.

During the inaugural session 16 Reference Libraries were set up in the offices of Superintending Engineers, under the supervision of the Local Secretaries. By the end of the 1907-08 session a sum of £140 from the Departmental Initial Grant had been spent on the equipping of these libraries, each of which comprised about 30 standard works of reference.

Despite a small but regular expenditure on the maintenance of the Reference Libraries, it was noted by Council in 1919-20 that the existing volumes had become largely obsolete, and it was therefore proposed to re-equip the Reference Libraries with selected up-to-date works of reference. Completion of this task was reported in 1922-23.

With the adoption by the Department over the following years of a more liberal policy in the provision of reference works of specific value to specialized duties, the need for local reference libraries became progressively less, so that by 1938 Council was able to authorize the closing down of the Reference Libraries.

The Post Office Electrical Engineers' Journal

In the 2nd Annual Report of Council appears the following paragraph:—

> "One of the most important events of the Institution year has been the establishment of a quarterly magazine. The first number was published recently under the title mentioned above. For many years past the staff of the Post Office Engineering Department have hoped for the appearance of a journal devoted to their interests as servants of the State, and as colleagues whose opportunities for mutual intercourse are somewhat limited. The new organ of the Institution will, it is believed, meet all the requirements of the staff, and will also appeal to a circle of subscribers outside the Department. It is too early to offer any definite pronouncement as to the financial result of the Journal, but your Council have sanctioned the scheme only on the definite understanding that the Journal shall be self-supporting, and there is good reason to presume that this condition will be satisfied during the first year of publication.
>
> The management of the Journal is vested in a Committee, consisting of a Chairman, who must be a member of Council, and six members, of whom three are nominees of the Council."

The first issue of the Journal, published in April 1908, was an immediate success, the whole issue of 2,500 copies being sold by the end of the year; and the next three issues, completing Volume 1, were equally in demand. There were 332 pages in Volume 1, including 120 illustrations. The page size (octavo) was smaller than the current size (demy-quarto), which was not introduced until 1927. The proviso that the Journal should be self-supporting was met in the first year of operation, the net profit being £25.

During the next five years the circulation stabilized at some 2,500 copies per issue, the amount of material published increasing to 432 pages in Volume 6 (1913-14), with more illustrations. In the Board of Editors' Report on this Volume their policy can be clearly seen—"So long as high-class matter is forthcoming for publication, the Board is of the opinion that the size of the numbers should be limited only by the cost of production. It will be the prime object of the Journal to continue to record the salient features of the British Post Office Engineering practice . . . The Journal has now an extensive international circulation and is, undoubtedly, fulfilling a valuable function."

During the First World War the size and circulation of the Journal decreased, and trading losses were incurred. The Council considered, however, that the Journal was such an important feature of the Institution's work, and was held in such high esteem by electrical engineers throughout the world, that every effort should be made to continue its publication despite the risk of further loss. As a consequence, in 1920, having made grants in support of the Journal totalling £400, Council recorded "The Journal has continued to hold its high place in the sphere of technical literature, and there is no doubt that the successful efforts made to continue publication throughout the War have been fully justified." By 1921-22 (Volume 14) the Journal was again showing a profit, and has in fact remained self-supporting ever since.

It was not, however, until Volume 18 (1925-26), of which nearly 3,000 copies of each issue were printed, that the circulation exceeded the pre-war figures. Thereafter circulation increased rapidly to 6,000 copies for Volume 23 (1930-31), 13,000 copies for Volume 28 (1935-36), and nearly 17,000 copies for Volume 31 (1938-39). The contents of the Journal also increased, the 332 journal pages, plus 72 pages of supplement, in Volume 31, being equivalent to nearly 1,000 pages of the original format.

As a feature of particular value to those who are eligible for membership of the Associate Section of the Institution, the supplement was introduced in 1931, consisting of Model Answers to the latest City and Guilds of London Institute examinations in telecommunications subjects. The supplement has been issued free with each copy of the Journal ever since. The activities of the Board of Editors were extended in 1947 to include the production for sale of books of questions and model answers for the less advanced grades of subjects in the City and Guilds Telecommunications Syllabus.

As in the 1914-18 war, publication of the Journal was maintained throughout the Second World War. The size was, however, drastically reduced because paper was rationed, but although circulation decreased, it did not fall below 75 per cent of the 1938-39 figure. During the war, due to curtailment of other facilities, the cost of distributing the Journal to members was met out of membership subscriptions, and in 1946 the rules of the Institution were amended to cover the continuance of this arrangement.

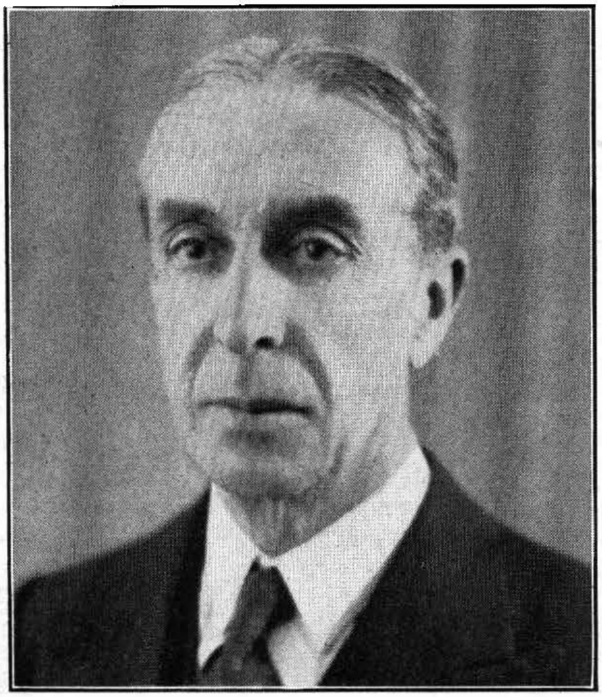
The Board of Editors reported in 1947 that the circulation exceeded the highest pre-war figure, and that the size had been increased to double that of the war years, although this was still only 75 per cent of the size of the immediately pre-war Journal. By 1951-52 (Volume 44) the number of copies distributed totalled almost 18,500, the highest recorded. In April 1951, a new format was adopted for Journal and supplement, which substantially increased the amount of material per page, but in spite of this economy the cost of producing the Journal had risen by 1952 to the point where it was necessary to increase the price. The circulation then dropped suddenly, but has since slowly increased again to 15,500 for the last complete volume issued (Vol. 48). In spite of the drop in circulation, the size of the Journal has continued to increase, and the total material in Volume 48 and its supplements exceeded the pre-war peak of 1938-39 by more than 15 per cent.

The policy of the present Board of Editors is fully in accord with the views of the earlier Board already quoted. Issues containing even more pages of authoritative articles may be expected, and circulation should continue to increase.

Associate Section

The establishment of the Associate Section of the Institution, originally named the Junior Section, was sponsored by the Institution during the session 1931-32, following the acceptance by Council of the report of a Special Committee to the effect that there existed a real and widespread desire on the part of the more junior grades of the Engineering Department, who are not eligible for membership of the Institution, for "facilities for the discussion and interchange of information and ideas on telegraph, telephone and allied sciences." It was also suggested by the Special Committee that success would be best assured if each Local Centre of the Associate Section (to be formed in any locality where the desire was expressed, and where conditions were suitable) were self-contained, self-supporting and self-governing, the management being vested in a Local Centre Committee elected by the members of the Centre. The parent Institution, however, was to assist in every possible way in an advisory capacity, and also by making available the facilities of the Central Lending Library, by offering Institution Printed Papers at two-thirds of the published price, and by annually awarding five prizes for the best papers written and read by members of the Section.

These proposals were accepted, and Council was able to record in its Annual Report for 1931-32 that detailed information had been circulated concerning the measures to be taken where the inauguration of a centre was desired, and that 10 centres had been formed during the Session. Mr. C. W. Brown, M.I.E.E., was appointed as President of the Section, to act in an advisory capacity to the Council in matters relating to its welfare. He rendered valuable service



C. W. Brown, M.I.E.E., First President of the Associate Section, 1931-36.

in this office until retiring from the Presidency in 1936; by that time the Section was firmly established, with 61 Local Centres and a total membership of 2,900.

At the outbreak of the Second World War some 64 centres, with a membership of 3,276, were in operation, but during the war years the loss of members due to mobilization, and to the pressure of official duties, created conditions which prevented all but a few of the centres from functioning normally.

In 1947, although some 60 centres, with a membership of 2,500, were registered, only half of these were active. Council was anxious for the Section to regain its pre-war position, and in January 1948 appointed a Committee to consider and report on the steps desirable to arouse greater interest in the Section and in the meetings of the Centres. As a result of this Committee's comprehensive report it was arranged, among other things, to appoint an Associate Section Liaison Officer in each Area, and a Liaison Officer to each Senior Centre Committee, so that the Senior Section could guide and foster Associate Section activities.

That the personal interest of Senior Section members is of importance in stimulating interest in the Associate Section has been fully demonstrated by the results since obtained. Thus in the 1949-50 session, 33 local centres were active, including the London Centre of which the membership was 2,480. For the 1955-56 Session, 44 centres were active, with a total membership of about 7,000, including the London Centre with a membership of over 4,000.

Associate Section Activities.

The policy of allowing self-determination to the Associate Centres has produced varying interpretations of the broad terms of reference. Some centres have concentrated on technical papers by senior staff, whereas others have stimulated the presentation of papers by their own members, but a common feature has been the wide range of subjects covered. Almost all centres have organized visits to a wide range of technical undertakings, and the circulation of technical periodicals is a feature everywhere. Though the number of members is as yet small compared with the possible membership, the meeting together of the enthusiasts has been of great value to the individuals and to the Post Office.

Institution Awards

Institution Senior and Junior Medals.

From its inception the Institution has offered four medal awards annually for the best papers read to meetings of Local Centres, subject always to sufficient papers reaching the requisite standard.

The design for the Institution Medal was produced in 1907 by a member of the Institution, Mr. O. P. Moller of the Engineer-in-Chief's office, who received the prize offered by Council for the best design. The same basic

The Institution Medal.

design has also been used since 1923 for the Institution's seal, embossed on Institution Certificates, and more recently in a form suitable for printing on Institution documents.

The first medal awards for papers read during the inaugural session were notified at the 2nd Annual General Meeting and were:—

Senior Silver Medal: Mr. J. E. Taylor, for his paper on "Electric Wave Propagation."

Senior Bronze Medal: Mr. J. G. Hill, for his paper on "Telephone Transmission."

Junior Silver Medal: Mr. A. O. Gibbon, for his paper on "Underground Construction (Provinces)."

Junior Bronze Medal: Mr. J. S. Brown, for his paper on "Telephone Trunk Signalling Arrangements."

At the 3rd Annual General Meeting, Council reported that—"Whilst there has been no diminution in the number of papers recommended for printing, the exceptionally high standard of the first year's contributions was not maintained during the second session, and no medals have been awarded." The records show that a similar high standard has always been observed in the allocation of medal awards; for instance, in the last five years only 10 of a possible 20 awards in the above categories have been made.

Institution Field Medals.

In 1950-51 the Council decided to broaden the scope of the medal awards by instituting a Field Medal for the best paper read at a Local Centre Meeting on a subject primarily of Regional interest. This step was taken in recognition of the value of papers on field subjects, even though they were not regarded as being appropriate for printing.

The first award was made at the 1951-52 Annual General Meeting to Mr. P. W. Crouch (South-Western Centre) for his paper "Television Interference." After four years' experience Council decided that there were sufficient papers of the requisite standard to justify further extension of the award to permit two medals being offered annually, and two medals were in fact awarded in the 1955-56 session.

Institution Certificates.

At the Annual General Meeting in 1923, Council notified its decision to introduce an Award Certificate to be known as the Institution Certificate, to accompany a medal or other award.

Institution Certificates are being currently awarded to those receiving Institution medals, and in respect of the Essay Competition and Associate Section Papers Award, mentioned later.

Essay Competition.

This competition, for essays submitted by the rank and file grades of the Engineering Department, was introduced by Council in the 1923-24 Session, "to further interest in the performance of engineering duties, and to encourage the expression of thought given to day-to-day departmental activities." It was an immediate success, no fewer than 60 essays being submitted to the Judging Committee of the day. Five prizes of two guineas each, and Institution Certificates, were awarded for the best essays submitted.

The award offered was extended in the 1925-26 session to include Certificates of Merit to the five competitors whose essays were next in order of merit, and in 1946-47 the value of the prizes was increased to three guineas. In 1951-52 the award to the first prize-winner was further increased to five guineas.

The competition was continued throughout the war and was well supported, for 55 essays were submitted in 1941-42 and 56 in 1943-44. Recently, however, the number of essays has decreased, and Council is now considering how to revive interest in the competition.

Associate Section Papers Awards.

This annual award of prizes of 3 guineas each, and Institution Certificates, for the best five papers written by Associate Section members and read at meetings of the Associate Section, was instituted by Council in 1932-33 as one of the measures for encouraging Associate Section activities.

As with other Institution awards, the Council reserves the right to withhold all or any of the prizes if in the opinion of the Judging Committee a sufficiently high standard is not attained, but awards have been made each year, except in the war and immediate post-war years.

For the 1952-53 and later sessions, Council has offered the additional award of one guinea for each paper considered worthy of submission to the Judging Committee for the main award, the selection at this stage being the responsibility of the local Senior Section Committee, with a limit to the number of papers which can be forwarded to the Judging Committee.

City and Guilds of London Institute Prizes.

In 1933 Council considered that the time was opportune "to encourage the work of the City and Guilds of London Institute in its efforts to promote technical education by awarding prizes in one of the examination subjects associated with the art of electrical communications." Arrangements were agreed, whereby the Institution would present annually a 1st prize of £3 and 2nd prize of £2 10s. 0d. to the candidates obtaining these places in the Intermediate Telephony examination.

The prizes were first awarded on the results of the 1933 examinations, and continued until the introduction by the City and Guilds of a new examination program in 1938, when the following annual awards were made:—

Transmission & Lines II	1st Prize £3.3.0 2nd Prize £2.2.0
Technical Electricity II	1st Prize £2.0.0 2nd Prize £1.0.0

A further revision was made in 1947, when changes in the examination syllabus again occurred, and the awards are now:—

Radio III Line Transmission II	alternate years	1st Prize £3.0.0 2nd Prize £2.0.0
Telecommunications (Principles) III		1st Prize £2.0.0 2nd Prize £1.0.0

Conclusion

It will be apparent from the foregoing that the Institution's activities are widespread. Successive Councils have spared no effort to further the general progress of electrical science and its applications, to enable the members of the Institution to keep abreast of developments, to stimulate interest, and to provide a forum for the interchange of ideas and experience. It is hoped that in the future the various services provided by the Institution will not only be maintained, but will be expanded wherever necessary to serve the needs of the members in all the many and complex aspects of telecommunications engineering.

D. A. BARRON,
Chairman of Council.

H. E. WILCOCKSON,
Secretary.

The Growth of Telecommunications Services in the United Kingdom

Post Office responsibilities for providing telecommunications services in the United Kingdom began in 1870, when the public telegraph systems operated by private companies were formally transferred to the State. In 1881 it was decided that the Post Office should enter the telephone field on a limited scale, and in 1896 the whole of the trunk services were placed under Post Office control. Finally, in 1912, the National Telephone Company's local services were taken over, and from that date the whole of the telephone system in the United Kingdom, with the exception only of a few municipal telephone systems, has been under Post Office control. To-day only Hull and the Channel Islands operate independent local telephone systems. Apart from war-time peaks the public telegraph system has declined as the telephone system has expanded, but there is now a rapidly expanding Telex service. The telephone system has grown from just under 500,000 subscribers stations in 1906 to 7,000,000 in 1956, and although the number of stations in service has been nearly doubled since the 1939-45 war, one of the major problems of to-day is to satisfy the large number of applicants still waiting for telephone service.

Early History

TELECOMMUNICATION in the modern sense, that is, communication over distances by electrical means, is little more than a century old. It began with telegraphy, which was first introduced by the railway companies between 1840 and 1850 to meet an obvious need for quick communication between stations. At about the same time private companies were set up to offer telegraph facilities to the public. Their services, understandably enough at that early stage, were poorly co-ordinated and, above all, very restricted; by 1866, little more than a quarter of the 500 large towns in the United Kingdom had a telegraph office. A truly national service was obviously needed, and the Government decided that it could be achieved only by public control. The Telegraph Act of 1868 gave them the power to take over the private systems, and by the Act of 1869 the Postmaster-General was granted a monopoly of telegraphic communication. The private systems were formally transferred to the State in 1870; there were then 2,800 telegraph offices, 1,800 of them at railway stations.

Thereafter, the growth of the telegraph service was very rapid. Within two years the number of telegraph offices had increased to 5,000 and the total number of telegrams handled per year from 10 millions to 15 millions; and in the following 13 years traffic more than doubled. New techniques were developed to speed up the service, and traffic was also stimulated by tariff revisions; the introduction of the tariff of "twelve words for sixpence" in 1885 increased the number of telegrams to 50 millions from 33 millions in the previous year, and traffic continued to increase until the turn of the century.

Meanwhile the telephone had begun to establish its value as an independent form of communication. Following the exhibition of Graham Bell's telephone at a meeting of the British Association at Glasgow in 1876, several telephone companies were set up to exploit the invention, and in 1879 the first telephone exchange in the United Kingdom was opened in London. It soon became clear that the telegraph service would have to face severe competition from the telephone, and in 1881 the Treasury agreed that the Post Office should enter the telephone field on a strictly limited scale. Control of private telephone development was established by a High Court judgment that a telephone was a "telegraph" within the meaning of the Telegraph Acts, from which it followed that telephonic communication between two independent persons was illegal without the licence of the Postmaster-General. Licences were granted to a number of private companies to operate anywhere within the United Kingdom, and to connect exchanges by trunk lines. In 1889 the principal telephone companies amalgamated under the title of the National Telephone Company, which—greatly helped by control of the telephone patents—gradually acquired most of the telephone services of the country.

The Company was greatly hampered by difficulty in securing wayleaves for the construction of lines. Rates were widely held to be too high and the public were not always satisfied with the service given, confined as it was to the larger towns. For these reasons, and also because of the increasing effect of competition on telegraph revenue, the Government decided, in 1892, to purchase and place under Post Office control the trunk lines of the National Telephone Company, whose operations would thereafter be confined to local service. This decision was put into effect by an Agreement of 1896. In developing the trunk network, the Post Office would have an important asset in its special powers for securing wayleaves rights.

A further move towards securing increased public control was the passing of the Telegraph Act of 1899, which authorized local authorities to operate telephone systems within their own boundaries. Municipal telephone services were then provided in six towns, Glasgow, Brighton, Hull, Swansea, Portsmouth and Tunbridge Wells.

In the ensuing period until 1912, local exchanges were provided partly by the National Telephone Company, partly by municipalities, and partly by the Post Office. Finally, in 1912, the State took over the whole of the National Telephone Company's service, bringing under Post Office control virtually the whole of the United Kingdom telephone system, trunk and local, with the exception only of a few municipal undertakings. To-day only Hull and the Channel Islands operate independent systems.

After the turn of the century telegraph traffic began to decline steadily as the telephone service became ever more popular, and the major problem became that of avoiding too great a financial deficit. Nevertheless, telegraphs met an essential public need which no other system could satisfy, and the work of improving the facilities continued. By 1900 the number of telegraph offices had grown to over 12,000 and, in addition to the public telegraph service, the Post Office carried on an extensive private-wire business, providing circuits between the premises of private individuals, and between such premises and Post Offices.

Developments Since the First World War

The Inland Telephone Service.

It is since the First World War that the telephone service as we know it has been mainly developed, and in any account of the progress made during that period pride of place must be given to the introduction of automatic telephony. The first public automatic exchange in the United Kingdom had been opened (at Epsom) as early as 1912, and although the number of automatic exchanges brought into service by 1930 was still relatively small—only 307, serving just over one-fifth of the telephones—these figures conceal the real measure of the progress made in laying the foundation for later rapid expansion.

To secure the full benefits of automatic working in the largest cities and, at the same time, to make dialling as simple as possible for subscribers, the director system, which uses the first three letters of the exchange name as part of the dialled number, was developed. The first director exchange was opened in 1927 in Holborn, London, and subsequently the director system was introduced also in Birmingham, Manchester, Liverpool, Glasgow and (more recently) in Edinburgh. In 1929 the first of an improved version of automatic exchange for rural areas came into service. These and other moves towards standardization facilitated the expansion of the automatic system to 3,213 exchanges by 1940, 4,091 by 1950 and 4,662 by 1956. To-day about three-quarters of the telephones in the country are served by automatic exchanges.

Automatic exchanges cost more than equivalent manual exchanges, but need fewer operators, and on balance provide service more economically. Broadly, the greater the proportion of calls that can be dialled direct by subscribers, the more the balance swings in favour of automatic working. On earlier automatic exchanges direct dialling was limited to the distance for which a unit fee was payable, calls beyond that distance being controlled by operators. But from 1930 onwards the subscribers' dialling range was raised progressively to 15 miles by the introduction of metering equipment capable of recording up to four units of charge for a call. Multi-metering equipment is nowadays provided as a matter of course at all new automatic exchanges, and can be installed fairly easily at many existing exchanges; there are now only about 300 automatic exchanges where for various reasons it has not yet been possible to provide such facilities.

The inland trunk telephone service has been completely revolutionized since the First World War, the number of trunk circuits increasing from about 1,500 in 1919 to some 22,000 to-day. At first the service operated on a "delay" system, in which a subscriber hung up after booking his call, and might then have to wait an hour or more for it to mature. The introduction of "demand" trunk working in 1932-33 speeded up the service very considerably. Technical advances since then have enabled trunk circuits to be provided at a fraction of former costs. Just before the Second World War, facilities were provided to enable trunk operators to dial calls direct to distant subscribers without the assistance of a second operator, and these facilities have since been greatly extended so that about 40 per cent of all trunk calls are now set up in this way.

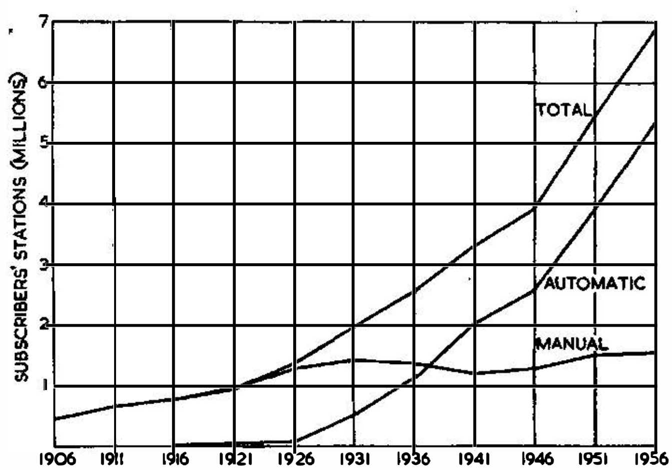
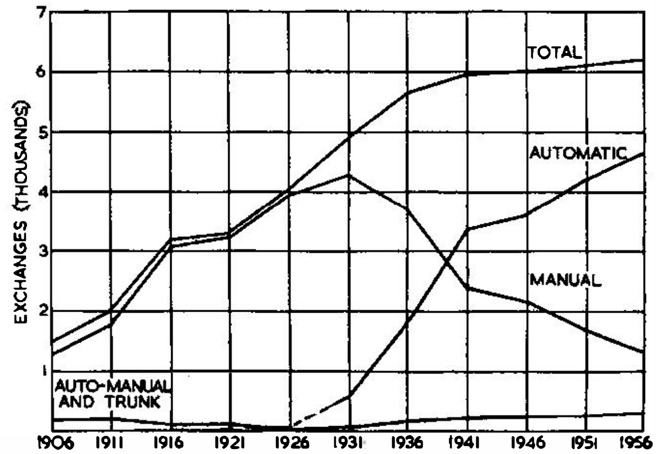


Fig. 1.—Number of Telephone Stations at 31st March, 1906 to 1956.

The expansion of the telephone service over the past 50 years can be most clearly seen by reference to Fig. 1 and 2. The million-station mark was reached round about 1922, the second million 10 years later, and the third million just before the outbreak of the Second World War; since then, the system has more than doubled.

The increase in the number of telephone calls follows a somewhat similar pattern, as shown in Fig. 3, though the increase in trunk traffic has been even more spectacular—



Note.—The number of automatic exchanges at 31st March, 1916, 1921 and 1926 —too few to show on the graph—were 6, 13 and 40.

Fig. 2.—Number of Telephone Exchanges at 31st March, 1906 to 1956.

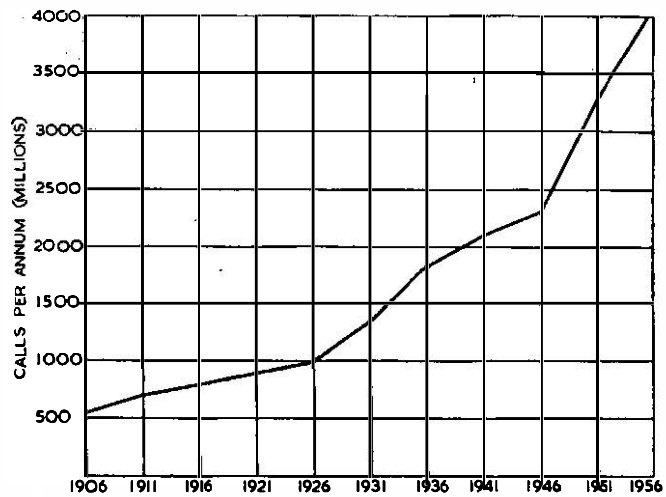


Fig. 3.—Number of Telephone Calls/Year ending 31st March, 1906 to 1956.

from 98 millions in 1936 to 193 millions in 1946, and to 333 millions last year.

These developments have naturally been greatly affected by the Post Office tariff policy. At the beginning of the century there was a variety of tariffs in operation for exchange line rentals and for local call charges, but in 1921 a great step forward was taken by abolishing the "unlimited service" rental, in which the rental included an unlimited number of calls, and the "measured rate" tariffs, which had sliding scales for local calls in excess of those included in the rental. At the same time a uniform system of local charges based on radial distance was introduced. Higher rentals associated with local-call charge concessions were also introduced in London, Birmingham, Glasgow, Liverpool and Manchester.

Various concessions and reductions in telephone charges were made between 1921 and 1939 with the object of stimulating the growth of the system. In 1922 a lower rental for residence telephones was introduced, and this was followed by other rental reductions in 1923, 1934 and 1936. The charge for a local call from ordinary subscribers was reduced from 1½d. to 1¼d. in 1922, and again to 1d. in 1924; the charge for a local call from call offices was reduced from 3d. to 2d. in 1923. A free-call allowance of 200 local-call units a year for residence lines was introduced in 1936, to stimulate the use of the telephone for social purposes. The present method of multi-fee charging up to 15 miles was also adopted in 1936, with a reduction in some call fees and the withdrawal of timing on calls of 7½-15 chargeable miles, the main object being to facilitate subscriber dialling of calls up to 15 miles.

In the trunk service, too, changes were taking place, and the present system of charging, based on radial mileage, was adopted in 1921. A cheap night rate (half the day rate) was brought in to attract traffic during periods when the expensive trunk circuits would otherwise be lying idle, and an intermediate afternoon rate was introduced in 1922, with a view to diverting some of the traffic from the morning busy hour, and so economizing in circuit provision. Reductions over various parts of the trunk-call tariff were made in 1923, 1924, and 1929. At that time trunk-call charges increased with distance, with no upper limit: thus in 1929 a three-minute call of 500 miles cost 7s. 6d. in the morning, 5s. 6d. in the afternoon, and 3s. 9d. at night. The trunk system had, however, become highly profitable owing to improved engineering techniques, and in 1934 a flat charge for calls beyond 300 miles was introduced, a three-minute call of any distance over 300 miles then costing 4s. during the morning and 3s. 6d. in the afternoon. Probably the most spectacular concession was the introduction of the 1s. evening trunk call for distances over 50 miles, which had a marked and permanent effect on evening trunk traffic. Further reductions in the day rates were made in 1936, bringing the maximum rate down to 2s. 6d. for a three-minute call, and at the same time eliminating the cheaper afternoon rate for calls beyond 50 miles, which had been increasing the afternoon traffic above the level of the morning traffic. Post-war changes in tariffs are referred to later.

The Inland Telegraph Service.

Although inland telegraph traffic increased during the First World War and reached a peak of 80 million telegrams in 1919, it has since declined steadily, and by 1935 telegrams were averaging less than 33 millions a year. To make the service more attractive the basic charge for a telegram was then reduced to 6d., and a new facility was introduced in the form of the Greetings Telegram. Traffic started to rise again, and during the 1939-45 war it averaged over 60 million telegrams a year. Once more, it was demonstrated how important a part is played by telegraphs in time of war, both for military and civil purposes.

After the Second World War, telegraph traffic declined once again. It became necessary to increase the basic charge by successive stages to 1s. 6d., and then to 3s. These increases produced a further decline and telegrams are now being handled at the rate of about 19½ millions a year,

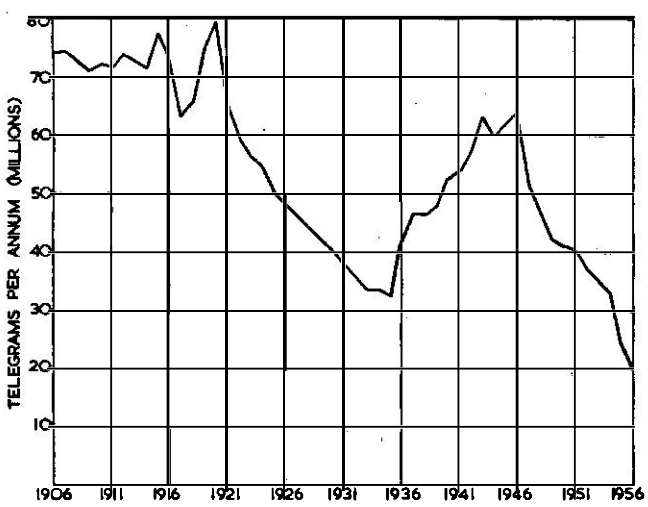


Fig. 4.—Number of Telegrams/Year ending 31st March, 1906 to 1956.

the same level as 75 years ago—just after the Post Office took over the system. The graph in Fig. 4 shows how traffic has varied over the past 50 years.

The inland telegraph service is in competition not only with the telephone trunk service but also with the telephone and telegraph private-wire services and with an efficient and relatively cheap postal service. Undoubtedly, there is a very close link between telephone expansion and the fall in telegraph traffic. As in the telephone system, financial considerations have played an important part in determining telegraph operating policy. At a time when line plant was relatively expensive compared with labour costs, the objective was to secure the maximum output from circuits; with the progressive cheapening of line costs and rising labour costs it became essential to aim at higher operator performance. Labour costs predominate in the telegraph service—a fact which has contributed to the continued deficit of the service. So far as available records show, the finances of the telegraph service have never been in balance, but as a truly national service it is obliged to give unprofitable facilities in the national interest. And also, like the railway network, it is a valuable strategic asset in emergency. The organization of the inland service is also necessary for handling a very large volume of international traffic which cannot be disposed of by the cable companies direct. Attempts have been made to improve the financial position; the concessions of 1935 certainly attracted more traffic, but the increased income did not meet the increased expenditure and the result was an even greater deficit.

Much has been done to improve the telegraph service. The replacement of multiplex equipment by teleprinters, then the introduction of manual teleprinter switching, and finally automatic switching, have done a lot to improve the efficiency of the service and reduce costs. The teleprinter also made possible the provision of a switched telegraph service between subscribers—the Telex service. This service was first introduced in 1932 using the public telephone system for interconnexion. In practice, however, it was found that this telex service could not provide reliable teleprinter communication between all subscribers and offered no advantage over the trunk service in call charges. Accordingly its expansion was limited. The early telex service failed to exploit another new development of that time, the multi-channel voice-frequency system, which made long-distance teleprinter communication both cheap and reliable. More, however, will be said of this later when the present state of the telegraph service, and also the new telex service, are reviewed.

Radio Services.

The rapid development of radio communications during the past 50 years is well known. One of the earliest uses of radio was by ships and, whilst radio telegraphy is still in wide use, many ships to-day are also fitted with radio-telephony, by means of which telephone calls may be made at sea to the public telephone networks of many countries. Ships above 500 gross tonnage are now obliged to carry radio, and all United Kingdom Post Office coast stations maintain a continuous listening watch on distress frequencies. But radio telephony is also being developed considerably for mobile purposes inland. Police and Fire services began to fit radio to their vehicles in 1932, and in recent years there has been a rapid development in providing radio equipment in vehicles used as ambulances, for the fuel and power industry, for public transport and for commercial purposes. In all, there are now 12,000 vehicles equipped with radio, operating through about 1,600 base stations.

The Postmaster-General has had a general responsibility in the radio field from the very early days. His current licensing powers come from the Wireless Telegraphy Acts of **1949** and **1955**, which cover transmitting and receiving stations, including those for broadcasting. The **1949** Act also gives the Postmaster-General power, in consultation with an advisory committee, to make regulations for the control of interference from electrical apparatus.

For the study of radio, as well as for other forms of telecommunication, regular consultations are held with other countries through the media of the International Telegraph Union and its consultative committees, and these are most valuable in co-ordinating methods and in promoting standardization.

Private Services.

This short history of the development of telecommunications in the United Kingdom must necessarily deal primarily with the public services, but it should at least be mentioned that the Post Office also provides private telecommunications facilities for other government departments, public corporations, business concerns, and so on, on a large and ever-increasing scale. Among its many customers the Post Office serves the B.B.C., and more recently the I.T.A., who require communicating links between their broadcasting stations, between stations and studios, and for the purpose of setting up outside broadcasts.

Problems of the Period after the Second World War

Inland Telegraph Service.

Labour costs have always formed a large part of the cost of handling of a telegram, and the upward movement of wages in recent years has therefore greatly added to handling costs. The raising of the school-leaving age has aggravated this situation, particularly as all the regular delivery staff (about a quarter of the whole staff) are juveniles.

In **1953**, with an expenditure of about £8 million and income of only £3½ million, there was a commercial account deficit on the inland telegraph service of about £4½ million, as compared with the pre-war deficit of about £1 million. At the tariff in force (1s. 6d. for 12 words) the situation could not be improved by attempting to attract additional traffic, for expenditure would then have risen more rapidly than revenue. On the other hand, it was realized that any increase in tariff would inevitably cause a further decline in traffic. It was finally decided, in order to reduce the deficit, to raise the basic charge for the inland telegram to 3s. This led, as was expected, to a substantial fall in traffic, but the telegraph deficit was, in fact, reduced.

One flourishing offshoot of the telegraph service, however, is the new telex service. After the war, telex assumed an important role in international communications and, with the United Kingdom more than ever dependent on overseas trade, it became urgently necessary to provide a more efficient service. A completely new system, using a network of multi-channel voice-frequency circuits instead of telephone trunk circuits, was instituted in **1954**. This gives unrestricted national and international communications with cheaper calls. The service began with **1,600** subscribers, and nearly 1,500 more have already been added. Manual switching was adopted in the first instance, but plans are in hand for conversion to automatic working.

Inland Telephone Service.

The problems of the telephone service in the early post-war years were described in an article in a previous issue of the Journal,[1] and a short review of the main features of that article may be useful. At the end of the war there were heavy arrears of plant provision to be overtaken and the release of the enormous pent-up demand for telephone service in **1946** made great inroads into the depleted resources of available spare plant. Plans were made and put into operation for a considerable increase in engineering staff; for gearing up the manufacturing industry to greater output; and for a large increase in telephone exchange building. By mid-**1947** the foundations had been laid for overtaking the bulk of the arrears of development in the telephone service during the next five or six years. Unhappily, however, the financial crisis in the autumn of **1947** made the postponement of this scheme inevitable; the civil engineering labour force was drastically reduced, and urgently needed exchange equipment was allocated to export orders.

There were indications in **1948** that the position was becoming easier, but the financial crisis of **1949** again brought severe restrictions on Post Office investment, and further deferment of schemes for development became inevitable. The expanded national defence program in the following year added to Post Office problems, for not only did it create large and continuing commitments in providing communications for the Services, but it also resulted in many essential raw materials becoming scarce. Thus it became impossible to make ordered development plans for normal civil purposes and, as demands for telephone service continued unabated, the outstanding telephone order list necessarily increased in size, reaching a peak of **560,000** in **1949**. Since then the funds allotted for Post Office capital development have been increased each year and much has been done to increase the rate of supply of telephone service; twice as many telephones are now being fitted each year as were fitted before the war. During the 10 years **1946-1956**, service has been given to more than **3½** million applicants. Demand has continued to rise, however, and despite the high rate of connexion there are still many outstanding applications. Fig. **5** shows how the order list has varied since the end of the war.

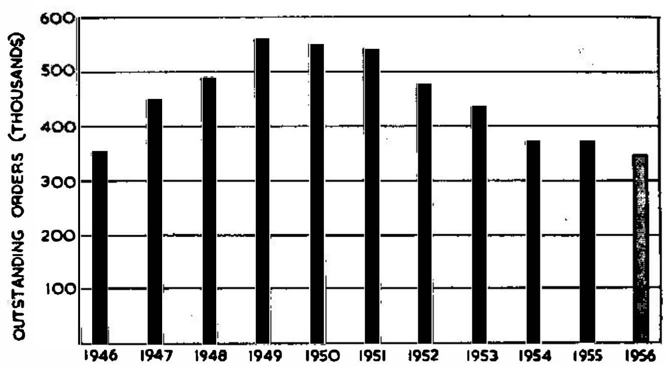


Fig. 5.—Outstanding Orders for Telephones at 31st March, 1946 to 1956.

Shortage of wires in the local cables accounts for more waiting applicants than does any other cause, but the position in this respect should improve in the next few years. The major problem for some years ahead will be insufficiency of exchange equipment, caused by a shortage of buildings in which to house it; the Post Office building program having necessarily been curtailed to meet the dictates of national policy. Expenditure on new telephone buildings has, nevertheless, been steadily increasing for some time, and still further increases are planned.

One feature that has greatly assisted the expansion of the post-war telephone service, despite the shortage of local line plant, has been the introduction of shared service. There had always been some form of party-line service in the telephone system, but before the Second World War it had been little used. There was the rural party-line

[1] Barnett, B. L. Post-War Telephone Developments. *P.O.E.E.J.*, Vol. 40, p. 145, Jan. 1948.

service for farmers, and also a two-party-line service, and in 1934 a Group Service had been developed which provided for serving up to eight subscribers in the same locality, from a control unit connected with the exchange by two pairs of wires. This last service was designed not so much to conserve line plant as to provide a cheaper form of service than could be given on exclusive lines.

During the war the Post Office was obliged to introduce sharing as a means of providing service which could not otherwise be given for some time, and this was continued afterwards as a recognized service. It became evident that, in the difficult circumstances that existed, the use of shared service on a really extensive scale offered a valuable means of using inadequate local line networks to better advantage, and so permitting service to be given quickly to as many people as possible. The Postmaster-General accordingly announced in Parliament towards the end of 1947 that all new and removing subscribers would be obliged to accept a liability to share their lines if called upon. The effect of this decision has been spectacular, for the number of shared lines rose from 132,000 in 1949 to almost 1,100,000 in 1956, and is still increasing at a rate of over 25,000 a quarter.

The telephone service has, like all other services, been greatly affected by rising prices, though staff costs do not play relatively so great a part in its operations as they do in the telegraph service. The 1939-45 war left the Post Office with its pre-war trunk charges increased by 50 per cent and other charges by 15 per cent, its tariffs widely out of relativity with costs, and rising wages and costs to be faced. The trunk service was profitable, but there were deficits on exchange line rentals and local call charges. The effects of increasing labour costs have been felt almost continuously since the war, but rising plant costs have affected the balance sheet more slowly, partly because of limitations in capital investment, but more especially because provision for depreciation was continued for a long time on the basis of pre-war prices.

The pre-war trend of tariff reductions has therefore had to be replaced by one of tariff increases. In 1949 the subscribers' local-call unit-charge was raised to 1½d.; in 1951 the call office charge for a local call was raised from 2d. to 3d.; and in 1952 subscribers' rentals were increased to 50 per cent above the pre-war level. More recent tariff changes were announced in the 1955 White Paper.[2] Telephone rentals were raised to an average of 80 per cent above pre-war; the local-call unit-charge was raised to 2d. on 1st January, 1956, and to 2½d. on 1st July, 1956; the call-office charge for a local call is to be raised to 4d. on 1st January 1957; and the evening trunk-call charges to about two-thirds of the full day rate.

These revisions of tariff formed part of a comprehensive review of Post Office finances made in agreement with the Treasury. The White Paper of 1955 recognizes that it is essential for the ordered development of the telephone service that the Post Office should work to a three-year plan, particularly as many of its projects take a number of years to complete. It records an agreement with the Treasury that the Post Office shall return to the earlier "Bridgeman" concept of "self-contained finance." This means that the Post Office will in future pay to the Exchequer a fixed annual contribution of £5 million —roughly the amount it would have to pay in taxation if it were a private concern—and will retain as a revenue reserve any remaining surpluses. In return the Post Office is under an obligation to ensure that, taking one year with another, expenditure and income are in balance.

[2]Report on Post Office Development and Finance (Cmd 9576). Presented by the Postmaster-General to Parliament by Command of Her Majesty, October, 1955 (published by H.M. Stationery Office).

The Future

Looking back over the past 50 years, one cannot but be impressed by the progress which has been achieved, and by the tremendous developments in the telecommunications field brought about by scientific thought and technical skill. But what of the future?

There seems little doubt that the public inland telegraph service will continue to decline as the telephone system grows, and is never likely to be self-supporting; but, so far as can be foreseen, there will always be a need for the facilities that it offers, particularly in times of national emergency. However, there are great hopes for the future of the telex service. The automatic system now being planned will enable subscribers to dial national and international calls, and it should provide a speedier and more efficient system which is certain to expand considerably as its value to commerce and industry becomes more widely appreciated.

It is undoubtedly in the telephone service that there is the greatest scope for expansion. The seven-millionth telephone was installed in this country during the summer; but it is still a far cry to the time when every home will have its own telephone. The most pressing task is to overtake the arrears of unsatisfied demand for telephones, but in the meantime, mechanization of the local and trunk exchanges is also proceeding and plans are being made for further modernization of the service and improvement in the facilities it offers.

The first installation of a new system enabling subscribers to dial their own trunk calls will be brought into use at Bristol in 1959. From the outset, subscribers will be able to dial calls to most of the large cities in the United Kingdom as well as to smaller towns nearer Bristol. Similar facilities will then be provided at other towns and later they will be extended to calls routed indirectly; for example, from Bristol to Dover via Tunbridge Wells. Coin boxes of a new types are to be introduced by means of which call-office users will also be able to dial trunk calls. The next step will be to introduce subscriber dialling on some international calls.

It will take a long time to reach the ultimate stage of automatization, but it no longer seems such a distant goal as it did a few years ago. Research into improved types of exchanges is being pursued with vigour and in a few years we may have our first all-electronic telephone exchange, which should bring with it reduced maintenance, increased speed of operation and greater compactness. One thing is abundantly clear: striking as are present-day achievements in the field of telecommunications, the achievements still to come are certain to be even more impressive.

Telegraphy

By 1906, 70 years had already elapsed since the opening of the first operational telegraph circuit, and a major preoccupation was the transfer of the main overhead telegraph circuits to underground cables. Methods of operating the long-distance circuits included the Wheatstone, Murray, Baudot, Hughes and quadruplex Morse systems, and Wheatstone speeds of 400 words/min were commonplace. The development of the telegraph service is traced from that time to the present day, when the page-printing teleprinter has supplanted other instruments in the inland network and connexions are established via automatic telegraph exchanges. The growth of the telex service and the development of facsimile telegraphy are also described.

Early Telegraph History

In 1908, Sir John Gavey, the first President of the Institution of Post Office Electrical Engineers, wrote in his "Words of Welcome," to the first issue of the Journal:

> " . . . even as recently as 40 years ago, telegraphy was the only existing branch of electrical engineering, and when the present Institution of Electrical Engineers was founded in 1871, with the title of The Society of Telegraph Engineers, it fully represented the whole of our interests."

The idea of the "sympathetic needle" for communicating intelligence over great distances is very old indeed. It is fascinating to read[1,2] of the practical attempts that were made to establish alphabetic electric telegraphy (often using one wire per symbol), even before the work of Volta made possible a continuous source of electric power and so prepared the way for Oersted and Ampere to demonstrate the magnetic effect of the current.

Early in the 19th century, Cooke in this country produced improved instruments, using various numbers of line wires and magnetic needles from one to five, and in 1837 he collaborated with Wheatstone to provide the first operational telegraph circuit in the United Kingdom, for the railway between Euston and Camden Town. In the same year the electromagnetic relay was invented by Davy. Attempts to lay lines underground were unsuccessful because of poor insulation resistance, and for a long time development in this direction ceased in favour of overhead lines. In the public eye, interest was quickly awakened to the potentialities of the telegraph by the dramatic arrest of a murderer in 1845 as a result of a message sent over a circuit between Slough and Paddington. Single-needle and double-needle instruments in association with some form of code soon became established in this country, the double-needle being favoured by the railways, but with the gradual improvements in line insulation, constancy of battery performance, and instrument production, the sounder slowly superseded the single-needle instrument on Post Office circuits. The double-plate sounder, which enjoyed a long period of popularity until about 1880, consisted of a polarized relay and a pair of sounders, fitted with sounding plates of brass and steel, respectively, to denote dot and dash signals by different notes. Wheatstone's more expensive ABC instrument, which appeared in 1840, remained in use until long after 1900.

Apart from attempts at duplexing, two outstanding inventions between 1850 and 1875 were the printing system introduced by David Hughes, of Kentucky, in 1855, and Wheatstone's automatic system, which was patented in 1858, and when first brought into use in 1867 operated at 70 words/minute(w.p.m.) The Hughes system (Fig. 1) was an improvement on House's system of some seven years earlier; it used a piano-type keyboard and printed at 60 w.p.m. Hughes printers were in use longer than any other type-printing instrument, their supremacy declining only as the result of demand for greater speed; in fact, three such circuits were still in operation at the Central Telegraph Office (C.T.O.) up to 1939.

A time-division system had been proposed by Wheatstone in 1841, and successful experiments with such a system were carried out by Farmer ten years later. Meyer, in 1871, devised a four-channel system, using keyboards having eight keys and printing Morse characters on paper tape. Baudot combined a printing instrument with the multiplex principle and, most important of all, used a code with five units of equal length, and in 1877 the French Administration decided to adopt Baudot's system. A keyboard perforator (which punched square holes in a paper tape) and a synchronous automatic tape transmitter were designed by Carpentier in 1887, but these instruments were not used in the telegraph services until much later.

Meanwhile, after taking over the private telegraph systems in the United Kingdom in 1870, the Post Office began to adopt duplex working extensively many years before it was used by other Administrations, although poor insulation resistance of lines and difficulty in obtaining accurately differential instruments presented a number of problems. Quadruplex circuits also came into use at this time (1872), and the first mobile telegraph office, complete with batteries and half a mile of three-wire iron-sheathed cable, was brought into service in 1873. In 1886, the American Delaney multiplex system appeared: despite many admirable devices such as the vibrating reed and phonic-wheel control, its use was abandoned in this country in 1903 after three years' trial, on account of the inherent mutilation of the signals. It used the Morse alphabet, fundamentally unsuited to multiplex systems, and was worked by key and sounder at 25 w.p.m.

The Post Office were slow in adopting the Hughes

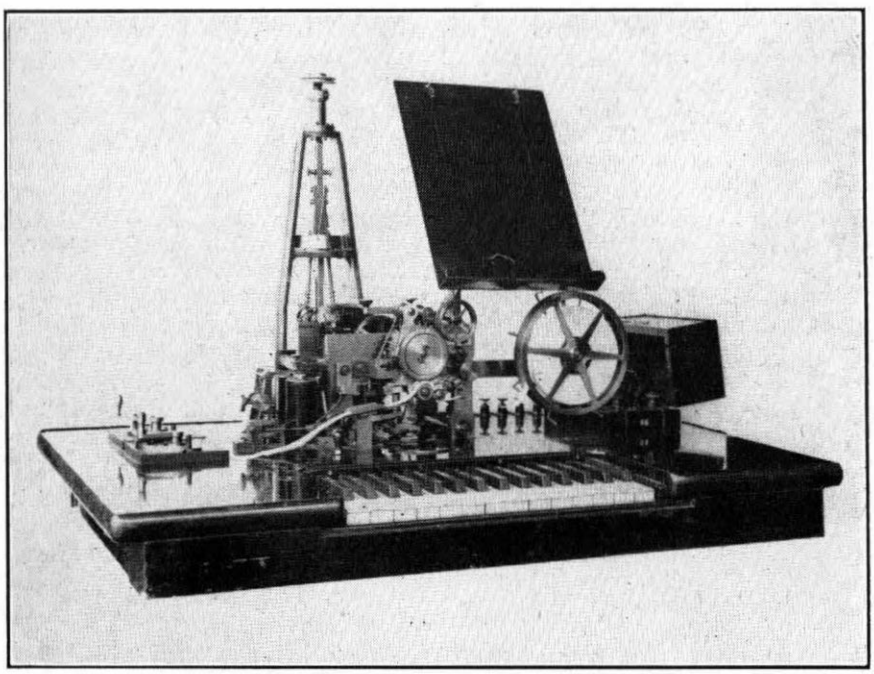


Fig. 1.—The Hughes Instrument.

Fig. 2.—The Metropolitan Gallery, Telegraph St. (1871).

instrument because of its cost and the special training needed, although it was used widely on the Continent, but, with the acquisition of the Submarine Telegraph Company by the Post Office in 1889, the Hughes instrument came to be used extensively on Anglo-Continental circuits, the Post Office Factory making its own instruments from 1890, which used an electric motor in place of the original pedal-wound weight drive.

A 12-channel v.f. system was introduced by Mercadier in 1895 employing frequencies in the range 480 c/s to 900 c/s, tuned headgear receivers being used for reception, but this system caused interference with telephone circuits, and so did not progress beyond the trial stage.

In 1901 the Murray high-speed automatic type-printing system was introduced, only to be abandoned after more than ten years of trials on London–Edinburgh, London–Dublin and London–Berlin circuits. The equipment comprised a keyboard perforator (40 w.p.m.), automatic transmitter (120 w.p.m.), reperforator and column printer (100 w.p.m.), and incorporated such novel features as phonic-wheel drive and speed correction from the intelligence signals themselves; in the tape all perforations appeared longitudinally on one side only of the centre holes. Murray later focused the attention of telegraph engineers upon start-stop working and the five-unit alphabet.

It is interesting to note that in the early trials of keyboard perforators each perforator was associated with an automatic transmitter, which was automatically switched to the line, under the control of perforations inserted in the tape by the perforator operator after a given batch of messages. The line was shared by two automatic transmitters.

The Telegraph Scene Between 1906 and 1908

By 1906-1908, 70 years had elapsed since the opening of the first operational telegraph circuit, and the International Telegraph Union—the oldest intergovernmental organization—had passed its 40th anniversary. In February, 1908, at the annual dinner of the Engineering Department, the Engineer-in-Chief, Major O'Meara, claimed that the British telegraph service was acknowledged throughout the world to occupy the premier position. Competition from the telephone system had, however, already caused a considerable reduction in the number of messages circulating from one part of London to another.

A major preoccupation was the transfer of the main telegraph circuits to underground cables to afford greater security from storms, and the Northern and Western Underground telegraph cables were well on the way to completion.

The standard method of working inland circuits was by some form of duplex system using sounders: a side-stable polarized sounder had just been introduced which responded to double-current signals produced from a single-current battery at the central office, by the charge and discharge currents of a capacitor. The non-polarized sounder had had its day as a line instrument, because of its heavy power consumption, the troubles due to unskilled adjustment of the associated polarized relay, and the sounder-chattering caused by the response of this sensitive relay to voltages induced into underground circuits. At central offices where secondary cells were not available, groups of bichromate cells were installed.

At the C.T.O., which had been opened in 1871 and replaced Telegraph St. ("TS"), Moorgate (Fig. 2) as the chief telegraph office of the Post Office, Metropolitan sounder circuits, as well as certain provincial circuits, were operated via new switching equipment (Fig. 3). The equipment used lamp calling and clearing, and by saving nearly 4,000 transactions a day, reduced the average cross-London delay from 18 minutes to five. To accommodate some 150 short provincial omnibus lines, each serving two or more offices, a two position central-battery concentrator

Fig. 3.—The Metropolitan Gallery, C.T.O. (1911).

with lamp calling and clearing was installed in the C.T.O. Coincident with the new installations in the C.T.O., a task of considerable magnitude was completed—the conversion of all the London offices to central-battery (C.B.) working—and great economies were achieved from the abolition of well over 1,000 scattered groups of primary batteries.

Many miles of pneumatic tube had already been laid between branch and head offices; on the longest tube circuit, connecting the House of Commons to the C.T.O. (3,992 yd), the transit time was just under eight minutes.

Long-distance overhead circuits within the British Isles could be operated commercially by Wheatstone apparatus at speeds up to 300 w.p.m. duplex and 400 w.p.m. or more simplex; some quadruplex circuits were also in use. The Wheatstone system had changed very little since its introduction many years earlier. Trials were being made with electric-motor-driven transmitters, the main problem being the achievement of constant speed. Perforated tape was prepared by the three-punch "stick" perforator, but operation of this device for long periods was very tiring. To increase the speed of punching tape, trials were being made with early designs of alphabetic keyboard perforator, but they were not entirely successful. At the receiving end the process of transcribing messages from the Morse signals recorded by an inker upon a paper tape, often under artificial light, caused considerable eye-strain. As a result this system tended to fall into disuse.

Circuits to the European capitals were operated by printing telegraph systems, using the Hughes apparatus except for a single Baudot system to Paris. The Post Office operated five repeater stations, at Nevin, Llanfair and Haverfordwest on the Irish cables; at Lowestoft and N. Walsham on the Continental cables. Nevin, for example, had nine Wheatstone duplex and two quadruplex repeaters, the latter carrying Wheatstone and key signals. The Post Office standard B relay was firmly established. At repeater stations, sounders repeating all signals were the cause of great inconvenience, and silencers were being provided which could be rendered inoperative from the distant station when it was necessary to call the repeater staff. Repeater stations were being converted to secondary cell working, to replace the many groups of line and local batteries whose maintenance occupied the full time of one man.

At this time an investigation was being carried out into the speeds and relative economics of various methods of operating long-distance circuits, including Wheatstone, Murray, Baudot, Hughes and quadruplex Morse. Although the quadruplex system worked for many years on London–Dublin and other long circuits, with Wheatstone on the "A" (polarized) side and key at 25 w.p.m. on the "B" (incrementing) side, there was a tendency to split the keyed signals, and the repeater with its 12 relays and 15 separate batteries (368 bichromate cells) was troublesome to adjust; hence it cannot have been a very stable system.

In the large offices secondary batteries were installed to provide $\pm$40V, $\pm$80V and $\pm$120V. The 80V and 120V sections were used only on the longer circuits and the loads at these voltages were lower than at 40V. A novel form of no-break rotary switch was therefore used to enable four sets of 40V cells to be cyclically switched, every two or three days as required, to occupy progressively different positions in the battery; each set in turn becoming available for charging, after which it carried the heaviest load (40V).

A Period of Transition (1908-1928)

From 1908 onwards the effect of the growth of the telephone service on the shorter-distance telegraph services became more pronounced. In the provinces, as well as in London, short-distance telegraph traffic decreased rapidly, and phonogram and telephone-telegram working were introduced. As fast as exchanges were installed in rural areas, Wheatstone ABC, Morse sounder and single-needle instruments, which had hitherto served small offices, were replaced by telephones used jointly for a public call-office and as a means of disposing of telegrams, and by 1915 one-half of the 14,000 telegraph offices were operated by telephone. This process continued steadily until 1932, when the last inland Morse circuit in the C.T.O. was closed, quietly and without ceremony, and Morse working was only retained in the inland system for a few circuits.

This period saw the rationalization of power supplies in telegraph offices. In the first place, conversions to central-battery working obviated the need for large numbers of scattered groups of primary cells, and the standardization of an improved Leclanché cell in 1911 led to the gradual abandonment of Daniell and bichromate cells. Secondly, as the spread of electric power mains brought charging facilities, conversions to secondary cells were steadily made, with considerable reduction in battery maintenance costs. Secondary cells in the C.T.O. replaced 5,000 "Z" cells used on underground loop circuits up to 1919; at the same time a ring-main was run to Fleet Street, so replacing 3,000 primary cells in newspaper offices by power supplies fed from the C.T.O. As secondary-cell batteries became universal the trend towards C.B. working was halted to obtain the improved transmission performance of double-current working.

During this period an extensive program of installing concentrator switchboards (including also some for phonograms) was completed at offices in all large towns. To dispense with the need for switchboard operators, this phase of evolution culminated in the installation of small automatic concentrators for trial at C.T.O. and Leicester (1923), and ancillary concentrators (for lines from "forwarding only" offices) which enabled the switching to be done by the receiving telegraphist. At this stage (1925) the London Intercommunication Switchboard, which had been a conspicuous feature of the London telegraph system for over 20 years, was finally closed down.

The important changes of this period, however, were in the methods of long-distance operation, though they were in fact destined to revolutionize all forms of telegraph working. Development proceeded along three lines, automatic high-speed transmission, multiplex systems, and direct keyboard transmission. For a long time competition was between the first two, typified by the Wheatstone and Bandot system; the former, after initial success, yielded to the latter, but both finally gave way to the third.

Against the high transmission speed of the Wheatstone automatic system must be set the disadvantages of operating methods which, being slow, needed a team of sending and receiving telegraphists to feed the line and handle the output. Indeed, these very disadvantages had, over a long period of years, brought about a tendency to revert to key and sounder except for special arrangements, breakdowns and press work. To speed up the rate of tape perforation, trials had been carried out for many years with keyboard perforators whose punches derived their power from a pneumatic source, from electromagnets or from an electric motor: the successful keyboard perforator solved the Wheatstone sending problem. At the receiver, the dot and dash slip from the inker was transcribed—whether for delivery or for re-transmission—by one or more operators, and delays were frequent. A revised operating procedure, known as "Systematic Wheatstone Working"[3] was introduced in 1908, in which all Morse slip was gummed on message forms, that for delivery being transcribed direct, using typewriters, and through messages being re-transmitted without transcription, so reducing the error-rate as well as the delay. Such was the improvement that at Edinburgh, for example, it enabled four out of

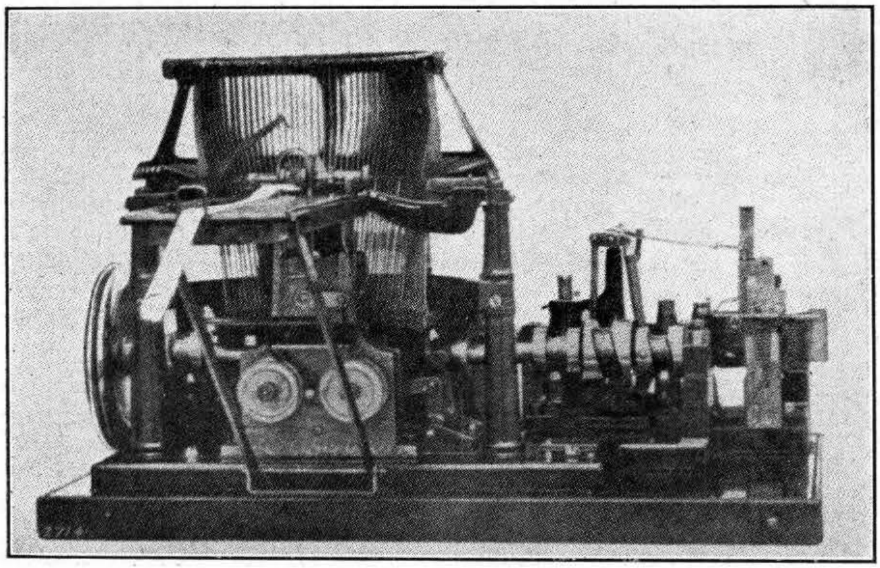


FIG. 4.—EARLY CREED PRINTER.

six London–Edinburgh circuits to be closed down, as well as the direct London–Inverness and London–Leith circuits. In London this procedure could not be carried out owing to the size and dispersion of the instrument room, but trials were in hand with a Creed reperforator and a Creed printer (Fig. 4); the reperforator automatically reproduced a perforated tape, at 150 w.p.m., which could be used direct for re-transmitting telegrams, or fed into the printer for producing a tape printed in Roman characters at 100 w.p.m., ready for gumming up. The subsequent improvement and adoption of keyboard perforators, reperforators and printers together with the provision of automatic transmitters, all electrically driven, put the Wheatstone automatic system on a firm basis in a form which is still in use for some radio circuits.

In Britain, multiplex systems were not looked upon with favour, largely due to the unsatisfactory results of the trials of the Delaney system and to some reluctance to embark upon large-scale adoption of any one system while other promising systems were under trial. True, a London–Paris Baudot system, working two channels simplex, had been operating satisfactorily since 1897, but in that form its output was no better than Morse-quadruplex and inferior to Wheatstone. In 1910, quadruple-duplex equipment was available for trials on a loop circuit in the London–Birmingham cable, and double-duplex trials were also made on a London–Berlin circuit. The French had long abandoned their only attempt to duplex the Baudot, on a Paris–Nantes single-channel circuit in 1887, on account of balance troubles coupled with the lack of any real justification for duplex working on that particular route. The protagonist of the Baudot duplex system,[4] against those who doubted its practicability, was A. C. Booth of the Post Office Engineering Department, and it was largely due to his efforts that the duplex Baudot was adopted, not only for the inland service, but also to displace the slower Hughes system on many Anglo-Continental circuits. Indeed, the British Post Office supplied apparatus and engineers to some of the foreign capitals to collaborate in setting-up Baudot circuits, and later supplied duplex repeaters to the French Administration for use on the London–Paris triple-duplex circuits. A lot of work was done to determine the relative efficiency of double, triple, quadruple, quintuple or sextuple Baudot, simplex or duplex, on any particular circuit whose Wheatstone speed was known. At 30 w.p.m./channel, the sextuple duplex was capable of maintaining 180 w.p.m. in two directions and provided formidable competition with the Wheatstone system at its best. As the result of consistently good performance the Baudot duplex system became firmly established technically in this country, so much so that in January 1914 the Postmaster-General appointed a Committee to inquire into high-speed telegraph systems. Telegraph engineers were rapidly coming to the opinion that the most promising line of telegraph progress was in type-printing multiplex systems.

A disadvantage of the Baudot system (Fig. 5) was the method of sending, which required the operator to memorize the 5-unit code in order to manipulate the five piano-type keys and to keep in exact cadence with the distributor. In the Murray and Western Electric multiplex systems, which the Post Office put on trial, the sending process was simplified by the incorporation of keyboard perforators coupled with automatic transmitters; other innovations were the use of phonic motors controlled from vibrating reeds to drive the distributors at a speed of 40 w.p.m./channel, and the introduction of page printers.

With the First World War telegraph traffic increased—91 million messages were handled in the United Kingdom in 1915. As a consequence the number of Wheatstone and Baudot systems had increased appreciably by the time the report of the High-Speed Telegraph Committee[5] was published in January 1916. The main conclusions of this committee endorsed the definite superiority of multiplex systems over high-speed automatic transmission for inland

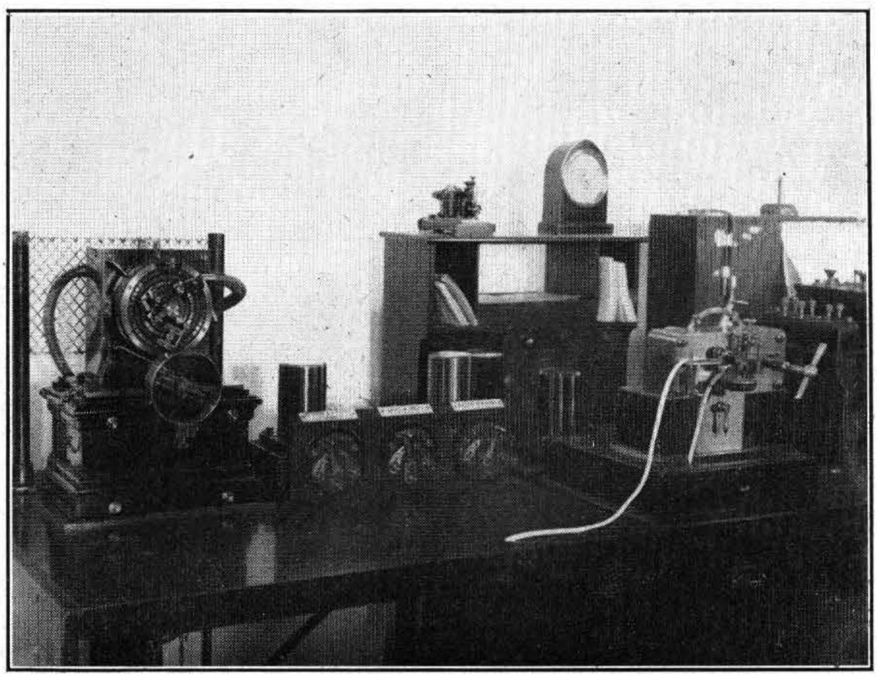


FIG. 5.—BAUDOT DISTRIBUTOR AND RECEIVER.

commercial traffic, and advised the gradual supersession of systematic Wheatstone by multiplex working. Other recommendations were that automatic transmitters be added to the Baudot equipment; that the 5-unit code was superior to Morse (excluding news traffic and submarine cable working); and that the application of printing telegraphy to less important circuits should be kept in mind. The committee also thought that page receivers were preferable to tape receivers.

After the committee's report, and particularly after the war, when apparatus was more easily obtainable, the use of duplex Baudot systems (mostly quadruple) extended rapidly both for the inland service, at the expense of Creed-Wheatstone and Hughes systems, and on Anglo-Continental circuits, where it superseded the Hughes system and doubled the output. The Baudot receiver was fitted with a mains-driven motor, the improvements already mentioned were incorporated in the later Baudot apparatus, and the speed was increased to 35 w.p.m./channel. By 1922 the number of Baudot channels had reached 700. The re-transmitter, a simple device which allowed channels to be coupled together and regenerated the signals, gave a certain amount of flexibility in utilization, though not without some complexity in connexion with speed control. This program of expansion was only halted by the decline in telegraph traffic which set in during the second half of the 'twenties. In all this program, and particularly on cable circuits, a most important part was played by the vibrating relay, invented by Gulstad in 1898, by means of which the performance and speed of operation of the circuits were appreciably improved.

In the early 1920s came the first of the radical changes to be made in telegraph technique and operation. In 1912 the first start-stop instrument had appeared in America, having been developed over a period of 12 years and more by Krum, a cold-storage engineer, financed by a Chicago millionaire named Morton. Far ahead of its time, this instrument used a typewriter keyboard in conjunction with a 5-unit code, and printed on a page. Some years later Morkrum instruments printing from a typewheel at 40 w.p.m., and known to the Post Office as the Teleprinter No. 1A, were giving satisfactory service in trials on two circuits in London. This was followed by other trials on longer circuits, and a Morkrum type-bar instrument working at 60 w.p.m. (Teleprinter No. 2A) was tried in 1925, one such instrument being used for booking calls over the new London–New York radio-telephone circuit. Other teleprinters[6] were also tried and by 1928 it was possible to standardize on the Creed No. 3A model with tape-printing at 65 w.p.m. for the inland service.

The general adoption in the early 1920s of loaded and repeatered underground cables for long-distance telephony raised fundamental problems in the transmission of telegraph signals through telephone cables. Investigations of d.c. transmission covered composited and superposed working; balanced circuits; and the design of new relays, such as the standard H relay, of increased sensitivity to work over long distances at reduced voltage and current. The solution to this problem of operating telegraph circuits in telephone cables clearly lay in voice-frequency telegraphy[7] and, following the development of filters, the first trials in this country were made in 1925 with Siemens-Halske 6-circuit v.f. telegraph equipment working over 40-lb loaded London–Derby and London–Manchester loops; then, in the following year, trials were made with a General Electric Company's 6-circuit v.f. equipment working over a London-Leeds, and later a London-Glasgow, circuit. In both equipments valves were used as oscillators (the G.E.C. equipment with tuning-fork control), amplifiers and detectors. The circuits used in the trial were equipped with Teleprinters No. 3A, of which several hundred were then in operation, some having already superseded Baudot apparatus.

For some time the need for standardization of alphabets and keyboards had been urgent. The Baudot system itself had variants for inland and international working, while the Murray system differed from both. The Baudot alphabet was designed primarily for ease in memorizing and manipulation on five keys, with the result that in keyboard working the numerals became scattered over the keyboard. The Murray alphabet was designed to take account of frequency of occurrence of letters in the English language, and so maintain the strength of perforated tape by punching the least number of holes in it; also, figures appeared in numerical order on a single row of keys.

The International Telegraph Union had never extended its activities far into the technical field, but in 1926 an organization was established to deal with technical matters, the International Consultative Telegraph Committee (C.C.I.T.). At its inaugural meeting in Berlin, in 1926, the C.C.I.T. decided to study the standardization of a single international 5-unit code based on the Baudot alphabet. A sub-committee was given the task of studying the problems of co-existence of telephone and telegraph circuits in the same cable. Until 1926 the only means of assessing the transmission efficiency of a circuit was in terms of its possible Wheatstone speed, or less precisely in its message-carrying capacity. At its first meeting the C.C.I.T. defined and recommended the baud as the unit of modulation rate, to honour the memory of Emile Baudot. At its second reunion (1929), held also in Berlin, the C.C.I.T. recommended the adoption of two codes: the International Alphabet No. 1 for multiplex systems; and the International Alphabet No. 2 for start-stop systems. Both were basically Baudot codes but the latter had the secondary symbols re-arranged to suit keyboard layout, made provision for page teleprinters and included a change in the erasure signal to cover the use of perforated tape. This form of the Alphabet No. 2 was not, in fact, adopted; it was changed by a C.C.I.T. sub-committee, which met in Berlin in July, 1931, and was replaced by what was practically the Murray alphabet, differing extensively from the Baudot alphabet. The other more important recommendations of the 1929 reunion were a 50-baud standard for start-stop apparatus (the Creed No. 3A teleprinter worked at 49 bauds); the choice of negative polarity for the start signal and positive for the stop signal (this recommendation was not, however, adopted in this country, where the opposite conditions already prevailed); and the use of 7-unit start-stop receivers. The maximum permissible power (5 mW) for v.f. multi-circuit systems was also established and a sub-committee was appointed to study the question of frequency division for v.f. multi-channel systems.

The Teleprinter and V.F. Era

With the introduction of the teleprinter and the development of a network of v.f. telegraph circuits, telegraphy changed its character completely.[8]

The v.f. network introduced complete flexibility as well as great economy in the provision and utilization of telegraph circuits, all with identical characteristics; it also removed the distinction between telegraph and telephone plant so far as cables and transmission equipment were concerned.

The teleprinter provided direct working to line at an adequate speed, and with the introduction of the page model (No. 7) in 1932 a telegraph instrument was available which, from its essential similarity to a typewriter, could be put into ordinary commercial offices.

As a result of these changes the techniques of testing and maintenance, for the first time, acquired precision in measurement. At its Third Reunion (Berne, 1931) the C.C.I.T. began to make recommendations for the measurement of distortion and margin, in addition to standardizing the carrier frequencies for multi-circuit operation. In the same year a 12-circuit system to the new 120 c/s spacing was in operation between London and Dundee.[9] Apart from superseding the polarized sending relay by a static modulator which appreciably reduced distortion, the design of this equipment was not changed until 1951 when a new detector of improved performance was introduced and the physical design changed. It has not yet proved practicable to displace the polarized telegraph receive relay.

In 1932 development in superposing had reached the stage where it was possible to offer by-product point-to-point teleprinter circuits—phantoms and double-phantoms—on main cable routes at rates that were attractive to the renter and remunerative to the Post Office. An extensive private-wire teleprinter service was built up on this basis, until circumstances forced abandonment of this method of providing teleprinter circuits, by which time the v.f. network had grown sufficiently to cater for the growing private-wire service.

For a long time telegraph engineers had advocated the introduction of a telegraph exchange service, but, in the absence of a universal telegraph instrument and sufficient relatively inexpensive similar circuits, those systems that had been tried, such as the sounder intercommunication switch, the Wheatstone ABC exchange, and the telewriter exchange, catered only for local services. In 1932 the Post Office was a pioneer in introducing a telex service which, with only a limited v.f. network and demand for service, was based on the use of telephone exchanges and the telephone network; transmission was on a 300-c/s (later 1,500 c/s) carrier, and page teleprinters were used. A "printergram" service was introduced for the direct handling of telegrams between business houses using the service and telegraph offices. In 1936 a limited service with the Continent was opened, using 1,500 c/s transmission.

In the public telegraph service the introduction of the tape teleprinter (No. 3), in association with v.f. circuits for the greater distances, quickly became universal. Instrument rooms acquired a new appearance with the introduction of double-tables and conveyor belts; the auxiliary apparatus which had hitherto encumbered operating positions was removed and mounted on apparatus racks. In the new conditions it became possible to envisage an automatically switched telegraph system, thus directly attacking the age-old problem of reducing the number of times that telegrams were re-transmitted. A Re-transmissions Committee set up to study the problem reported in favour of a national teleprinter automatic switching system. Switching equipment was designed and successful large-scale field trials were held, but plans for the introduction of a pilot stage of the network were suspended on the outbreak of the Second World War.

One result of the war was the decentralization of telegraph operating from zone to area centres, a step which involved an increase in re-transmissions and in staff. To reduce this extra work, it was decided to introduce a switching system with manual switchboards at six zone centres, the first two being brought into service early in 1944.[10] The completed program required the use of more than 1,500 circuits at 134 multiple switchboard positions, some 75 per cent of the total public traffic being handled in this way. Manually switched teleprinter networks were also set up for the Services,[11] for various Ministries, and for other important users, with the result that the v.f. network expanded considerably.

Radio teleprinter circuits were also brought into use, employing two-tone and frequency-diversity transmission.[12]

After the war the resumption of telex working with the Continent became urgent; it was at once decided that this service should be on the basis of a network of exclusively telegraph circuits using standard v.f. multi-circuit working. Temporary switchboards, which were quickly built, enabled service with Holland to be re-opened early in 1947; this was followed by considerable expansion until at the present time the international telex switchboard in the C.T.O. (Fig. 6) has more than 70 positions giving access to practically every European country, as well as to the whole of the United States and to parts of Africa. It is notable that since 1948 connexions with European subscribers served by automatic telex networks have been established by direct dialling from the C.T.O. switchboards.

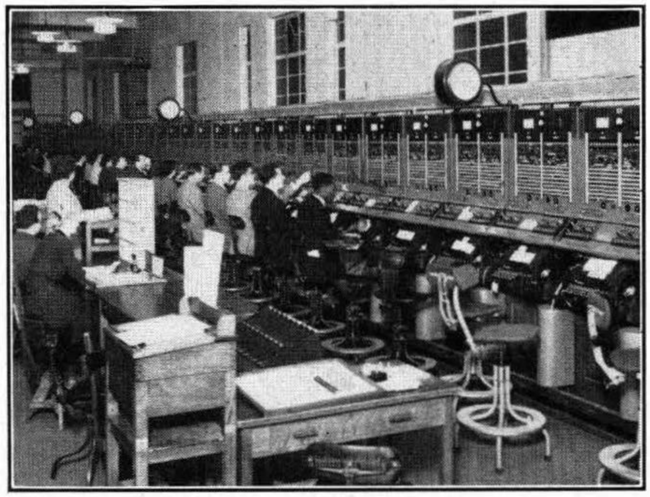


FIG. 6.—THE INTERNATIONAL TELEX SWITCHBOARD, C.T.O.

For some time it had been apparent that operation of the inland telex service on the telephone network suffered from certain disadvantages, and a Committee set up in 1947 to study this question recommended the establishment of a new inland telex service using a network of exclusively telegraph circuits, to be started temporarily by using manually operated switchboards. The final stage in this conversion program was completed in 1954, giving complete flexibility between the inland and international telex services. At the present time there are just over 100 inland switchboard positions and approximately 3,000 subscribers.

The period of post-war activity included the conversion of the whole of the inland public network from manual to fully automatic working. The deferment of the pre-war switching scheme was not without advantage, since it gave the opportunity for further thought on signalling methods and resulted in the adoption of principles that were laid down for the telex service at the Sixth Reunion of the C.C.I.T. (Brussels, 1948). The conversion of the public service to automatic switching,[13] involving the opening of 22 telegraph exchanges serving 2,200 lines and the introduction of a new teleprinter (No. 11) conforming to international standards, was completed early in 1954 and has been very successful (Fig. 7).

Concurrently with the adoption of the principle of random selection of v.f. circuits to form switched connexions, much work has been done in the design and utilization of electronic equipment for measuring and analysing distortion and investigating its cumulative effect in tandem-connected circuits.

FACSIMILE TELEGRAPHY

Facsimile telegraphy is almost as old as electrical telegraphy itself, having been introduced by Bain in 1842, using a receiver which recorded from five electrodes in contact with a moving tape of chemically treated paper, so reproducing letters that had been set up in metal type and scanned by five metallic feelers at the transmitter. The following year Bain patented an instrument in which scan-

FIG. 7.—MODERN INSTRUMENT ROOM, EQUIPPED WITH TELEPRINTERS NO. 11.

ning and synchronizing were based on his electromagnetically-maintained pendulum; the swinging pendulum carried a scanning stylus and also controlled a traversing mechanism.

Bakewell, in 1848, patented a "copying telegraph" which laid the foundations for the design of orthodox present-day facsimile equipment. His instrument embodied a drum around which was wrapped the message form to be scanned, and an electrical contact device, traversing by means of a lead screw, scanned the message form. The message could be written in insulating varnish upon metal foil, or alternatively written upon a varnish-coated foil with a sharp point to expose the metal; recording, which could now include drawings, was again on chemically treated paper.

Various forms of non-facsimile chemical telegraphy were also in vogue for some years, and around 1910 the Siemens Photoprinter and similar machines used photographic paper for reception of printed characters: both these methods of telegraphy were capable of recording at speeds far in excess of existing electromagnetic means.

With improvements in electromagnetic telegraph instruments, facsimile telegraphy declined for some time until interest was revived following the development of photography. Some early work was carried out by Korn, who transmitted pictures by radio from Berlin to Paris in 1913. Ten years later a system was in use for transmitting pictures with limited tonal gradations by the use of ordinary five-unit perforated tape in conjunction with an automatic transmitter and reperforator: though special equipment was needed to prepare the tapes and record from it, the transmission itself was entirely by conventional telegraphic means.[14]

By the late 1920s the developments in photo-emissive cells, electronics, valve-maintained tuning forks and quartz crystals, and the availability of channels of suitable characteristics enabled picture transmission of reasonable quality to be realized. In 1928 the Post Office provided four-wire circuits into newspaper offices equipped with Bell or Belin photo-telegraph apparatus, and in the following year a public photo-telegraph service with Continental stations was opened with the installation in the C.T.O. of a Siemens-Karolus equipment.[15] At its Second Reunion (Berlin, 1929) the C.C.I.T. made recommendations for standardization of photo-telegraph apparatus and circuits.

The original picture-telegraph equipment was destroyed during the Second World War when the C.T.O. was very severely damaged, but in 1948 the service was re-opened using a new Muirhead equipment, and to-day the photo-telegraph service is world wide, using sub-carrier-frequency modulation for extra-European radio transmission.

TOWARDS THE FUTURE

It is difficult to foresee any radical changes in telegraph technique in the near future. From various causes, during recent years the inland traffic of the general telegraph service has fallen sharply. The future rests more with the telex service,[16] which is rapidly growing and has, no doubt, a remarkable development before it. Plans are well advanced for converting the inland telex service to automatic working within the next few years, and the ultimate aim is for full subscriber-to-subscriber dialling within Europe. A project is also being examined for the establishment of a European switched teleprinter-network for the general telegraph service.

The expansion of the international telex service has been aided by the recent introduction in this country of electronic regenerative repeaters, and of error-correcting equipment for use on radio circuits. To provide telegraph circuits over the transatlantic telephone cable, the first installation in this country of narrow-band frequency-modulated v.f. telegraph equipment has been made.

Switching methods that involve the use of reperforators and automatic transmitters, interconnected automatically under the control of perforations forming the prefix in a tape, may, for special requirements, have advantages over more orthodox step-by-step systems. Equipment for this purpose has been developed and some systems of this type are already in operation. Magnetic storage methods may also have some influence on switching applications.

During recent years, trials have been in progress for the local transmission of telegrams by direct-recording facsimile telegraphy. It is difficult to foresee a wide application of this service, but the same technique is being applied in the reception of meteorological charts, and the C.C.I.T. is at the present time studying the question of design standards for such services.

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External Construction

The local line network has grown twenty-fold, and the trunk network at least one-hundred-fold, in the last 50 years. The heavy pole line has all but disappeared from the roadside; now, a series of small repeater stations indicates the existence of an important trunk route. The poles that remain, small and light by the standards of 1906, now carry, besides subscribers' lines, at most a few junction circuits to country exchanges; about 90 per cent of the subscribers' network is underground. Less obvious are the many refinements in line plant design that through the years have made their contribution to the efficient and inexpensive telephone service now taken for granted, and to the elimination of electrical hazards.

Line Construction

At the turn of the century overhead construction predominated and most telephone exchange buildings supported gigantic roof standards, of which Fig. 1 is an extreme example. From these standards local distribution to telephone subscribers was effected largely by

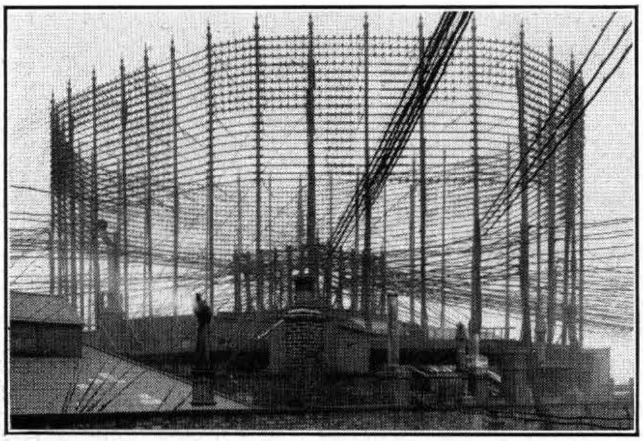


Fig. 1.—The Roof Standard at the National Telephone Company's Avenue Exchange.

over-house construction. The National Telephone Company had only limited powers to place its plant in public streets, and had, in the main, to rely on private wayleaves. When the erection of a distribution pole was necessary, it was, therefore, often the practice to make it tall enough to clear surrounding buildings and stout enough to carry 25 lines or more. It was by no means unusual for overhead construction parties of those days to lift a stout pole, 60 or 70 ft long, clear over the tops of buildings for erection in some small court or garden.

Trunk telephone lines and all telegraphs were by this time constructed[1] wholly by the Post Office and were placed on public roads under the statutory powers vested in the Postmaster-General under the Telegraph Acts of 1863 and later. Stout poles were invariably used, and where a large number of circuits had to be carried it was common to brace together two similar poles in either A or H formation. Lines thus constructed possess great stability; the few that remain have weathered the storms of half a century and could, if necessary, last many years more. The timber used for poles was almost exclusively Scots pine imported from Scandinavia, dressed and creosoted in this country by the full cell (Bethel) process. This treatment called for complete impregnation of the sapwood, which required 12 lb of creosote oil to be injected per cubic foot of timber. Poles thus treated oozed wet creosote and were unpleasant to handle. Conductors were of heavy-gauge galvanized iron, bronze or hard-drawn copper. Galvanized iron was used mainly for telegraph circuits and to a small extent for telephone subscribers' circuits, bronze wire for telephone subscribers' and short junction circuits, and hard-drawn copper for the longer junction and trunk circuits.

The majority of the very early telephone circuits were worked on a single wire with earth return and were therefore particularly susceptible to crosstalk interference. It was not until about 1892 that systematic conversion to "metallic" or "loop" circuit working began, permitting the close spacing of conductors without excessive interference between circuits, and hence the use of paper-insulated multi-pair aerial or underground telephone cables. About this time two 41-pr, 20-lb lead-covered paper-core cables were installed in the Mersey railway tunnel to provide telephone circuits between Liverpool and Birkenhead. The conductors were joined by an unsoldered twist and enclosed in a braided-cotton sleeve impregnated with paraffin wax, and the joints were "boiled out" by pouring hot wax over them to remove moisture. The use of cable for the local telephone system rapidly increased, and by 1905 the National Telephone Company operated some 500,000 wire-miles of underground cable. Conductors were mostly of 20-lb gauge, but 10-lb conductors were making their appearance.

An alternative type of cable was also in service and was used extensively for leading-in to buildings. It was composed of copper conductors with rubber or gutta-percha insulation, enclosed in a lead sheath for underground use. For use as aerial cable, the sheath was of rubber, and a steel suspension wire was employed from which the cable was supported by strips of raw-hide fixed to the suspension wire with metal hooks.

The first main underground cable of any appreciable length was laid between London and Birmingham in 1898 and consisted of 38 pairs of 150-lb paper-insulated conductors laid up in some sections in twin and elsewhere in star-quad formation. Although intended for telephony its circuits compared so unfavourably with the overhead trunks of the day that the whole cable was given over to telegraphy.

Underground cables were usually laid in cast-iron pipes (Fig. 2) or octagonal earthenware ducts. The cast-iron pipes had spigot-and-socket joints which were caulked with lead, while the octagonal ducts had their joints wrapped

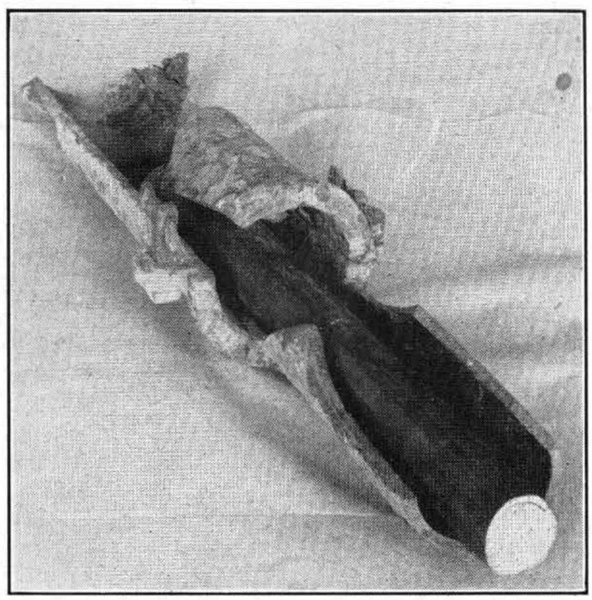


Fig. 2.—Section of the London–Birmingham No. 1 Cable in its 4-in. Iron Pipe, Recovered from Newgate Street, London, in 1948.

with calico strip and were embedded in concrete, as in present-day practice. Early jointing chambers were constructed in brick, with roofs formed from stone slabs or steel plate. Access to footway chambers was obtained by lifting the plain slab covers, which were laid directly on the brick walls. Cast-iron covers set in cast-iron frames were used to give access to chambers in the carriageway.

Progress up to the First World War.

Those were the days of heavy overhead construction (Fig. **3**), but the growth of the telephone service in London and other large cities soon outran the capacity of overhead construction and cables became an essential part of the telephone network.

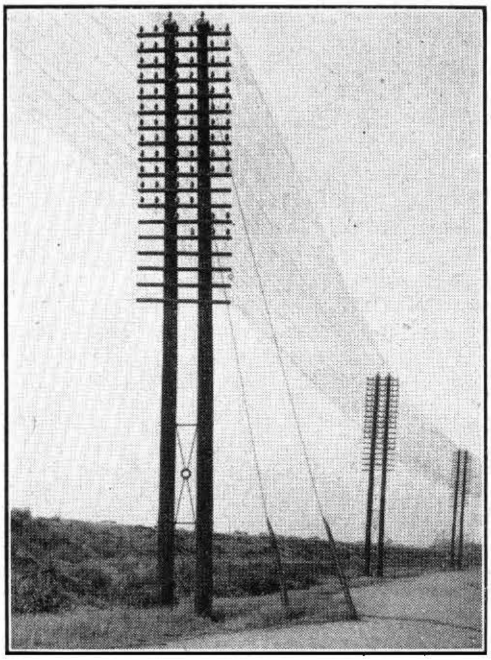


FIG. **3**.—AN H-POLE ROUTE.

Direct underground service to subscribers was employed in the congested centres of towns, but elsewhere overhead distribution to subscribers continued to be used. The pattern changed a little after the transfer of the National Telephone Company's undertaking in 1912; the Post Office had more effective powers to construct overhead lines in public streets, and the erection of plant on private property was avoided as far as possible. Distribution poles were frequently cross-armed and were fed with a 7-pr to 25-pr underground cable terminating in a joint known as a "solid plug" at the top of the pole. The majority of the major overhead trunk routes were constructed during this period.

In 1913 a change was made in the preservation treatment of the poles, the "empty-cell," or Rüping, process being adopted as standard. In this process approximately 50 per cent of the creosote was recovered from the wood by the application of a vacuum immediately after injection, leaving the pole with 4 to 5 lb of creosote per cubic foot. The main reason for the change was the direct saving in creosote, but in addition the Rüpingized poles were lighter, easier and cleaner to handle, and required less weathering before erection.

The National Telephone Company used copper sleeves extensively for making joints in overhead conductors, whereas early Post Office practice favoured the Britannia joint, in which the wires to be joined were laid parallel to one another, lapped with binding wire, and soldered. After the transfer of the National Telephone Company system, jointing sleeves were introduced into Post Office practice, and became the standard method of jointing for all but the heaviest conductors.

The black composition insulator also made its appearance at about that time. Previously, porcelain insulators had been used almost exclusively, but in some areas they proved to be irresistible targets for stone-throwers. The composition insulators resisted impact very much better than porcelain ones, although their insulating properties were not quite so good and their life was shorter. They were, however, considerably cheaper than porcelain insulators, and in consequence their use has since increased, particularly on subscribers' lines, where their shortcomings are of less consequence.

The scope of overhead construction was increased by the Telegraph Act of 1908, which extended the Postmaster-General's flying-wire powers over private property from large towns only to the country at large, and by the Telegraph Act of 1911, which gave the Post Office the right of entry on railways and canals for the construction of lines up to a quarter of a mile in length.

The rapid growth of the local cable network had produced a demand for a conduit cheaper than cast-iron pipes. In 1907 the Sykes duct was introduced, which was the forerunner of the modern self-aligning glazed earthenware duct (Fig. **4**). Multi-way formations with spigot-and-socket joints were installed, and many of the earlier installations are still serviceable. Cast-iron frames and covers became the universal means of access to all jointing chambers.

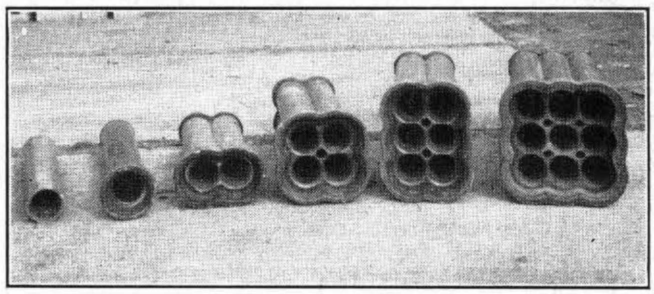


FIG. **4**.—SELF-ALIGNING GLAZED EARTHENWARE DUCTS.

The introduction of loading.—Cables in general use at this time for trunk telephone and telegraph purposes were usually of composite make-up and contained twin, multiple-twin and screened single conductors, often of several gauges. The poor transmission efficiency of cables, compared with open-wire lines, precluded their use for long telephone circuits; cables were for many years limited to short sections through the congested centres of large towns and cities where overhead lines were impracticable. The introduction of the loading coil considerably reduced the attenuation of underground circuits and opened up a wide field of use for cables in the trunk network. A noteworthy example of loading was the London–Birmingham–Liverpool cable completed in 1915-16, which contained two 300-lb, fourteen 200-lb, twelve 150-lb, and twenty-four 100-lb pairs in multiple-twin formation, loaded at $2\frac{1}{2}$-mile intervals.

The first loading coils were air-cored solenoids but these were found to be affected by external interference, and were soon abandoned in favour of toroidal coils wound first on soft-iron-wire cores and later on iron-dust cores. Phantom circuits as well as side circuits were loaded. The largest loading pot contained 64 coils, was 44 in. × 25 in. diameter, and weighed 1,500 lb.

Increasing the capacity of cables.—For local line networks, the air-spaced paper-core cable became standard, generally of 20-lb or even larger gauge, a common maximum size being 300 pr, 20 lb. The first "transmission plan," making an apportionment of line loss between "main" and "local" lines, appeared about 1905. By the use of an improved telephone it became possible to use 10-lb conductors in the local network and still suit the requirements of the plan. The largest cable was then increased to 600 pairs and a little later 800 10-lb pairs were incorporated in one cable. Shortly before the transfer of the local plant to the Post Office in 1912, the National Telephone Company introduced 6½-lb conductors in cables of up to 600 pairs, and after the transfer the sizes of pairs increased until by 1914 1,000-pr, 6½-lb twin cables were in common use.

From the First World War to 1925.

The development of the telephone system was seriously retarded by the war, and afterwards reconstruction was hampered by shortage of materials until about 1921. The next few years, however, saw the beginning of a period of rapid expansion and development.

Overhead practice had reached a stage of relative stability and there were few significant changes in standards of construction. A number of expedients were adopted because of the shortage of materials, and timber other than Scots pine was accepted for poles; none, however, proved a serious competitor to Scots pine when this was available.

In 1918 lead-covered paper-core aerial cable was introduced. It was attached to a steel suspension wire, as used for earlier cables, with "marline ties."

Employment of contractors for duct work.—The rapid growth of underground plant following the war led to the wide-scale employment of public works contractors for laying ducts and building jointing chambers. This practice developed until only a very small portion of such work was carried out by Post Office staff, and this is the situation to-day. The contractor was required to accept the Postmaster-General's responsibilities under the Telegraph Acts and, as far as possible, to act on his behalf in meeting the requirements of local authorities, particularly in respect of road-surface reinstatements. The Post Office appointed works supervisors who were responsible for ensuring that all work was performed in accordance with the Specification and Conditions of Contract.

There was a growing need for very large formations of conduits in London and other large cities and octagonal earthenware ducts set in concrete (the most economical in space of all systems) came to be extensively used.

Wood troughing secured by wire clips came into use, mainly for small cables in residential areas. It was inexpensive but difficult to rod and not very permanent, and its use was discontinued after a few years.

Standard jointing chambers.—A range of standard manholes in reinforced concrete and small joint-boxes in brickwork or reinforced concrete was introduced during this period. Roofs of manholes in the carriageway were constructed of reinforced concrete with steel joists either embedded in the roof or set beneath it. Brickwork construction, although sometimes more expensive than reinforced concrete, was still necessary in difficult situations where obstructions prevented the free use of shuttering for concrete. Access to manholes and surface jointing boxes continued to be provided by cast-iron frames and covers, but for footway boxes concrete-filled cast-iron covers were developed and are still employed with little variation from the original design. Carriageway covers consisted of a cast-iron framework filled with wood blocks, circular frames and covers being used for manhole entrances and oval frames and covers for surface boxes. The oval cover in particular was found to be very prone to rock under the weight of passing traffic, and towards the end of the period the rectangular Wood's-type frame and cover, which had serrated seating surfaces, was introduced. Although not completely free from rocking, these frames and covers proved durable, and gave better access and working conditions.

The Decade 1925-35.

This period saw the end of the heaviest overhead construction and the general expansion of underground cabling, particularly in the trunk network. Few new overhead trunk lines were built, and conductor gauge seldom exceeded 150 lb.

Cadmium-copper replaced bronze for the lighter-gauge overhead conductors for nearly all overhead work. Of a strength similar to that of bronze, its conductivity is much better and approaches that of copper. In 1932 ring-type pole-heads were introduced (Fig. 5) as a more elegant means

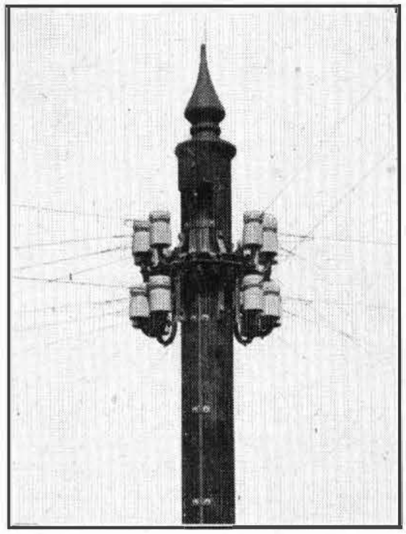


FIG. 5.—THE TOP OF A RING-TYPE DISTRIBUTION POLE.

of mounting spindles and insulators for the radial distribution of wires from distribution poles in residential districts. In 1932, also, the covered drop-wire system was introduced as an alternative to open-wire distribution. This system makes use of a flat twin cable consisting of cadmium-copper conductors, rubber insulation and an overall textile braiding treated with a water-proofing compound. The drop wire is attached to poles and buildings by means of simple clamps, and can be run without a break direct from the terminal block on the distribution pole to the subscriber's protector, with a consequent saving of installation time.

The use of marline ties for attaching aerial cables to suspension wires was discarded in 1933, and metal cable rings were adopted as standard. These rings were fashioned from galvanized steel, and could be clipped on to the suspension wire, the cable then being drawn-in much as in underground practice. The inclusion of a small amount of antimony had been shown to increase the resistance of lead to fatigue, and the use of antimonial lead was now standard for aerial cables.

Consideration was again given to the standardization of manholes[2] and four standard sizes were introduced in 1932 to meet nearly all requirements. There was little change during the period in the design of frames and covers, but an anti-rocking device was introduced for use with carriageway covers, which consisted of a retaining ring carrying "Ferodo" pads.

A sleeve, secured and sealed mechanically, was introduced for use at joints on local cables where pair-diversions were liable to be of frequent occurrence. This took the form of a copper canister with a toggle-jointed cast-iron clamp containing a double U-section rubber washer to make the joint watertight.

The introduction of quad cables.—A major change in cable design was introduced at this time. Cables with the wires laid up in quad formation had been tried in earlier days, but lack of symmetry in the quad structure impaired their electrical characteristics. Now, owing to improved manufacturing methods, quads could be made up having a high degree of symmetry. One improvement was to place a spiral thread of cellulose string over the conductor wire before applying the insulating paper. This ensured a good space-characteristic and accurately centred the wire inside the paper wrapping. A similar effect could be obtained by using specially-crimped paper. The four wires of the quad were laid up round a central string which formed a bedding and provided for uniform spacing of the quad wires. The first cable of this type, 254 pr, 40 lb, was laid between the G.P.O. Headquarters in the City and Ealing in 1925. Others followed, and by 1930 it had become the standard for all trunk and junction cables. The great attraction of the "star-quad"[3] cable, as it was called, was the greater number of pairs it provided in a given diameter of sheath; the increase was as much as 40 per cent over multiple-twin construction. The adoption of star-quad formation for local cable networks quickly followed. To meet the more stringent requirements in respect of capacitance unbalances, the spiral string over the conductor wire was retained for trunk and junction cables ("Cable P.C.Q.T."), but for local cable ("P.C.Q.L.") the crimped paper lapping sufficed. Within the standard maximum diameter of sheath (2·75 in.) it was now possible to have 254 40-lb, 542 20-lb, 1,100 10-lb or 1,400 6½-lb pairs.

The gas-leak detector.—In 1928 a serious explosion took place in a Post Office cable tunnel under Holborn, London, causing very extensive damage to the roadway and involving the death of a Post Office jointer. It was established that a considerable quantity of coal-gas had leaked into the tunnel, forming an explosive mixture of gas and air. Following a review of this and other gas explosions in the Post Office underground system, an efficient gas-leak indicator was developed, based on the use of palladium chloride solution to detect small amounts of carbon monoxide. Tests for gas were made compulsory for all staff entering manholes or other underground structures.

Reinstatement of road surfaces.—The rapid growth of the underground cable system created a need for closer co-operation with the highway authorities, and the Post Office accepted a number of codes of practice and conditions for reinstatement. This led to the opening of discussions with the Institution of Municipal and Civil Engineers (as it was then known), which culminated in 1933 in the Memorandum of Agreement for the reinstatement of Post Office trenches. Briefly, the Memorandum laid down the general principles governing methods of charging by highway authorities, use of new materials, provision of additional strengthening materials for foundations, tunnelling, filling-in and measurement of trenches, and liability for accidents. The Memorandum was accepted by probably 90 per cent of the highway authorities, and has remained substantially in use until the present time.

The Late Thirties and the Second World War.

In 1935 the practice of "pre-cutting" light and medium poles[4] before creosoting at the pole depot was introduced as a means of saving time in the field, the poles being "scarfed" at the top and drilled for the arms. This avoided cutting slots in the pole when the arms were fitted and ensured proper creosoting of all cut surfaces. Stability of the arms was achieved by bracing.

The growth of the local network called for an ever-increasing number of distribution and subsidiary poles, and the construction of many light routes to serve farms, rural kiosks, etc. Some 200,000 poles a year were being used, and to cheapen construction in rural areas, extra-light poles were introduced, originally for the 1935-36 Jubilee Kiosk scheme, and later for routes where only a few circuits were ever likely to be needed. During the war, supplies of poles from Scandinavian countries were cut off, and standards had to be lowered once again, particularly in the specification for home-grown poles. Bent and twisted poles and a variety of species of timber had to be accepted.

During the war the use of aerial cable (Fig. 6) was considerably extended, because of its low initial cost and rapidity of construction compared with underground cable and duct. Some very large aerial cables were erected during this period to meet urgent defence requirements, and most of these cables are still in use to-day.

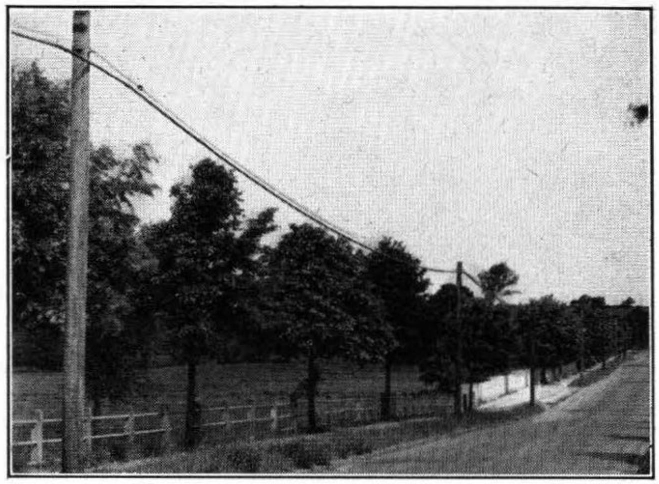


Fig. 6.—An Aerial-Cable Route.

The earliest self-supporting aerial cable (i.e. one needing no separate suspension wire) was a stainless-steel-sheathed paper-core cable, the first lengths of which were erected in 1940. This type of cable has continued to be used, chiefly in areas where there is a serious risk of damage due to gunshot. Elsewhere its use is restricted, partly because of its high cost and partly because the type of steel used for the sheath is not readily available. Erection costs are, of course, low.

During the early part of the war it was anticipated that both steel, and perhaps concrete, might become very scarce, and once again new manhole designs were introduced, in which the required strength was obtained with the minimum expenditure on materials, particularly steel. The new designs, one of which is shown in Fig. 7, were

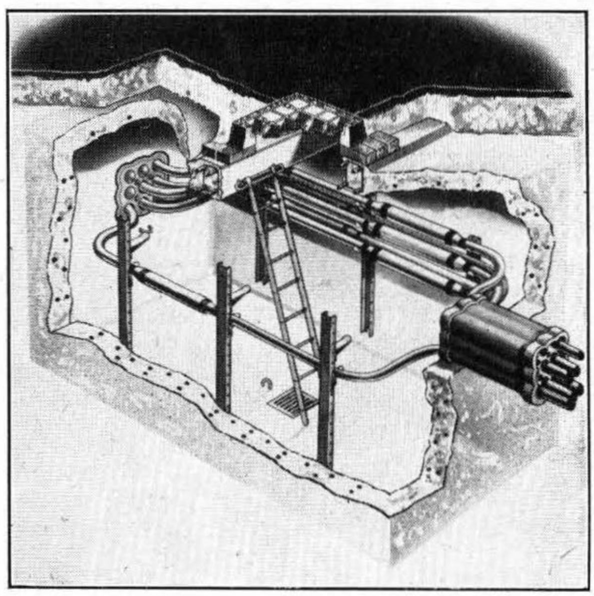
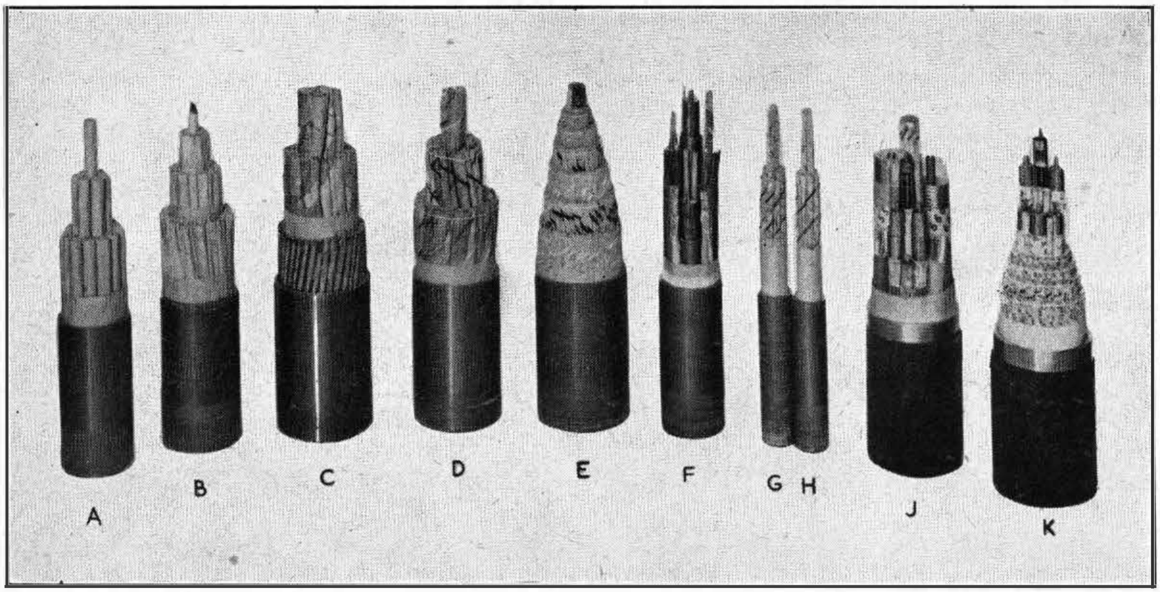


Fig. 7.—View of Typical Manhole (Type R1).



Ref.	Cable	Approximate date of installation	Size	Type
A	L-BM No. 1	1897-98	38 pr., 150 lb Q.	D.C. telegraph
B	L-BM No. 1	1897-98	38 pr., 150 lb T.	D.C. telegraph
C	L-BM No. 2 (recovered)	1908-09	8 pr., 200 lb M.T. + 22 pr., 150 lb M.T. + 34 wire, 70 lb S.S. and other sizes.	D.C. telegraph
D	L-BM-LV (recovered)	1914-15	2 pr., 300 lb M.T. + 14 pr., 200 lb M.T. + 12 pr., 150 lb M.T. + 24 pr., 100 lb M.T.	Multiple-twin audio telephony
E	L-BM-LV	1930-31	4 pr., 40 lb S.P. + 352 pr., 25 lb Q.T.	Star-quad audio telephony
F	L-BM No. 3	1935-36	4 cx. pr. 450 + 4 pr., 40 lb S.P. + 12 pr., 25 lb P.C.Q.	Coaxial carrier telephony
G	L-OF No. 4 and 5	1940-41	24 pr., 40 lb P.C.Q. carrier.	12- and 24-channel carrier telephony
H	BM-OF No. 1 and 2	1940-41	24 pr., 40 lb P.C.Q. carrier.	12- and 24-channel carrier telephony
J	L-BM No. 4	1946-47	4 cx. pr. 375 + 2 cx. pr. 975 + 2 pr., 20 lb P.C.Q. + 16 pr., 20 lb P.C.T. + 16 pr., 40 lb P.C.Q. + 8 pr., 40 lb S.P.	Coaxial carrier telephony and television
K	L-BM No. 5 (London-Banbury section)	1954 (not yet completed)	6 cx. pr. 375 + 4 pr., 25 lb S.P. + 12 pr., 20 lb P.C.Q. + 344 pr., 20 lb P.C.Q.T.	Coaxial carrier telephony and television

Note: L, London; BM, Birmingham; LV, Liverpool; OF, Oxford.

FIG. 8—DEVELOPMENT OF THE LONG-DISTANCE UNDERGROUND CABLE, AS SHOWN BY THE LONDON–BIRMINGHAM ROUTE.

notable for requiring only about 50 per cent of the weight of steel and about 75 per cent of the concrete previously used for manholes of equivalent size. They were made standard for both carriageway and footway installations, thus frequently avoiding reconstruction on account of road widening. Concrete construction was made standard, with brickwork as an alternative in special circumstances. Surface-joint-box designs were revised at the same time and some little-used types were eliminated.

"Cable P.C.Q.T." continued to be used for audio trunk and junction cables and "P.C.Q.L." for local cables (Fig. 8). War-time conditions made it necessary to economize in the use of lead, and a small general reduction was made in 1942 in the thickness of sheath of cables above 0·6 in. diameter.

Twelve-circuit-carrier and coaxial cables.—This period marked the introduction of two major developments, both in the field of high-frequency transmission. In 1935-36 the first coaxial cable was laid between London and Birmingham and contained four 0·450-in. coaxial pairs, each individually lead sheathed, laid up with four 40-lb screened music pairs and twelve 25-lb pairs for control purposes. At the same time the first pair of 12-channel carrier cables was installed between Bristol and Plymouth. They were 19-pr, 40-lb low-capacitance twin-type cables. Subsequent 12-channel carrier cables were of 24-pr quad-type formation, and by 1945 some 6,000 sheath miles had been laid. Fewer 12-channel carrier cables were laid after this date on account of the more extensive use of coaxial cables, or, more precisely, of large audio cables containing two or four 0·375-in. coaxial pairs.

The Post-war Years.

As in industry generally, post-war developments have been largely directed towards raising productivity. Materials have been scarce and much attention has been given to the use of substitutes.

On account of the shortage of suitable timber, a number of galvanized sheet-steel poles were purchased. Pre-stressed concrete poles were also tried, but their high initial cost and weight made them uneconomical.

The difficulty in obtaining pole fittings in the post-war years led to the production of substitutes, cast or fabricated, in light alloys. For one reason and another, few have proved acceptable alternatives to the galvanized wrought iron and steel fittings normally used. An exception to this is the ring-type pole head for which a cast aluminium alloy type was introduced in 1951 and is now standard. The development of a small unobtrusive drop-wire cable and cheap pole fixing suitable for ring-type distribution is in hand and should reduce considerably the erection time for subscribers' spurs.

Increasing use has been made of mechanical aids, such as cranes and power-driven earth augers, to assist in the erection of poles, and the use of explosives has also been extended. Properly used, with adequate safeguards, explosives can be very satisfactory for pole-holes and stay-holes in the softer soils. A terminal block has recently been introduced (Fig. **9**) which allows better access to terminals and provides much-improved safeguards against low insulation.

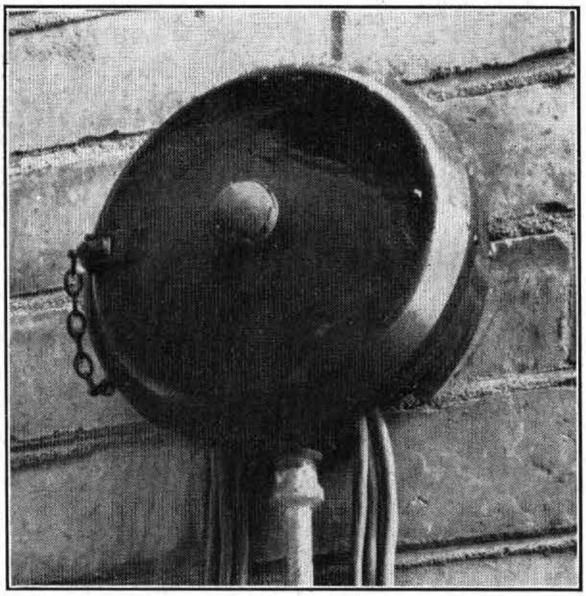


Fig. **9**.—Modern Terminal Block.

Systematic inspection of poles.—During the war the inspection of overhead lines virtually ceased, and shortly afterwards it was found that many poles were badly decayed. A special inspection by men trained in methods of detecting decay, particularly internal decay, is now carried out at regular intervals; this has revealed that there are several thousands of poles in service that show signs of decay but do not justify immediate renewal. Attempts have been made to extend the life of these poles by the direct injection of preservatives and by the use of preservative-impregnated bandages.

From statistics on decayed poles and examination of both sound and decayed poles it was concluded that the Rüping treatment was not fully adequate and in 1951 a modified Rüping process was introduced; 7 to 8 lb of creosote per cubic foot is now left in the pole.

Developments in aerial cables.—An analysis of the fault history of aerial cables has shown a large percentage of faults due to ring-cutting. To eliminate this trouble a method of lashing the cable closely to the suspension strand was introduced in 1947,[5] using a special machine for the purpose.

The use of plastic-sheathed cables made possible the introduction of a lighter suspension wire in 1950. The development of cables that can be suspended without a supporting wire has received attention and experiments are proceeding with three new types of self-supporting aerial cable. In these, the conductors are all insulated with polythene, but the suspension strength is provided in different ways. In the first type, cadmium-copper conductors are used to provide the necessary strength, and in the second a galvanized-steel suspension wire is moulded into the plastic sheath of the cable. The third type has no sheath and consists of insulated wires lapped around an insulated steel suspension wire. This type has the added advantage that pairs can be connected to subscribers' leads at any point along the route without the need for a terminal block.

Multi-way duct formations and cable tunnels.—Comparison over the years of the various forms of duct has shown that for normal use the standard self-aligning earthenware duct is still the most satisfactory, either single-way or multiple-way, in various arrangements up to about 12 ways. There is little to choose between the merits of asbestos-cement or octagonal earthenware ducts when set in concrete in multiple formations of, say, 20-60 ways. Beyond 60 ways it may be more economical under certain conditions to employ a cable tunnel constructed in cast iron or concrete. Such tunnels of about 7 ft diameter have been successfully used at depths of 30-80 ft and can contain up to about 160 cables carried on bearers fixed to the tunnel walls.

A range of standard triangular manholes constructed of reinforced concrete has been introduced to provide for leading-in to exchanges and repeater stations, and for turning cables at street corners and at the intersections of large routes.

Development of Coaxial Cables.—The coaxial cable network has extended considerably, based on two, four and sometimes six coaxial tubes laid up together with a suitable complement of audio pairs. The $\frac{3}{8}$ in. tube size has remained standard, but the form of construction has evolved through the years.[6]

The first (1935) design comprised a solid centre wire supported by a spiral of "cotopa" string within an outer conductor tube of 0·45 in. internal diameter. The tube was formed from 12 interlocking tapes. Over the outer conductor was extruded a thin lead sheath. In the next design the lead sheath was replaced by two mild-steel tapes and reduced attenuation was obtained by using an improved cotopa string. A third design incorporated two major changes—the cotopa string was replaced by hard rubber disks spaced at 1·3-in. intervals and the number of interlocking tapes was reduced to ten, giving a tube of internal diameter 0·375 in. The steel tapes were retained in this and in all superseding designs. The next significant change was the use of a tube formed from a single copper tape instead of the ten interlocking tapes. The edges of the tape, when formed, butted together and accurately fixed the dimensions of the tube, and were prevented from overlapping by small projecting teeth. The new outer conductor improved attenuation stability. In a further design the hard rubber disks were replaced by polythene disks with a further decrease in attenuation. At this stage several different manufacturers began to produce their own designs, the main variations being in the way in which the outer tube is formed. In one type the teeth on the edges are replaced by marginal corrugations arranged to butt out of phase. In other types the outer conductor consists either of two convolutions of a single tape soldered together, or of two tubes, one inside the other, soldered together.

A notable exception to the almost universal $\frac{3}{8}$-in. tube was the London–Birmingham No. 4 cable, designed for wide-band television as well as telephony. The cable contained two 0·975-in. tubes, four 0·375-in. tubes, quads and pairs. The centre conductor of the large tubes consisted of a continuous cylinder made by suitably shaping a copper tape. The outer conductor was formed in a similar way, but was corrugated in order to give sufficient flexibility for manipulation. Both conductors embodied safeguards against overlapping at the edges of the tapes. Spool-type polythene spacers were used between inner and outer conductors.

The use of composite audio and coaxial cables made it necessary to give special attention to the method of making the joints, so that under fault conditions access to the coaxial pairs could be obtained without having to break down the surrounding audio pairs.

Unit-type local cables.—With the introduction of cabinets and pillars in the local line network, a cable made up in "units" of 50 or 100 pairs was considered to offer advantages in pair distribution over the standard quad-type cable. In 1946 therefore a new type of cable—Cable, Paper-Core, Unit Twin (P.C.U.T.)—was introduced[7] in a complete range of sizes. In the range 50 to 450 pairs, the make-up is based on the 50-pair unit; above 450 pairs on the 100-pair unit. P.C.U.T. cables (Fig. **10**) are slightly larger in diameter than P.C.Q.L. cables, but possess better crosstalk characteristics.

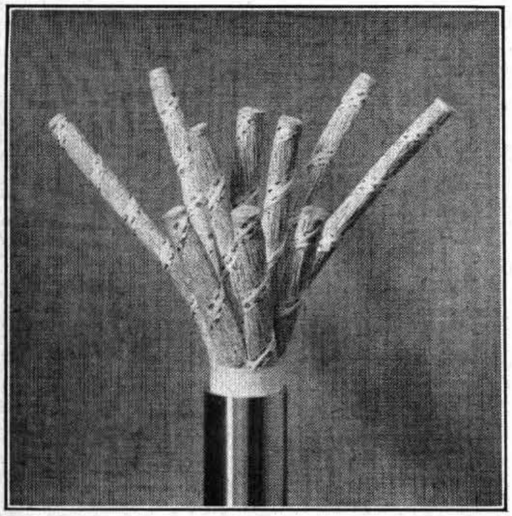


FIG. **10**.—SAMPLE OF 1,000-PR, 6½-LB P.C.U.T. CABLE.

Application of plastics to telephone cables.—A world shortage of lead shortly after the war gave rise, in 1946, to a further slight reduction in lead sheath thickness and to the introduction of "thin lead and protected" cables, about a year later.

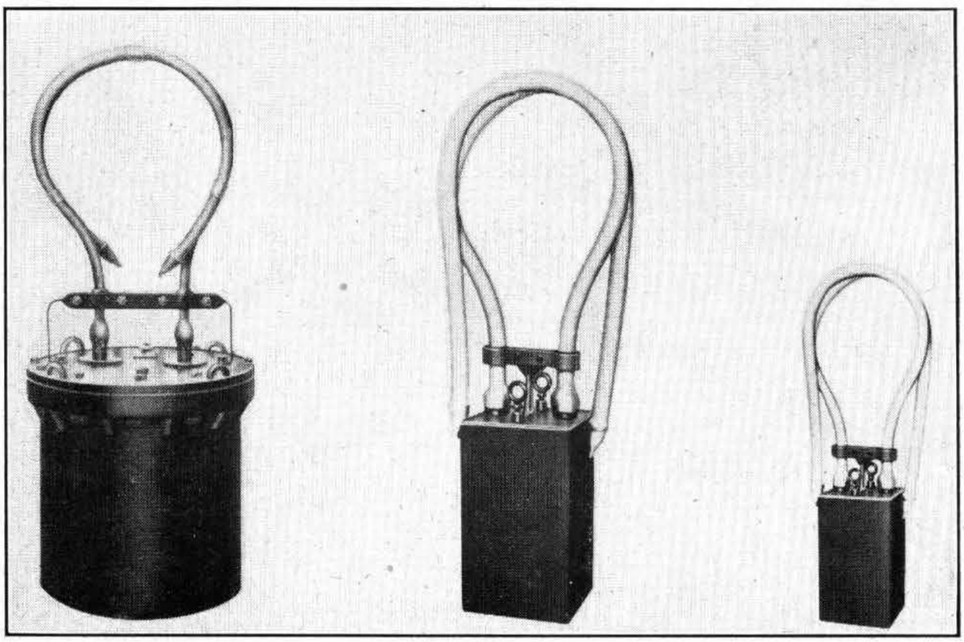
In these cables the sheath was still further reduced in thickness, but the thinner sheath was supplemented by a protective covering, normally of bitumen-impregnated layers of paper and hessian. They were intended for use as an alternative to plain lead of the 1946 thickness. A search for alternatives to lead commenced, and attention was directed to the use of polythene and p.v.c. as cable insulants and sheathings. To meet the demand for long service-leads to remote farms, a one-pair cable, polythene-sheathed and insulated, was developed, which lent itself to moledraining or otherwise burying directly in the ground. This "all-polythene" cable was very successful, and in 1950 the range was extended to 30 pairs in both 10-lb and 20-lb conductor sizes. The cost of this cable is comparable with the same size of lead-covered cable, but economies result from the elimination of duct, its freedom from corrosion, and from the use of much smaller jointing chambers into which the very flexible cable can be placed after jointing it above ground. In 1953 the range was extended to cover 6½-lb conductors, and later to 50-pair cables. There are difficulties in extruding an insulant of less than about 12 mils in thickness; if these difficulties can be overcome, the all-polythene cable may be no larger in diameter than the corresponding P.C.U.T. cable, and may become competitive over a wider field. For use with polythene cables, a range of mechanical joints using rubber plugs as a means of sealing has been developed.[8]

Concurrently with the development of this "all-polythene" cable, experience has been gained with a polythene sheath extruded over a thin lead sheath as an anti-corrosion measure. Up to the present, the standard form of protection for cables with thin lead sheaths has been a double layer of hessian tape impregnated with bitumen, supplemented with two layers of paper over the lead, and finished overall with a coating of graphite. The thickness of the hessian protection is approximately 125 mils. It has been found that the thickness of a protective sheath of polythene can be reduced to 60-80 mils, and that it will produce a smooth-sheathed cable very easy to draw into ducts. Difficulty has, however, been experienced in making a joint to the same high standard of insulation as can be achieved over the cable lengths between joints. An overall high standard of insulation has certain advantages, but a lower standard at jointing points is not a very serious defect, and the cable has attractive features compared with its hessian-wrapped equivalent.

Improvements to loading coils.—Very considerable progress has been made in the use of the newer magnetic alloys for loading coil cores. Loading coil cases have been much reduced in size (Fig. **11**) with a corresponding saving in the cost of manhole construction.

Statutory Powers.

The Public Utilities Street Works Act of 1950 was, in many respects, the most important legislative measure affecting Post Office line construction since the Telegraph Acts of 1863 and 1878. The new Act regulates the opening of streets for the purpose of placing and maintaining plant, and the subsequent reinstatement of pavings. It governs the relationship between the Street Authorities and all "Statutory Undertakers," which include the Post Office. The Telegraph Acts required the Post Office itself to meet the cost of alterations to plant consequent upon an alteration in the line or level of a street. Under the terms of the new Act, however, the cost of alterations to plant is proper to be borne by the party carrying out the street works. The change in obligations has led to the introduction by road surveyors of a considerable number of codes of practice which attempt to govern the opening of trenches and the restoration of surfaces; discussion centring upon these has led to the realization that a common approach is necessary in the interests of all concerned. In 1954 a joint committee of statutory undertakers compiled



| 12 inches |

Note: Left to right, 1924-1931, 1931-1951, after 1951.

FIG. **11**.—TYPICAL LOADING POTS, EACH CONTAINING 108 LOADING COILS.

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a model code of practice and this was followed a few months later by a set of recommendations on somewhat similar lines by the Institution of Municipal Engineers and the County Surveyors Society. In 1955 the two sides commenced negotiations and have since made substantial progress towards an agreed code of practice. These negotiations continue.

Flexibility in the Local Line Network

In order to forestall—within economic limits—the premature exhaustion of Distribution Points (D.P.) where the demand for service locally exceeds the forecast, a substantial margin of extra pairs is provided to each D.P. in the local line network. It is not normally economic to extend all these pairs back to the exchange, nor to provide the larger cables, nearer the exchange, with capacity sufficient to last for the full 20-year period of growth for which the D.P. layout is designed. Provision for a much shorter period—about eight years—has been usual.

Some means is required of providing pair flexibility between cables provided on a long-period basis with generous spares, and those provided on a short-period basis with limited spares. Early attempts to give this flexibility made use of the "cable distribution head" (Fig. **12**). This was a cast-iron box into which the cables

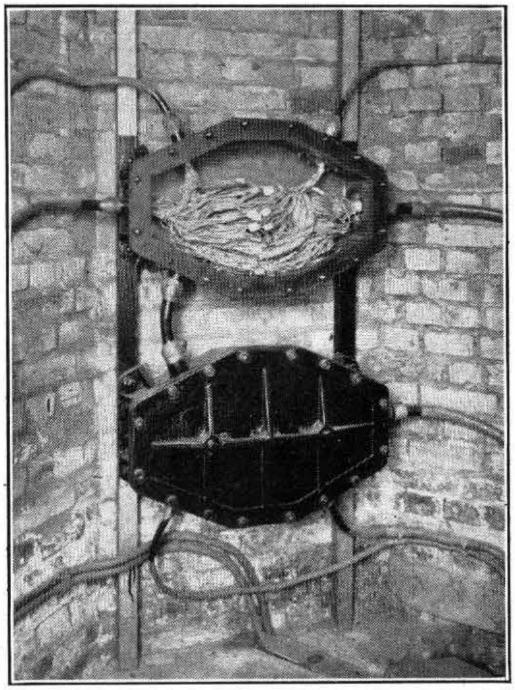


Fig. **12**.—An Early Cable Distribution Head.

were led through brass glands to which the sheaths were plumbed. Rearrangement was effected by breaking down and reconnecting the wire joints, but paper insulation does not stand up to repeated manipulation and faults were frequent. Cable distribution heads became, in fact, potential "trouble-spots" and their use was discontinued in the early thirties.

About 1925 the "auxiliary joint" was introduced. A proportion of the pairs, both exchange-side and distribution-side, were brought out in subsidiary cable tails from the main joint to form the smaller "auxiliary joint," the intention being that all rearrangements could be effected therein, without disturbance of the main joint. In practice, due largely to the incidence of cessations and the random nature of demand, the flexibility obtainable was insufficient with any reasonable size of auxiliary joint and their use gradually lapsed. Multiple-teeing between distribution points had also been used to a limited extent but was found in practice to lead to difficulties in fault localization and in record-keeping.

Depletion of spare-pair reserves at the end of the recent war supplied the impetus for a fresh study of the problem, and a group set up in 1943, under the chairmanship of Mr. Harvey Smith, recommended the introduction of the now familiar cross-connexion cabinets and pillars,[9] installation of which began about 1945. Cabinets and pillars (Figs. **13**, **14**) were designed on a compact basis to

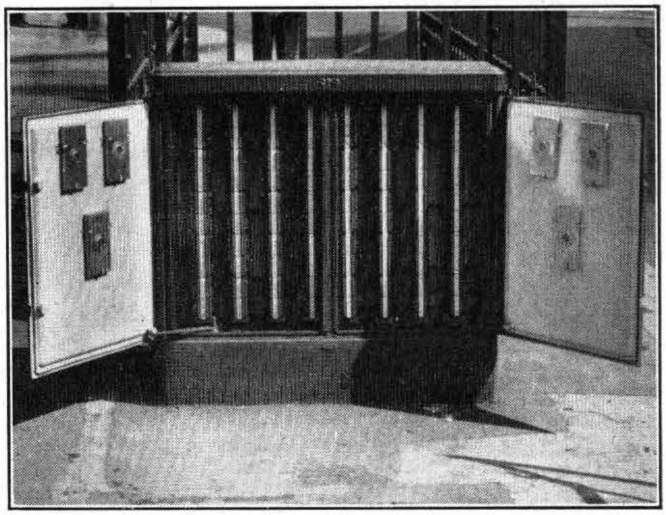


Fig. **13**.—Cross-Connexion Cabinet.

offer above-ground facilities for making connexions between cable pairs properly terminated on terminating assemblies. In the cabinets, additional assemblies could be added as required, and the new street cables could be jointed to cable tails terminated on these assemblies in the factory.

A feature of the assembly design is that flexibility is available between every pair of terminals on both the exchange and distribution sides. To avoid congestion of jumpers, short bridging-pins, as shown in Fig. **15**, are used where connexion is required between opposite exchange-side and distribution-side pairs. In a typical installation the majority of the connexions would be so made. Once installed, flexibility units would eliminate the need for elaborate pair rearrangements each time the cable system

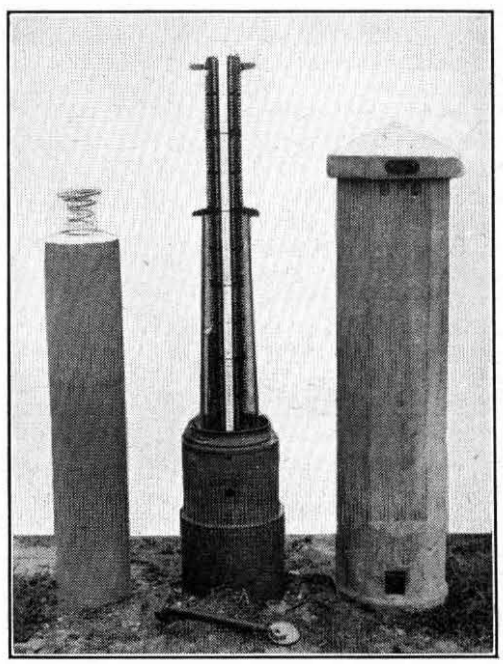


Fig. **14**.—Pillar, with Covers Removed.

was augmented. Originally the pillar units were designed for a maximum of 70 circuits (in and out) and the cabinets for 400. Later, capacities of 100 and 800 respectively were found possible. This increased capacity proved very valuable in view of later upward revisions of the national forecast figures.

Pillar shells are of asbestos cement and cabinets of cast-iron. External dimensions are kept as small as possible in order to minimize siting difficulties. Neither unit is strictly air-tight but air circulation is very limited. Humidity in both units is controlled by silica-gel desiccators of the "indicating" type, in which the active material changes colour when exhausted.

A sketch of the assembly strip is shown in Fig. **15**. The assembly strips, each of 20-pair capacity, are mounted in groups of five on a sheet-metal box which contains the cable form. The box is filled with a wax of closely specified physical and electrical properties. The exchange-side and the distribution-side pairs are brought out in separate "tails" of paper-core cable, unit-type or quad.

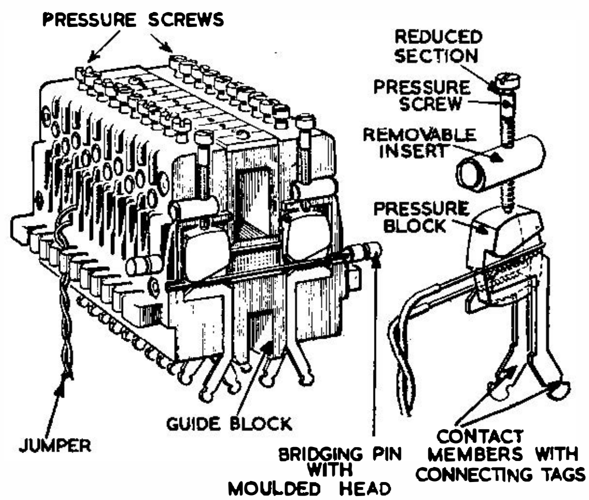


Fig. **15**.—Sketch of Assembly Strip.

To date, about 10,000 cabinets and 20,000 pillars have been connected into the network; some 40 per cent of the total pairs connected to exchange M.D.F.s now terminate at flexibility points. Apart from the basic purpose of providing for pair flexibility, and for the maximum effective use of cables nearing exhaustion, flexibility units offer the possibility of speedy testing and fault localization, provide points of connexion for unforeseen extensions to plant and allow of much shorter routings for miscellaneous circuits. Initial difficulties in securing a completely reliable wax seal have now been overcome, and the fault incidence is low.

Protection from Power Lines

Guarding against Contacts with Power Lines.

Telephone plant requires protection from the effects of lightning and chance contacts with power circuits. The earliest published Post Office regulations on the subject appeared in 1898. In those days overhead power lines were few in number and protection was elementary, consisting, in most cases, merely of a spark-gap. With the development of tramway systems operating from bare overhead trolley wires, usually at 600V d.c., the possibility of contacts with Post Office overhead wires became a real danger. On the Continent several fires were caused in telephone exchanges by such contacts. It became necessary to interpose earthed guard wires between the two sets of plant wherever there was a risk of contact.

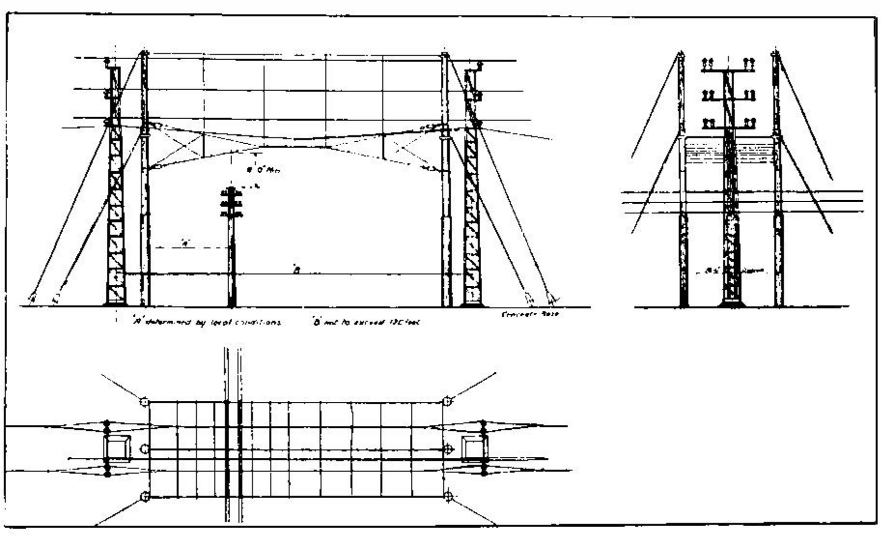
Very elaborate arrangements of guard wires were often found necessary to safeguard overhead telephone circuits in congested urban conditions and attention turned to the possibility of using some simpler form of guarding. As a result, telephone wire with a covering described as "paper-braided jute" (P.B.J.) was introduced about 1910 as an alternative to the use of guard wires at tramway and other low-voltage and medium-voltage power-crossings.

In 1924 this practice was extended to allow either telephone or power wires to be insulated with P.B.J. where the two sets of plant were in proximity. This enabled a more economical solution to be adopted where the power lines were few in number compared with the wires on the telephone route. In the same year bare telephone wires were permitted above bare low-voltage and medium-voltage power wires, provided that the earthed neutral power conductor was uppermost—a logical extension of the earlier practice, which required an earthed guard wire between the two sets of plant.

About 1910, overhead power distribution at high voltages began to be introduced and the Post Office took the view that at crossings the only real safeguard was to place one or other of the systems underground. This view was maintained for some years, but in 1914 cradle-guards were accepted as an alternative where the line voltage did not exceed 3,000.

In 1925 the constructional requirements for cradle-guards at high-voltage crossings came under review and were specified more precisely. Fig. **16** shows a cradle-guard of this period. The cradle encloses the power wires and is carried on independent steel poles.

About 1928, construction commenced of the 132-kV Grid, linking the principal electric power stations throughout the country. There ensued a large growth in the overhead high-voltage distribution network (mainly 33 kV and 11 kV), and a Memorandum was issued by the Post Office setting forth the requirements where these high-voltage lines crossed overhead telephone lines. It was laid down that one or other of the lines should be placed underground but, as an alternative, except at 132-kV crossings, a cradle-guard was permitted. The guard, as specified, was very ex-



Notes:
1. Distance between telephone pole and cradle-guard poles is determined by local conditions.
2. Distance between power-line poles not to exceed 120 ft.
3. Clearance between top of telephone pole and cradle guard to be at least 6 ft.

Fig. **16**.—An Early Form of Cradle Guard. (Reproduction of an Old Print.)

pensive, and in the light of later experience it became possible for the Post Office to accept a lighter form of construction.

In 1952 new methods of guarding were introduced which took advantage of the high dielectric strength and permanence of p.v.c. and polythene. These methods permit the use of individual telephone wires insulated with p.v.c., or of polythene-sheathed aerial cable carried by a steel suspension strand, at crossings where the power lines operate at voltages up to 33 kV and 11 kV, respectively. P.V.C.-covered power conductors are also permitted over bare Post Office wires at crossings where the power voltage does not exceed 11 kV.

For the termination of circuits at subscribers' premises and in Post Office exchanges, the arrangement shown in Fig. 17 has remained since early in the century, with the exception of the changes indicated below, the standard method of protecting against lightning and all other extraneous voltages. It consists essentially of fuses, carbon-

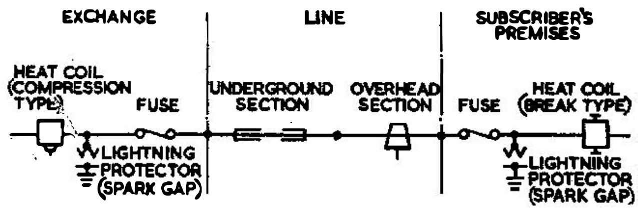


FIG. 17.—PROTECTION OF SUBSCRIBER'S TELEPHONE LINE.

block and mica-strip lightning protectors, and heat coils. There was a major modification in 1939, when a new type of protector, consisting of a synthetic-resin moulding completely enclosing the spark gap, was introduced for new work. In 1939 heat coils were omitted at subscribers' premises, and since 1945 there has been no protection at the subscriber's end of underground lines. Full protection is still maintained at the exchange end because of the practical difficulty of segregating completely underground circuits from those which include overhead wires.

With the large extension of the trunk cable network after 1925, underground cables were terminated at repeater stations on test tablets and the pairs were extended to transformers without any form of protection. Consideration was given subsequently to the provision of protection where the tappings of line transformers had a d.c. connexion with earth for signalling, but the development of a suitable fuse or other device never matured. The experience gained on such circuits without protection showed the risk to be negligible, and in 1953 it was decided to omit protection entirely from all wholly underground trunk and junction circuits terminating both at exchanges and repeater stations.

Inductive Interference from Power Lines.

The construction of the 132-kV Grid and the development of subsidiary 33 kV and 11 kV power transmission and distribution lines focused attention on the problems of electrical interference with telephone circuits, which can arise from their proximity to power lines and traction systems. Such interference may be dangerous and may disturb working circuits, particularly under fault conditions when a heavy flow of current in the power lines may induce high voltages in neighbouring communication circuits.[10] Where adequate separation of the power and communication plant is not practicable, this induced voltage can sometimes be reduced to an acceptable value by such measures as sectionalizing the line by means of transformers, or by the use of gas discharge tubes. Interference can also arise from the harmonic components of currents flowing during the normal operation of a power line.

The whole subject of protection from lightning and power lines has been continually under discussion. A study group appointed by the C.C.I.F. deals more or less continuously with the two main problems of induced noise and of danger from induced voltages due to the flow of heavy fault currents in high-voltage power lines.

In addition, the complexity of interference problems led to the appointment, in 1927, of a committee of power and telecommunication engineers called the "Commission Mixte Internationale" (C.M.I.), charged with the study of questions of protection in collaboration with the C.C.I.F. As a result, directives[11] on the steps to be taken have been drawn up and accepted by common consent. These are the subject of constant revision in the light of experience.

Joint Construction.

It is, of course, to the mutual advantage of the Electricity Boards and the Post Office to run power and telecommunications wires on the same pole-line, and the practice is welcomed by local authorities and all who are interested in preserving the amenities of the countryside. Joint construction had been adopted widely in other countries, but not until 1939 did it come into use in this country to any extent, and then only with low-voltage power lines.

In 1937 the Electricity Authorities introduced a light form of 6·6-kV power line to facilitate rural electrification. Frequently the new lines ran along roads where a telephone line already existed. Difficulties arose in maintaining clearances when it was necessary to cross the power line to feed telephone subscribers, and an agreement was reached under which the attachment of not more than four P.B.J.-covered telephone wires to a power pole was accepted without further protection if the neutral was lowermost. Crossings in the span were not permitted, nor the running of telephone wires along the power route.

In 1938, as an experiment, Post Office wires were erected on a 6·6-kV power route, a cross-laced horizontal earthed guard being interposed between high-voltage and telephone wires, but because of the cost of construction this form of joint construction was seldom employed.

In 1939 the attachment of low-voltage power lines to Post Office poles at crossings was permitted, using an extension piece at the top of the pole, and approval was also given to the running of power wires on a telephone route for two (and, later, six) consecutive poles.

The general shortage of timber after the war did much to focus attention on the joint use of poles. To facilitate matters, formal agreements between the Post Office and Area Boards of the British Electricity Authority were compiled and brought into force in 1951. These agreements covered attachments to poles (at voltages up to 250V to earth) and also cases involving the recovery of an existing line (telephone or power) and its replacement by a joint line. Since the introduction of these agreements extensive use has been made of joint construction (Fig. 18) and attachment cases (telephone wires on power poles) involving the use of about 15,000 poles are now negotiated each year.

Recent successful experience with plastic-insulated wires and cables at high-voltage crossings has paved the way for discussions on the possibility of running both Post Office and high-voltage circuits on the same line of poles, and some experimental schemes involving power lines up to 6·6 kV to earth have been successfully installed.

CABLE CORROSION

Whilst corrosion of lead-covered cables has occurred from the time of their introduction, no records were kept of cable failures due to this cause before about 1920. The few cables laid directly in the ground were then, as now, protected with hessian tape and bitumen compound; the remainder, drawn into earthenware, concrete or cast-iron conduits, were unprotected. About 1920, cable failures due

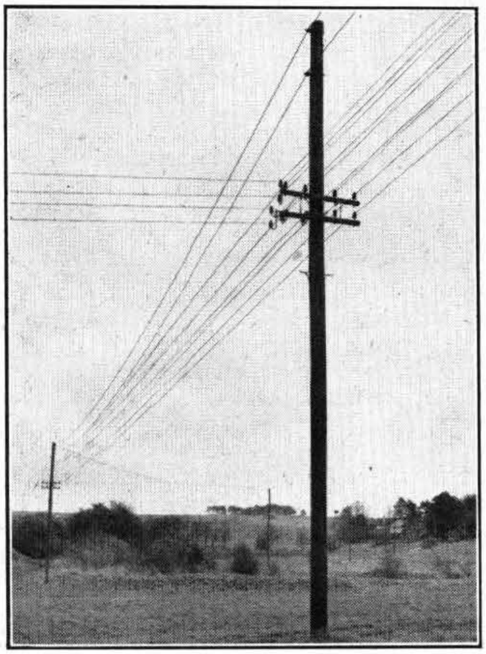


Fig. 18.—An Example of Joint Telephone and Low-Voltage Power-Line Construction.

to corrosion became increasingly frequent and were mainly attributed to leakage from d.c. tramway systems and d.c. supply mains. In order to establish the liability of the tramway company, the Post Office introduced, in 1921, its method of measuring the "stray" current in a cable sheath, using the Tester No. 36. In addition to the sheath current, measurements were taken of cable potential to earth (using a lead electrode) and to the nearest tram-rail.

By 1925 the annual number of corrosion faults had reached almost a hundred, and was still rising. More and more faults were occurring in areas remote from d.c. systems. Sometimes the cause was traced to self-generated currents in metal pipes; in others, to corrosive fluids filtering through into the duct from factory waste pipes, etc. The mechanism of corrosion due to natural conditions in the soil—electro-chemical corrosion—was becoming better understood and some attempt at cathodic protection by means of zinc earth-plates was made in 1926 without great success. To combat corrosion due to stray currents from tramway systems, the introduction of insulating gaps to limit the pick-up of current and to separate "pick-up" from "discharge" areas, proved generally successful. A new instrument, the Voltmeter No. 26, was introduced for measuring cable potentials to rail and earth. This was a sensitive instrument of 4,000 ohms/volt with a dial engraved to show the permissible limits of voltage between cable and rail, and between any two points on the rail, as prescribed by the Ministry of Transport Regulations governing the operation of a tramway system. Clear evidence of the infringement of these regulations became one of the criteria for justifying a claim by the Post Office against a Tramway Authority.

As the importance of corrosion damage became more fully appreciated in this country and abroad, a study group of the C.C.I.F. was formed to deal with the protection of telecommunications cables from corrosion arising from chemical action or electrolysis due to stray currents, and recommendations[12, 13] on these problems were published. A section of the C.M.I. also commenced work on the problem in 1929.

The continued increase in the corrosion of cables in the post-war years, despite the gradual reduction in the number of tramway systems, turned attention to the prevention of corrosion from natural causes. In new work this is best achieved by the use of protected cable, or cable with a non-corrodible sheath, and, by the end of 1955, more than 80 per cent of all new trunk and junction cables laid were protected from the outset. There remained, however, a vast amount of bare cable in ducts, and to safeguard this the Post Office turned to cathodic protection. The cable sheath is given a negative bias with respect to earth by connecting it either to buried billets of magnesium, which is anodic to lead, or to a mains-driven rectifier, the positive side of which is connected to a "sacrificial" earth electrode of iron.

The application of cathodic protection to underground plant may increase the risk of corrosion to other undertakers' plant nearby, and thus each proposal to install cathodic protection needs careful investigation by the owners of all underground plant in the area concerned. Because of the risk of interference with other undertakers' plant the Post Office has not, so far, applied cathodic protection where other complex underground services exist, but from experience with the relatively simple installations completed to date it appears that the corrosion rate can be at least halved on selected cable networks. A central co-ordinating committee, composed of the principal undertakers concerned, has been set up to consider the question of cathodic protection generally, and a technical sub-committee is studying the possible results of corrosion due to this form of protection.

The closer study of corrosion and the introduction of cathodic protection have indicated the need for much better testing apparatus. Very high resistance potentiometric voltmeters, or valve voltmeters, are now commonly used for measuring potentials accurately to within a millivolt; and the lead electrode formerly used has been replaced by the copper/copper-sulphate half-cell or by other non-polarizing reference electrodes.

The value of improved methods of corrosion control can be judged from the high cost of making good corrosion damage. The number of faults has continued to rise from about 3,500 in 1946-47 to 5,500 in 1954-55, with an annual repair bill exceeding £500,000. It is to be hoped that cathodic protection, coupled with the more extensive use of protected and plastic-sheathed cable, will check these rising costs and ultimately reduce them.

Future Development

In the search for alternative cable-making materials, aluminium shows promise both as a conductor and for sheathing. Trends indicate that whereas the price of lead and copper will tend to rise, that of aluminium (which is mainly the cost of the electrical power necessary to reduce the ore) will tend to fall, particularly with the development of vast hydro-electric schemes in countries well endowed with water power.

As a conductor, aluminium wire is cheap, being roughly one-third of the cost of copper wire for a given resistance. The jointing of aluminium conductors at first posed a problem but this has been neatly solved by a simple process of electric welding.

A cable using aluminium conductors would have a diameter some 1¼ times that of the equivalent cable using copper. Where duct space is important, the advantage would lie with copper.

As a sheathing material aluminium has a high screening factor and can be employed successfully to reduce induced voltages from power and traction circuits. It is, chemically, a highly reactive metal and must therefore be protected against corrosion by a good-quality covering. Three processes are possible for the manufacture of aluminium-sheathed cables: drawing the core into an over-sized aluminium tube, which is then drawn or swaged down to fit the core tightly; forming an aluminium strip round the cable core, making a continuous-seam weld, and swaging down; or extruding the aluminium direct over the core. The first two methods use aluminium of commercial purity, but by their nature cause work-hardening of the metal and tend to produce a stiff cable which, while satisfactory for direct laying in the ground, is not, at least in the larger sizes, so suitable for cabling in ducts through manhole entrances. The stiffness may, to some extent, be reduced by giving the sheath a corrugated finish. The third method produces a more flexible cable but requires the use of super-purity aluminium. Extrusion temperatures are necessarily high and considerable care is required to prevent scorching of the core. This process is not yet in regular commercial use.

There is undoubtedly a wide field of service for a successful aluminium-sheathed cable possessing the necessary degree of flexibility.

Besides aluminium, polythene or other plastics will tend to be used more and more as a sheathing material. The "all-polythene" type of cable previously referred to will be increasingly used for local distribution purposes, particularly where it can be laid direct in the ground, or where duct space is not important. Until a plastic insulant can be applied in lesser thicknesses than at present, paper insulation will continue to be employed. Polythene, with or without a water barrier, is therefore likely to be used as a sheath for paper-core cables; the first experimental cable of this type, Fig. 19, has already been installed between Dover and Deal and described in a previous issue of this Journal.[14] Improvements in the quality and grade of polythene will undoubtedly be made. The development of an improved

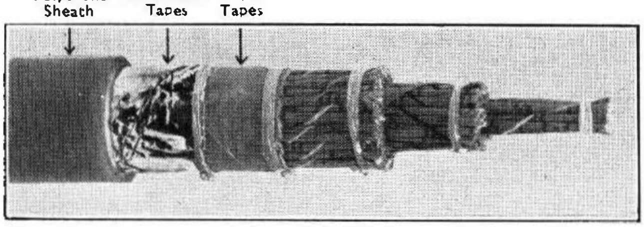


FIG. 19.—EXPERIMENTAL 54-PAIR POLYTHENE-SHEATHED CABLE WITH ALUMINIUM CONDUCTORS.

and tougher grade was recently announced, which withstands higher temperatures and resists water permeation very much better than the present grades of polythene. Developments of this nature may mean that polythene might, before long, replace lead as the standard cable sheathing material, aluminium being used in addition or as an alternative where screening against electrical interference is necessary.

Increasing attention is being directed to the gas pressurizing of cables[15] by means of dry air or nitrogen at a pressure of 10 lb/in^2. This will prevent the ingress of moisture should a leak in the sheath develop; and, provided means are taken to maintain the pressure, the fault need not be given urgent attention as at present. Contactors placed in a cable at convenient points can be used to give an indication, both of the presence of a leak and of its location. The decision has been taken to pressurize all new coaxial cables, and the Glasgow-Oban coaxial cable, which will carry the transatlantic circuits, is the first to be so treated. Extension of the system to other important main cables will follow, and its application to the local subscribers' network will be considered in due course.

Improved methods of locating sheath leaks make use of tracers in the escaping air. Tracers may be either radioactive gases, which can be detected with a geiger counter, or halogen gas, which will colour the flame of a test lamp or give a deflection on an ionization detector. Such methods of detection are of particular use for finding leaks in aerial cables; the sampling tube feeding the detector can be mounted on a long stick and carried by a man walking along the route.

In the sphere of local line distribution the use of the "all-polythene" type of cable laid directly in the ground should enable an underground lead-in to subscribers' premises to be more freely adopted. Overhead distribution may take the form of a light inconspicuous p.v.c.-insulated drop-wire supported on simple brackets and run direct from the terminal block on the pole to the subscriber's protector.

The use of self-supporting aerial cable will undoubtedly be extended; the "all-plastic" type is light, easy to erect, free from corrosion and vibration troubles, and does not require guarding for voltages up to 11 kV. A polythene-insulated cable will no doubt be developed in due course that will withstand a voltage of 33 kV and underground cable will then only be necessary in the case of 132 kV, 275 kV or higher-voltage crossings.

In the field, better equipment will help to reduce costs, improve working conditions, and reduce the risk of accidents. Engineering vehicles of new design will incorporate features for the convenience of staff, for the satisfactory storage of tools and equipment, and for the inclusion of winches, hoists and other devices to assist heavy engineering operations.

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The Inland Telephone Exchange System

The first public telephone exchange in the United Kingdom was opened in 1879 at Coleman Street, London, and since then the telephone system has grown to some 6,000 exchanges, serving 7,000,000 subscribers' stations. Between 1912 and 1915 several types of public automatic exchange were installed experimentally, but from 1915 to the early 1920s the Strowger, step-by-step, system established itself and after 1921 was adopted for the larger new exchanges. It was not until 1928 that small automatic exchanges were introduced as the normal means of serving rural areas, but since then the use of these small, Unit Automatic, exchanges has increased rapidly, and there are now more than 3,000 in service. Until the middle 1930s an operator was necessary at each end of trunk circuits but, with the introduction of voice-frequency signalling and dialling equipment, shortly before the 1939-45 war, it became possible to introduce single-operator control on certain main routes. Since the war the range over which controlling operators can complete calls automatically has been extended and it is planned that, by 1961, single-operator control will be achieved for all trunk calls to automatic-exchange subscribers. Early 1959 will witness the completion of the first installation of equipment that will enable subscribers to dial their own trunk calls.

Introduction

"The National Telephone Company's system had a net increase of 45,323 stations during the year 1906, bringing the total stations in service at 1st January, 1907, to 407,736. . . . Ninety new National exchanges have been brought into service during the year just gone, bringing the total up to 1,285. . . . New common battery equipment has been installed at 11 exchanges in London and the Provinces, with an aggregate capacity of 19,020 lines . . . . in various stages of construction, there are 16 other common battery equipments with an aggregate capacity of 35,000 lines."

THESE extracts, from an editorial article in the February 1907 issue of the *National Telephone Journal*, indicate the stage of telephone development reached in this country when the Institution of Post Office Electrical Engineers was formed. The year 1906 can, in fact, be regarded as the end of the first era in the telephone history of the United Kingdom. The preceding 30 years—since Bell's momentous discovery—had seen notable technical developments and the evolution of a system which, for manual switching, remains substantially unchanged to this day. Furthermore, by 1906 the future pattern of the telephone system in this country had been set by the decision that within a few years the whole of the telephone system would be controlled and operated by the Postmaster-General.

Early Development of the Telephone in the U.K.

The British public telephone exchange system dates from the opening of the first exchange (Fig. 1) at 36 Coleman Street, London, in 1879, by the then newly formed Telephone Company, Ltd. (Bell Patents). This was quickly followed by further installations at Leadenhall Street and Palace Chambers. In the same year a rival company, The Edison Telephone Company of London, Limited, was founded, and exchanges were opened at Lombard Street and Queen Victoria Street, in competition with the growing network of the Bell-controlled company. There followed a short period of intense competition between the Telephone Company, whose instruments employed the electromagnetic transmitters and receivers of the original Bell patents, and the Edison Company, whose system was based upon the patented carbon transmitter and the Edison "chalk" receiver. It was soon recognized that the carbon transmitter, covered by the master patents of Edison, was superior (from a volume-efficiency point of view at least) to the electromagnetic transmitter devised by Bell. But there was little doubt that Bell's electromagnetic receiver was more reliable than the chalk receiver devised by Edison to avoid the Bell patents. The conflict between the companies was cut short by an action against the Edison Company on behalf of the Crown, alleging that the operation of public telephone systems contravened the Telegraph Acts of 1863, 1868 and 1869, which gave the Postmaster-General a virtual monopoly to operate all forms of "telegraphic communication," and under this threat the two companies amalgamated in 1880 to form the United Telephone Company. Contrary to the expectations of the telephone company, judgment was given in favour of the Crown, but the United Telephone Company was permitted to continue business, with certain restrictions, under licence from the Postmaster-General and subject to the payment of a 10 per cent royalty. During the following years, new companies were formed to provide telephone service, under licence from the Postmaster-General, in many of the major cities and towns, and the United Telephone Company itself floated several subsidiary companies to develop telephone systems in the Provinces. Notable amongst these subsidiaries was the National Telephone Company, established in Glasgow with the express task of developing telephone service in Scotland, Northern England and Ireland. The number of independent authorities continued to grow until 1889, when the United Telephone Company and its subsidiaries were amalgamated into one company under the title of The National Telephone Company, which then had a share capital of some £4,000,000 and provided service to about 24,000 subscribers.

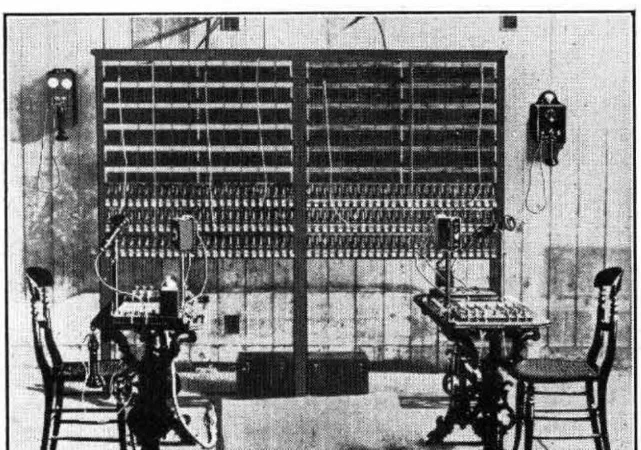


FIG. 1.—THE FIRST PUBLIC TELEPHONE EXCHANGE IN THE U.K., AT 36 COLEMAN ST., LONDON.

During this first decade of public telephone service, switchboard design had followed two distinct lines. The switchboards originally installed by the Telephone Company used elementary jacks for line terminations, and plugs and cords for interconnecting the lines. The early Edison switchboards, on the other hand, were based on the co-ordinate switching principle, in which subscribers' lines were terminated on vertical bars, a series of horizontal bars provided the connecting circuits, and metal pegs were used to connect the vertical and horizontal bars when establishing connexion between subscribers. As the number of subscribers increased, the simple "crossbar" system of interconnexion became unwieldy, and in due course there was general acceptance of the "plug and cord" switchboard except for very small exchanges. An early cord-type switchboard is shown in Fig. 2. There were various forms of calling signals between the subscriber and

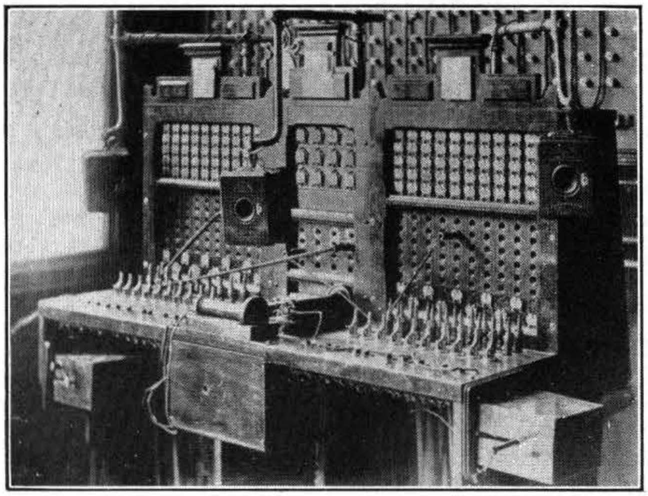


FIG. 2.—MIDDLESBROUGH EXCHANGE IN 1885.

the exchange, most of which relied upon the use either of a primary battery at the subscribers' premises or, later, of a central signalling battery located at the exchange. It was soon apparent that some form of supervisory signal was desirable to indicate the end of a call, and a number of ingenious methods were devised. In some early designs a galvanometer was inserted in the connecting circuit, but this was later replaced by a clearing indicator, and in one system a permanent current flowed when the receiver was on the switchhook. Possibly the greatest advance in switchboard design was the introduction of the subscribers' multiple, with facilities for the operator to apply an engaged test before connecting to the required line. Some of the earliest multiple boards had a horizontal multiple so that telephonists could have access from both sides, but the vertical multiple introduced into this country by the Western Electric Company of America was eventually found to be preferable, and became the standard arrangement.

The next 10 years (1889-1899) were marked by extensive development and installation of the magneto system with multiple switchboards to serve the ever-increasing size of exchanges, and the introduction of self-restoring indicators and lamp-calling signals on junctions as operating aids. An interesting innovation during this period was the introduction of the "call wire" system, in which a form of omnibus order-wire was shared by groups of 30 to 40 subscribers. During this period a major change in the inland telephone system occurred when, in 1896, the trunk lines of the National Telephone Company were purchased and all trunk services placed under Post Office control.

Introduction of the Common Battery System.

Although the common battery (C.B.) system had been first proposed by Hayes in the United States in 1892, it was not until 1900 that the first C.B. multiple installation in the United Kingdom was opened at Bristol. In 1901 the Postmaster-General and the National Telephone Company agreed to develop the telephone system in the London Metropolitan area jointly—with the ultimate object of the whole system being taken over by the Postmaster-General in 1912, and an extensive program for the conversion of London exchanges to common battery working was begun. By 1906 no fewer than 26 such exchanges had been opened in the London area. Fig. 3 is typical of these exchanges.

Until 1901 the Post Office had played a very minor part in the development of the local telephone system, and at that time the Post Office local services contained no more than 2,000 lines, mainly concentrated on three exchanges, at Newcastle, Cardiff and Newport. From the turn of the century, however, the Post Office took a more active part in the provision of telephone exchange service, not only in London but also in a number of provincial towns. It was during this period that the Post Office designed the Central Battery Signalling system, which, under certain conditions, was more economical than full C.B. working.

The first decade of the 20th century also marked the establishment of the British telephone industry. Prior to about 1905 most of the major items of exchange equipment had been imported from the U.S.A.—although British firms were by that time manufacturing most of the subscribers' apparatus. In 1906 the Peel Connor Telephone Works was established at Manchester, and by 1910 the first large British C.B. multiple exchange was installed at Glasgow.[1] It is notable that the Peel Connor C.B. design employed a 40V central battery and impedance coils, instead of the repeating-coil type of transmission bridge used on the Western Electric switchboards.

On the 1st January, 1912, the Postmaster-General took over all the assets and business of the National Telephone Company and, for the first time, a unified telephone system was available throughout most of the British Isles. In all, 1,565 exchanges were transferred from the National Telephone Company, of which 231 had more than 300 subscribers each. Some 68 exchanges were of the C.B. type, but the majority of the rest were magneto.

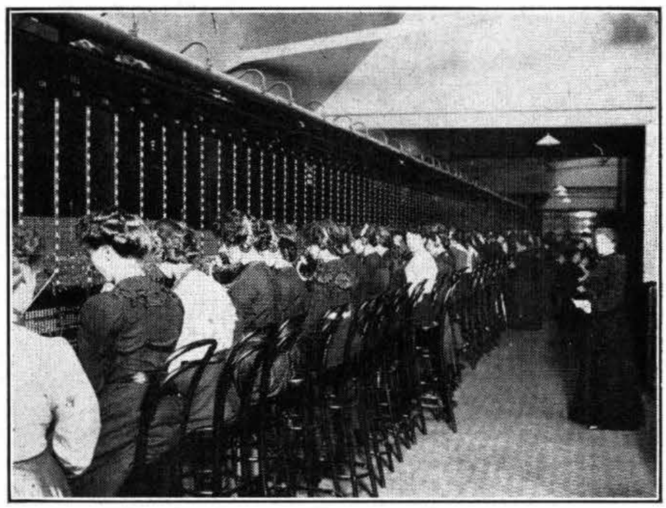


FIG. 3.—HOLBORN EXCHANGE SWITCHROOM.

The effects of a single, national control of the telephone system were soon apparent. In the first three years (i.e. 1912-1914) the Post Office opened no fewer than 450 exchanges in small villages and rural areas which had not been served by the telephone companies, and many of the separate Post Office trunk exchanges were amalgamated with local exchanges taken over from the companies.

THE INTRODUCTION OF AUTOMATIC SWITCHING

The year of transfer to the Post Office was marked by the opening at Epsom, Surrey, on the 13th March, 1912, of the first public automatic exchange system in the United Kingdom.[2] Automatic telephony at that time was by no means new. The Strowger patents had been filed in 1889, and by the end of the 19th century there were many automatic exchanges in operation in the United States. There had been several demonstrations in Britain of Strowger and other automatic systems, and there were a few small private installations prior to 1912.

The Epsom equipment, which was of American design and manufacture, was installed by the newly formed Automatic Telephone Manufacturing Company of Liverpool, which had acquired the British and Colonial patent rights of the Strowger system. The Epsom exchange provided for 500 subscribers initially, and had an ultimate design capacity of 1,500 lines. Subscribers were given the facility of direct access, by dialling, to the manual exchanges at London Central, Croydon and Sutton. A small two-position manual switchboard was provided for dealing with assistance and trunk traffic and to handle all incoming calls. It is interesting to note that this first "auto-manual" switchboard was closed down at night, when all incoming traffic was routed via a special position (fitted with a dial) at Croydon Exchange.

The trunking was based on the use of 3-digit and 4-digit numbers for subscribers, with 2-digit dialling codes for access to the adjacent exchanges. The final selectors (Fig. 4) and the group selectors were 100-point two-motion switches, with the controlling relays mounted vertically. Subscribers'

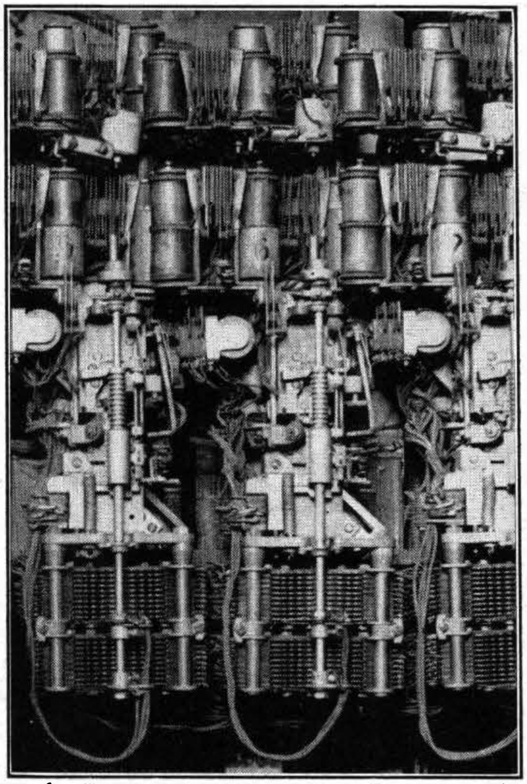


FIG. 4.—FINAL SELECTORS AT EPSOM EXCHANGE, 1912.

traffic to the first selectors was concentrated by means of the now historic Keith line switch. The circuits were arranged for "calling party" release, but the contract specified that the equipment should readily be convertible to "first party" release so that the method of control could be changed if service difficulties were encountered. Message-rate metering was provided, the meters being included in the subscriber's line circuit and responding to a reversal of line current when the called party replied. The subscribers' instruments were fitted with a rotary dial of the same general appearance as a modern dial; the pulsing speed being controlled by means of a clock spring in conjunction with a centrifugal governor.

The subscribers' line switches, the final selectors and the meters for 100 lines were accommodated on one double-sided rack, whilst the group selectors were fitted to special "selector houses," each accommodating up to 160 selectors together with the connexion strips, etc., for interconnexion. This form of construction set the pattern for Strowger exchanges in this country for many years. Viewed in retrospect, one can appreciate the soundness of this original design, which employed the minimum amount of inter-rack cabling.

The second experimental automatic exchange was opened at Hereford on 1st August, 1914. The equipment, with an initial capacity of 500 subscribers' lines, was of the Lorimer type, manufactured by the Canadian Machine Telephone Company of Toronto. The Lorimer system was based on an entirely different approach to the automatic switching problem, and contained many novel features. The basic mechanism was a rotary switch, with a 100-point cylindrical bank, driven via electromagnetic clutches from a system of continuously rotating shafts. Each switch had 10 sets of brushes or wipers, equally spaced around the shaft; any required group of 10 contacts being chosen by selecting the appropriate wipers by means of a pulse-driven register switch associated with each main switch. The switches were connected to form the equivalent of a line-finder, group selector and final selector switching train.

The novelty of the system was the method of signalling between the subscriber and the exchange equipment. Instead of the rotary dial of the Strowger system, each telephone of the Lorimer system was provided with a calling device consisting of a mechanism which could be set by four levers for the thousands, hundreds, tens and units digits. The levers were set by the subscriber before the call was originated, and the mechanical arrangements provided the caller with a visual indication of the setting of his calling device. To start the call, the subscriber gave a single turn on a crank handle, which positioned the mechanism and established the calling condition. At the exchange a disengaged "pilot" switch started the linefinder, which, in due course, was arrested by a marking condition on the bank contact of the calling line. A "signal controller" switch then transmitted a series of current pulses to operate an electromagnet in the calling subscriber's instrument and thus to step the mechanism of the calling device. When this mechanism had been stepped to the position marked by the selector lever, a signal was returned to the exchange to mark the end of the digit. Coincident with the transmission of pulses to line, synchronized pulses were also sent to position the register switch of the selected circuit. A feature of the Lorimer scheme was the automatic disconnexion of a call after a predetermined time.

A few months later, a trial of yet another method of switching was commenced by the opening of the Darlington exchange on the 10th October, 1914. The equipment was manufactured by the Western Electric Company, and was based on the now well-known "Rotary" system, which has since been extensively developed by the Bell Telephone Company of Antwerp. The initial equipment at Darlington had a capacity for 800 lines, with a nine-position auto-manual switchboard for dealing with outgoing and incoming junction traffic. The Rotary system, like the Lorimer system, employs continuously rotating shafting and electromagnetic clutches associated with unidirectional rotary-switch mechanisms. The trunking arrangements of the Darlington scheme were based on a linefinder, group selector and final selector combination. The linefinders had a capacity of 60 subscribers, the group selectors provided up to 22 trunks on each of 10 levels, whilst each final selector group served a maximum of 200 subscribers. The large circuit capacity of the rotary switches permitted a higher degree of trunking efficiency than was then obtainable in the Strowger system with its limitations of 10 circuits per level.

The most distinguishing feature of the Rotary system is the method of switch control. The incoming signals from the subscriber's dial are stored in a "register," which, in turn, controls the movements of the rotary switches by pulses which are returned from the selectors to the register as movement proceeds. The circuits of the Rotary system are considerably simplified by the use of "sequence" switches, which are used in a number of the main circuits to rearrange the circuit conditions as the call proceeds. The switch multiples are provided with a special form of ribbon multiple cable, consisting of parallel wires insulated with woven silk, the whole ribbon being neatly tucked away between the wiring tags of the switch banks.

The First World War.

The First War World slowed the development of automatic telephony in this country. Nevertheless, a detailed study was made of the performance of the early experimental exchanges, and, in collaboration with the manufacturers, a number of changes were made to improve their performance under the operational conditions existing in this country. During the period 1915-1918, Strowger exchanges of A.T.M. manufacture were brought into service at Accrington, Chepstow, Newport (Mon), Portsmouth, Paisley, Blackburn and Leeds. The Leeds installation[3] was the most ambitious scheme attempted up to that time, with an initial multiple capacity for 6,800 lines, a 5-digit numbering scheme and a layout designed for an ultimate capacity of 15,000 lines.

The Strowger exchanges installed during the war incorporated a number of interesting new features. Perhaps the most important was the introduction of keysender B positions, which permitted a high speed of operating on incoming calls from nearby manual exchanges. The operator at such positions was provided with a digit key-strip, by means of which she could set up the call quickly by the successive depression of the appropriate digit keys. Mechanical keysenders associated with the B positions received the signals from the operator's key-strip, and established the connexion over the automatic switching train by the transmission of normal make and break pulses. Provision was also made for direct dialling to the automatic subscribers from nearby automatic and manual exchanges with standard supervisory facilities.

During the war, and for some years afterwards, much attention was given to the application of the mathematical theory of probability for assessing the traffic carrying capacity of the various links in an automatic switching system. These investigations were reflected in the modification of the original Strowger trunking scheme to provide secondary line switches in order to increase the traffic carrying capacity of the 1st selectors by making them available to a larger number of sources. The same ideas were applied on the second Western Electric Rotary installation, which was opened in September 1916 at Dudley, where first and second linefinders were employed instead of the single 60-point linefinder provided in the original Darlington equipment.

The year 1918 saw the entry of Siemens Bros. (who had for some years been manufacturing manual exchange equipment) into the field of public automatic exchanges. The first Siemens exchange was opened at Grimsby[4] in September 1918 and was followed by a second installation at Stockport a year later. The Siemens system was essentially a Strowger step-by-step system with 10-point first and second preselectors, and 100-point two-motion switches for the group and final selectors (Fig. 5). There were, however, some important differences in the circuit arrangements. Perhaps the most significant of these was the use of machine-generated pulses to drive the preselectors and the rotary action of the group selectors. The Siemens system also introduced the principle of "battery testing," which has found numerous applications in modern circuits. The original Siemens exchanges were also noteworthy for the arrangement of the equipment on single-sided apparatus racks (Fig. 6).

There were two further installations in this first experimental phase in the development of the automatic switching system. The first was the installation at Fleetwood, in July 1922, of a public exchange of 500 line capacity, based on the Betulander all-relay switching scheme and manufactured by the Relay Automatic Telephone Co., Ltd., which had been set up in 1915 to exploit the Betulander patents in this country. The Relay system had been used previously, and continued to be used for many years later, for private automatic branch exchanges where the absence

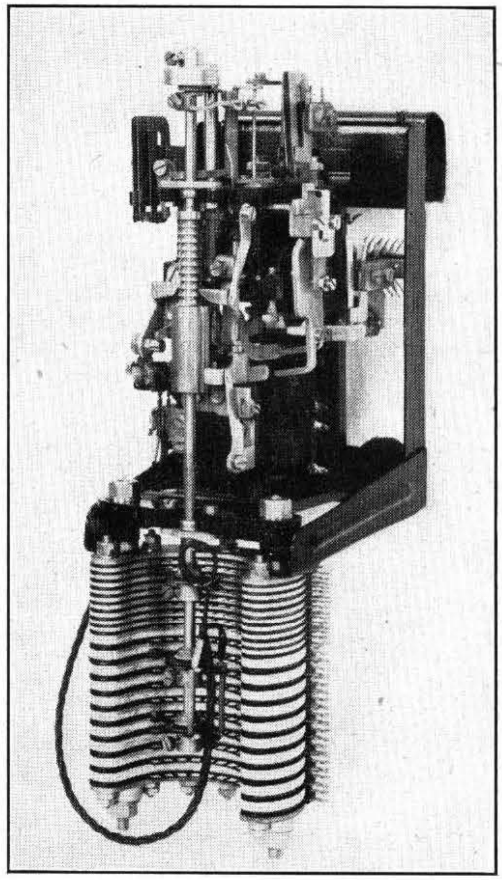


FIG. 5.—AN EARLY TWO-MOTION SWITCH (SIEMENS BROS.).

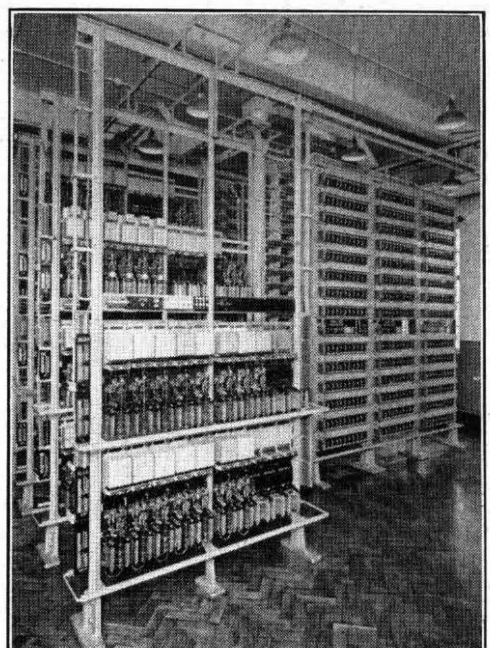


FIG. 6.—SINGLE-SIDED APPARATUS RACKS AT AN EARLY SIEMENS EXCHANGE.

of complex mechanisms resulted in a system that required very little maintenance attention. When used for larger public exchanges, the circuits, although employing simple elements, tended to become rather complex as a whole, and mainly for this reason the system was not extensively developed for large exchanges. The Fleetwood installation had a 3-digit numbering scheme, with the subscribers' lines arranged in groups of 10. A suitable number of such groups shared a common multiple served by 14 incoming trunk links and 14 outgoing trunk links. Any subscriber's line could be switched to any incoming or any outgoing trunk link by the operation of relays. There were further groups of "trunk connecting relays" which switched any desired incoming trunk link to a required outgoing link. The subscribers' calling signals were received and stored in a recorder, which in turn took into service one of a number of common markers that applied the appropriate operating conditions to the various relay groups (the method of operation being on the co-ordinate principle, using relays with two coils).

Another interesting adaptation of the Strowger step-by-step system was demonstrated by the opening of the Dundee and Broughty Ferry automatic exchanges[5] in March 1924. The opening of these exchanges also marked the entry of the General Electric Company (who, it will be recalled, had been making C.B. and other manual equipment since about 1907) into the automatic switching field. The Dundee equipment used mechanisms purchased from the North Electric Company of the U.S.A., but the associated relays, racks, manual switchboards, etc., were designed and manufactured in this country. A feature of the North Electric system was the arrangement of the selector banks so that the face of the bank contacts lay in a vertical plane. The group and final selectors stepped first in a rotary direction, and then vertically upwards into the "level" selected. The subscribers' lines were terminated on 25-point preselectors arranged for self-interrupted drive via a ratchet-and-pawl system.

Acceptance of the Strowger Step-by-Step System and Development of the Multi-Exchange Area

It was apparent early in the 1920s that the Strowger automatic system was rapidly becoming established throughout the United Kingdom. By 1924 there were 18 main public automatic exchanges of all types, with a total capacity for about 36,000 subscribers. Almost 95 per cent of this multiple was on Strowger exchanges—mostly of A.T.M. manufacture. There will always be different opinions on the balance of merits of different switching schemes, but the decision to adopt the Strowger system in the United Kingdom has been proved by the simplicity of maintenance, reliability in service, and flexibility to meet extended switching requirements, offered by this system. Up to this time a very careful economic study had been made of every new exchange project before a decision was made to install automatic equipment. By 1921, however, sufficient experience had been gained for general rules to be formulated, which avoided detailed cost studies of a large number of individual cases. Previous experience had suggested that exchanges which would not grow beyond 1,000 lines at the 20-year design period could be more economically served by manual switching methods. For larger exchanges, with high calling rates and where a high proportion of the total traffic was local, automatic switching was clearly more economical.

From 1924 to 1930 the number of automatic exchanges of the step-by-step type increased rapidly, and 147 were in service by the end of 1930. At first, most of the equipment was provided by the Automatic Telephone Manufacturing Company, Siemens Brothers, and the General Electric Company, but later two more manufacturers, Standard Telephones and Cables, Ltd., and Ericssons Telephones, Ltd., entered the public automatic exchange field. There followed a period of rationalization and standardization of facilities. In 1922, for example, the Post Office decided that all future automatic exchanges should be designed to operate with subscribers' dials having a 66 per cent break period on each pulse.[6] The Keith line switch and secondary working were abandoned in favour of a 25-point subscriber's uniselector, the outlets of which were graded to the first selector stage. During this phase, each of the manufacturers employed relays of his own design, and the subscribers' uniselectors also differed in mechanical detail. The two-motion selectors of the main switching train were broadly similar, but there were many minor differences. All manufacturers had adopted the "line switch and final unit" (Fig. 7) and the "double-sided selector house" for

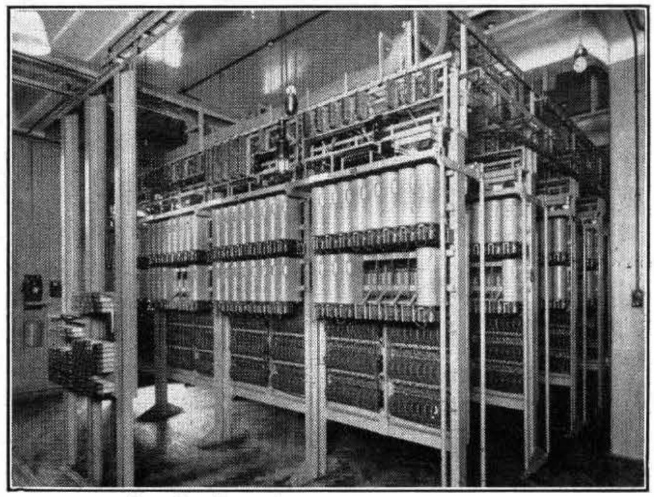


Fig. 7.—Line Switch and Final Units.

the main switches, and the facilities provided were mostly uniform to Post Office specifications. The use of different types of relays and the minor differences in mechanisms resulted in circuits that differed from one manufacturer to another; but on the whole circuits were rapidly becoming standardized.

Probably the most important aspect of this stage in the growth of the telephone system was the development of multi-exchange systems[7] in the larger provincial centres. The idea of satellite exchanges[8] was the subject of much study, and circuits were evolved which provided greatly increased facilities. The introduction of the Discriminating Selector Repeater[9] (D.S.R.) made it possible to discriminate between local calls, calls to the operator, which might require high grade junctions, and other junction calls; it also permitted absorption of digits before and after discrimination to save ranks of selectors.

The Leeds area was expanded in 1925 by the opening of four new satellite exchanges, and in 1926 a multi-exchange system was installed at Edinburgh with a capacity for 15,600 lines. A similar installation followed at Sheffield, where there were nine exchanges in the linked numbering scheme, providing in all a capacity for 14,500 subscribers. An unusual arrangement was adopted in the Brighton new multi-exchange area, which was opened in 1927 with a total multiple of 10,500, where a special dial was introduced on which the various exchange names were shown adjacent to the appropriate initial numerical digit.

Apart from the steady growth of the automatic system during the 1924-1930 period, there was considerable expansion of the manual switching system, especially in the large city areas and in the smaller towns. In some small ways automatic switching principles had been used to improve the manual system; e.g. in the manual straightforward junction system,[10] which employed automatic switches and relays to provide a much improved method of handling large volumes of traffic between manual centres.

Conversion of the London Network to Automatic Working

The conversion of the London manual switching system to automatic working presented special problems. Due to the high telephone density in the central part of the London area, a very high proportion of the calls originated on any one exchange must be switched to subscribers on other exchanges. It was not practicable to change over all the manual exchanges to automatic working simultaneously, as was done in the provincial multi-exchange areas, and a plan for gradual conversion, exchange by exchange, had to be devised. Moreover, a system was required which divorced the routing of the call from the digits dialled by the subscriber, thereby permitting flexibility and economy in the design and provision of the junction cables and switching plant.

The Americans had been faced with a similar problem in New York and had devised the Panel system of switching for use in such circumstances. Apart from the mechanical differences of the Panel system, the main feature was the introduction of a device to translate the digits dialled by the subscriber into any other digits which were required to route the call to the required destination in the network. Discrimination was provided so that on calls to an automatic exchange dial-type pulses were transmitted to operate the automatic selectors, whilst on calls to a manual exchange coded signals were transmitted to present an illuminated display of the required number to the B-position operator. Serious consideration was given to the adoption of the Panel system for London, but before a decision was taken the Automatic Telephone Manufacturing Co. offered an alternative scheme, based upon the Strowger system, which would give comparable facilities to the Panel system. In the A.T.M. scheme the device that undertook the translation of routing information was termed a "director" (Fig. **8**), and hence the system using

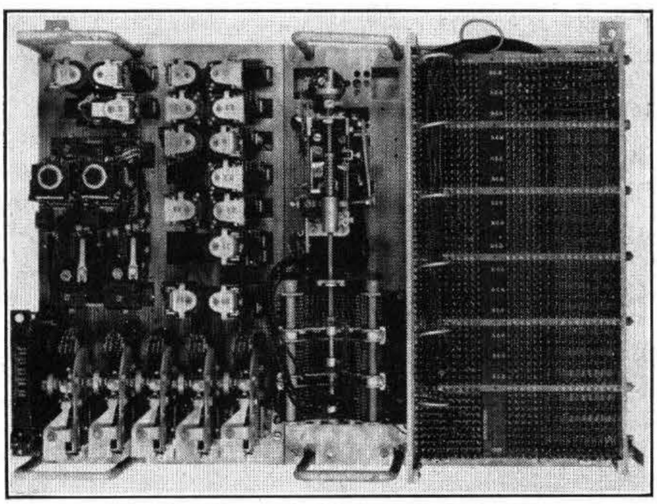


Fig. **8**.—Director, with Cover Removed.

this device has become well known as the Director system.[11] It is now used extensively in London, Birmingham, Manchester, Liverpool, Glasgow and Edinburgh.

The first demonstration of the Strowger director system was given at the British Empire Exhibition in 1924. In addition to the arrangements at the automatic exchange, this demonstration included a complete model of the "Coded Call Indicator" (C.C.I.) system, which could be installed at existing manual exchanges to provide a visual display of the required subscriber's number to operators on calls incoming from automatic exchanges. The C.C.I. equipment was designed expressly to require a minimum of floor space and the lowest possible power requirements, so that it could be installed at existing exchanges where, in many instances, accommodation was very restricted. The C.C.I. system also provided for the automatic distribution of incoming traffic amongst the available B-position operators, and many operating aids were also included. During 1926-1927, all London manual exchanges were provided with C.C.I. equipment in readiness for the opening of the first automatic exchange.

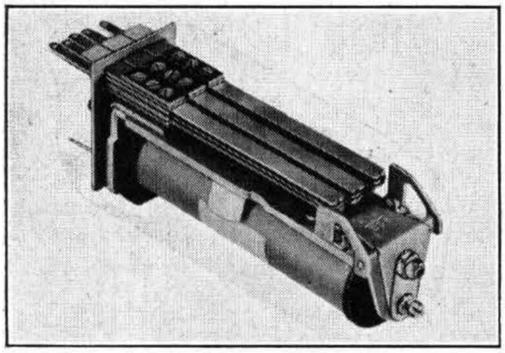
Holborn[12] was the exchange selected to be the first automatic exchange in London, and director equipment with a capacity for some 9,800 subscribers was installed in 1927. The Holborn installation included a mechanical tandem switching centre[13] for handling calls from Holborn to the London manual exchanges, and also to act as a junction-lending centre for the manual exchanges. The opening of the mechanical tandem at Holborn permitted the closing down of existing manual junction-switching centres at Central, Hop, Gerrard, North, East and Croydon. The mechanical tandem had associated with it a series of cordless B positions (Fig. **9**), on which were terminated the order wires from manual exchanges. The operator at

Fig. **9**.—Cordless B Positions at a Mechanical Tandem Exchange.

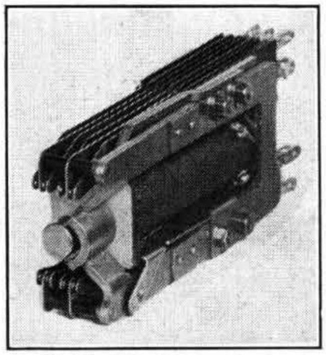
the B position, on receipt of a request from a distant manual exchange, assigned the junction to be used, and keyed the number required on a digit key-strip on her position; 7-digit keysending equipment associated with the mechanical tandem exchange received the signals from the key-strip and established the call, firstly over the mechanical tandem switches, and then to the C.C.I. equipment at the required manual centre.

A second director exchange, at Bishopsgate, was opened for service in March 1928, with 8,500 subscribers' multiple, and during 1928 and 1929 further exchanges were opened at Sloane, Western, Bermondsey, Monument, Maida Vale, Temple Bar, Langham and Edgware. The stage had now been set for the complete change-over of London to automatic working, and the introduction of automatic telephony on a big scale at Manchester and, later, at other large provincial cities.

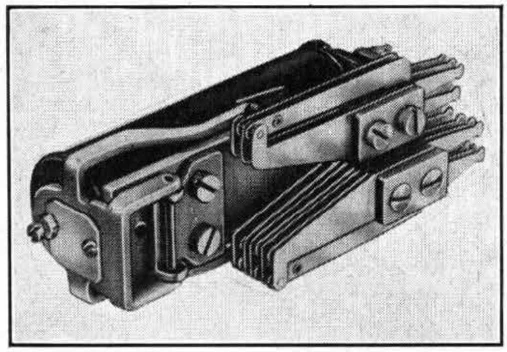
During the following years there were a number of improvements in the arrangements for handling traffic



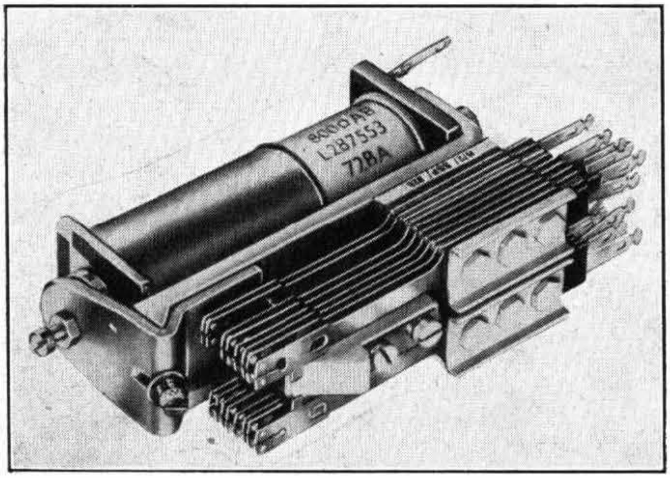
(a) Relay Used in Manual Exchanges—about 1914—(A.T.M. Co.).



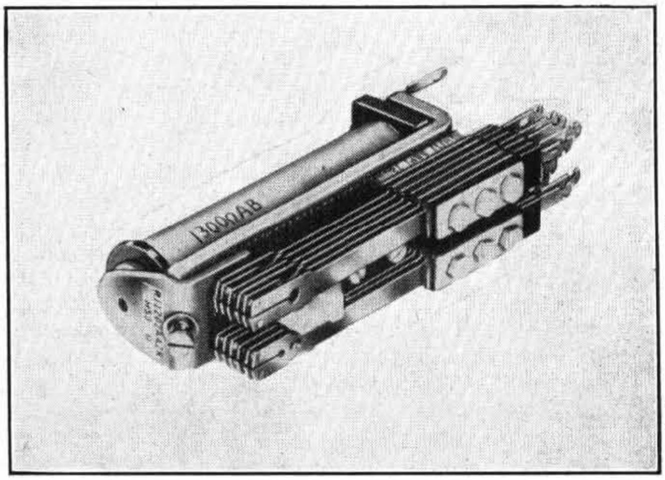
(b) Flat Relay (Siemens Bros.).



(c) Strowger Horizontal Relay (A.T.M. Co.).



(d) Post Office 3000-Type Relay.



(e) Post Office 600-Type Relay.

FIG. **10**.—EXAMPLES OF EARLY RELAYS AND POST OFFICE STANDARD RELAYS.

during the transitional period in a director area. The first of these was the application of "straightforward junction working," whereby the order wire was eliminated and the distant manual exchange A-position operator given direct access to the keysender B-position operator over the normal junction. A "pip-pip" signal was returned to the A operator to indicate when the B operator was connected and ready to take the demand. Shortly afterwards a scheme was introduced for eliminating the B operator by providing the distant manual exchange A operator with a digit key-strip on her position. The digits were signalled between the two exchanges by means of combinations of several voice-frequency tones,[14] which were converted back to d.c. signals at the automatic exchange by the use of mechanically-tuned detecting relays.

STANDARDIZATION OF AUTOMATIC-EXCHANGE EQUIPMENT

Up to about the year 1930 very little had been achieved in the detailed standardization of the components and equipment units used in automatic telephony. With the growing number of automatic telephone exchanges it was clearly desirable, from many points of view, that the circuits and the physical design of equipment supplied by all manufacturers should, as far as possible, be identical. Absolute identity of parts from each of five large manufacturers could not be attained immediately, because of tooling problems and different manufacturing techniques, but a start was made with the introduction, in 1930, of a new type of standard apparatus rack for use in automatic exchanges.[15] The double-sided line switch and final unit and the double-sided selector house, which had been a feature of most earlier exchanges, were abandoned. In their place a series of standard single-sided racks was evolved, the main unit for the more important items of equipment being 10 ft 6 in. high by 4 ft 6 in. wide. There were smaller widths for miscellaneous apparatus racks, and for certain special purposes, but the standard height was retained for all racks (there was an alternative height of 8 ft 6 in. for use in buildings with sub-standard ceiling heights). A pressed-steel channel-type shelf was designed as the standard mounting for all relay sets and selectors, and the new design envisaged that all components of such circuits should be mounted on the jacked-in selector or relay-set unit. Provision was made for separate racks for subscribers' uniselectors, for group selectors, for final selectors and for the various other functional units of exchange equipment. Standard designs were also introduced for travelling ladders and for rack lighting.

The first exchange employing the new standard single-sided racks was opened at Bristol in 1931, and was quickly followed by a similar installation at Acorn, London. Standardization of the subscribers uniselector followed, based on a design of the General Electric Company. The most important measure of standardization at that time was probably the introduction of the Post Office relay (Fig. **10**), which has now become widely known as the 3000-type.[16] For the first time, twin contacts were employed to minimize the number of circuit failures caused by dirty contacts. The 3000-type relay also introduced the idea of a "buffer block," which predetermined the positions of the fixed springs and greatly facilitated adjustments. A smaller and cheaper version of the 3000-type relay (the 600-type[17]) was introduced for use in subscribers' line circuits and in similar situations where the number of contacts required is small and where no critical timing requirements are specified. The introduction of the standard Post Office relay made it possible to obtain identical circuits and wiring in equipment manufactured by all contractors.

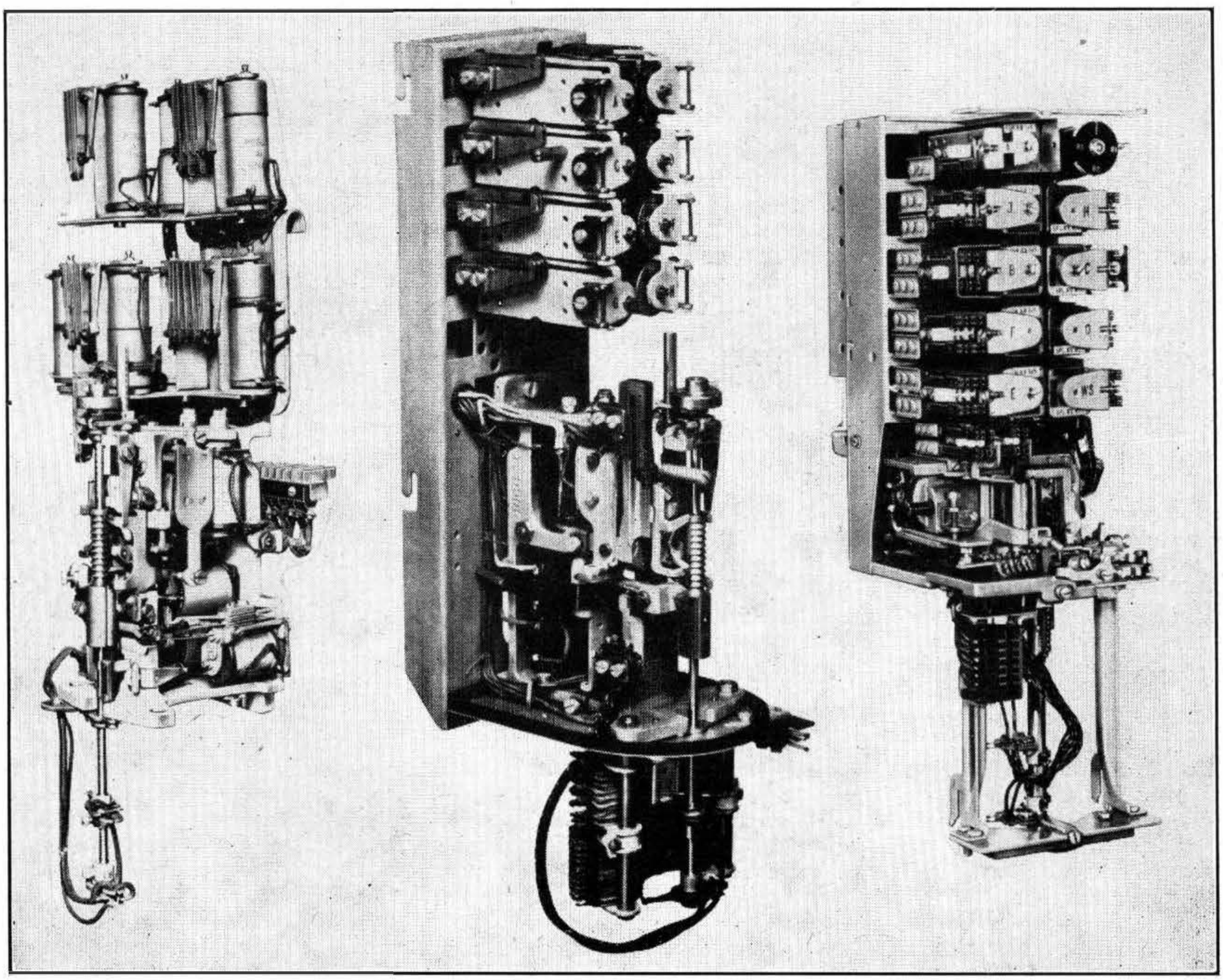
Advantage was taken of this fact to introduce, in 1934, a greatly simplified form of wiring diagram (known as the "Routed Schematic Diagram"[18]) which was suitable for both wiring and maintenance purposes. The remaining major item of equipment on which standardization had not been achieved was the two-motion selector. Standardization of this item was perhaps more important in many ways than the standardization of racks, etc., since this would offer considerable advantages in the stocking of piece-parts, and in the training of staff on switch adjustments. The two-motion selector, however, contained a large number of piece-parts, and there was a considerable investment in the tools and production processes of the five manufacturing firms. There was, therefore, a pause at this stage in the process of standardization, and the Post Office decided to make a further investigation of certain alternative forms of switching before taking this major step of unification.

One alternative switching scheme, known as the Bypath system, was proposed by Standard Telephones & Cables, Ltd. This is a marker-control system based on the use of 51-point ratchet-and-pawl uniselector mechanisms. Its distinguishing feature is the use of a system of high-speed "bypaths," for establishing the call stage-by-stage, the main conversational switches (the "paths") being positioned by marking conditions set up by the bypath circuits. Experimental exchanges to illustrate the use of the Bypath system in both director and non-director areas were set up at Advance (Bethnal Green) in 1933, and at Burton-on-Trent in 1935. It is interesting to note that the Bypath system is, in many respects, similar to the present standard provincial system (R.6) of the French Administration.

The Automatic Electric Company (formerly A.T.M.) proposed two modifications to the Strowger system which, it was claimed, would produce worth-while plant economies. The subscriber's uniselector was replaced by a 200-point two-motion linefinder, with partial secondary working to obtain a higher traffic loading on the 1st selectors than is obtainable with a simple linefinder scheme. The main feature of this proposal was, however, the use of common control circuits, which could be associated with the group or final selectors as required during the setting up of a call. Those elements of the selector circuits which were not used during the conversational period were embodied in the control circuits, thereby making it possible to obtain economies in the main selector circuits. A trial exchange of the Common Control system was opened at Wigan in 1933.

Siemens Bros. offered their newly designed No. 17 system, which was a marker-control system based upon the high-speed motor uniselector. This, like the Bypath and the A.E. Co. systems, used common controls. There was no trial installation of a complete No. 17 exchange, but the linefinder portion of the system was installed experimentally at North Exchange, London.

The A.E. Co. also proposed a new type of two-motion selector, later to become the 2000-type selector, which, it was claimed, would be cheaper than the existing models



(a) Early Strowger Switch. (b) Pre-2000-Type Switch (A.T.E. Co.). (c) 2000-Type Switch.

FIG. 11.—TWO-MOTION SWITCHES.

and which required considerably less rack space. The new switch, designated by the Company as the No. 32 type, eliminated the release magnet of previous Strowger switches, restoration of the mechanism being obtained by re-establishing the rotary drive. The switch was tried out at Ashton-in-Makerfield in September 1934, and, with certain modifications, was eventually accepted by the Post Office as the future standard two-motion switch. The Post Office 2000-type switch (Fig. **11**)[19] was first installed at Rugby in 1936. The adoption of the 2000-type switch necessitated the abandonment of the pressed-steel channel-type shelves which had been standardized some years earlier. The new design of shelf is a rolled steel member, to which suitable cradles for relay sets or selectors are bolted. Although there have been a number of detailed improvements during the past 20 years the 2000-type switch is still the Post Office standard mechanism, and has been used in many hundreds of exchanges; typical installations of pre-2000-type and 2000-type equipment are shown in Fig. **12** and **13**.

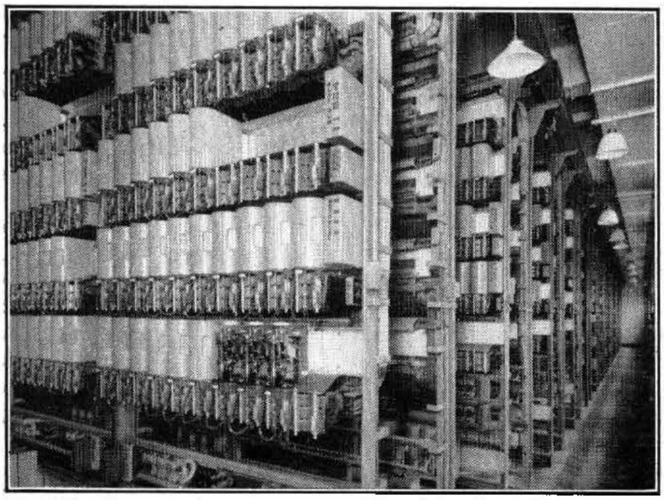


Fig. 12.—Typical Installation of Pre-2000-Type Equipment.

Advantage was taken of the re-design necessitated by the adoption of the 2000-type switch to introduce a number of improvements in various circuits.[20] Notable amongst these was the introduction of the low-resistance transmission bridge with ballast resistor,[21] which enabled line resistances to be increased. Current through the transmission bridge, when connected to short lines, was limited by the ballast resistor, which consisted of a tungsten filament enclosed in a hydrogen-filled bulb.

In the early days of automatic switching, the normal

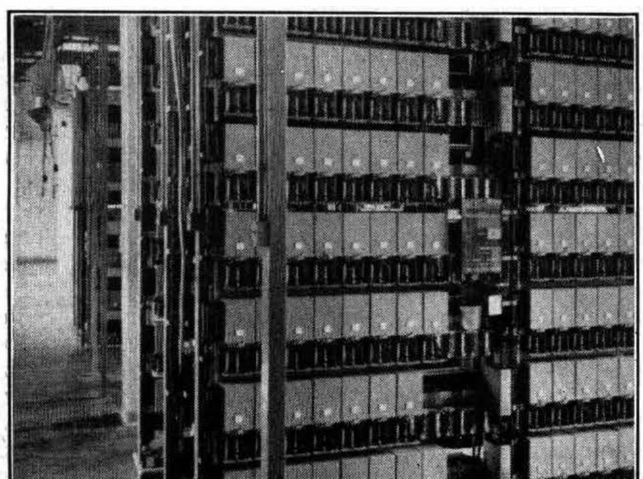


Fig. 13.—Typical Installation of 2000-Type Equipment.

method of supplying power was to provide two batteries connected alternately to the exchange load, the idle battery being charged by motor generators. The current required by the larger automatic exchanges involved the provision of very large and expensive power plants, sometimes with batteries of 8,000 or 10,000 Ah each. New methods of supplying power were evolved, which require less floor space and can be provided at much lower cost whilst retaining the necessary reserve in the case of mains failure.[22] The simplest of these schemes uses a single battery, the charge and discharge of which is controlled by an ampere-hour meter. Counter-e.m.f. cells are used to adjust the potential difference between the exchange busbars during the various parts of the discharge cycle. For somewhat larger exchanges a parallel-battery-float scheme was designed to allow maintenance work on one battery whilst the exchange load is carried by the other. Static metal rectifiers are used extensively with this system. For the largest exchanges a divided-battery-float scheme was evolved, in which one battery is floated across the generators and the exchange load, whilst the second battery is maintained in a charged condition by suitable trickle-charging arrangements. Accurate voltage-control devices are fitted to the generators.

The Automatization of Rural Areas

The provision of telephone exchange service in rural areas has always presented particular problems. With manual switching the traffic can often be insufficient to justify a full-time telephonist, and part-time attendance may be necessary, or possibly the exchange may be closed during the night. It was evident from the early days of automatic switching that when automatic equipment had reached a sufficient degree of reliability it would offer considerable scope for providing an economical and efficient service in rural areas. The first experiments with rural automatic exchanges took place as early as 1915, and there were further installations of "village exchanges," designed by the A.T.M. Co. and Siemens Bros., during the years 1921–1924. The first large-scale application of automatic telephony to rural areas did not occur until 1929, when the Post Office introduced its first standard rural automatic exchange equipment, under the title R.A.X. No. 5.[23] (The designation Rural Automatic Exchange (R.A.X.) was later changed to Unit Automatic Exchange (U.A.X.) to avoid any possible objection from communities who did not consider themselves rural.)

The R.A.X. No. 5 was arranged with all switching equipment enclosed in pressed-steel cavity-walled cases with rubber gaskets round the access doors, so that the equipment could be housed in unheated buildings. Each unit had a capacity for 25 lines, and four such units could be installed to form a 100-line exchange. Shortly afterwards, a modified rural exchange (known as U.A.X. No. 6) was introduced to cater for areas with up to 200 subscribers. The Unit Automatic Exchange, which was installed in buildings of standard design, was of considerable value in the extension of telephone service in the less populous areas. More than 1,100 such exchanges were opened for service between 1929 and 1934.

About this period, designs were also produced for a "country satellite" exchange[24] that would serve 10 subscribers over a 2-wire circuit to a remote manual parent exchange. The country satellite equipment consisted almost entirely of relays and, since it required no power supply, could be accommodated in a watertight box fixed to a convenient distribution pole.

In 1935 a new design of unit (U.A.X. No. 12)[25] was introduced to provide direct routing with multi-metering from the U.A.X. to exchanges other than the parent exchange. Opportunity was also taken to provide certain standard supervisory tones, which for simplicity had been omitted from the original No. 5 equipment. U.A.X. No. 12 superseded U.A.X. No. 5, and during the ensuing years some thousands were used in exchange areas where the 15-year development was not expected to exceed 100 lines. The next standard Unit Automatic Exchange, U.A.X. No. 13,[26] was based on the use of the 2000-type selector and, by providing capacity for a maximum of 200 subscribers, together with junctions to adjacent exchanges and to the parent exchange, it superseded U.A.X. No. 6. Since the 1939-45 war, it has been found possible to increase the capacity of the U.A.X. No. 13 equipment up to 400 lines, and sometimes up to 600 lines, in order to postpone the capital expenditure and labour involved in replacing the U.A.X. equipment and providing a larger non-director exchange building.

Another, somewhat larger, exchange, known as U.A.X. No. 7, was also introduced around 1935. This exchange was designed to cater for up to 800 subscribers. It was replaced, after the standardization of automatic equipment, by the U.A.X. No. 14,[27] which employs single-sided open-type racks without protecting cabinets, and is normally installed in a heated building. As with U.A.X.s No. 13, post-war expediency has made it necessary to postpone replacement of U.A.X.s No. 14 and means have been devised to increase the size of many existing U.A.X.s No. 14 up to 1,200 or even 1,600 multiple.

At the present time there are over half a million subscribers connected to some 3,800 U.A.X.s of all types.

The Development of the Trunk Service

After 1896, when the Post Office assumed full control of the national trunk service, the trunk system passed through various phases, but by 1912 it had assumed a definite pattern, with the country divided into 40 to 50 trunk areas or zones.

There were 287 Post Office trunk exchanges, giving access to the trunk network and connected to the local exchanges by a system of trunk junctions. The principal trunk exchange in each zone had access over direct long-distance circuits to such other "zone centres" as the traffic warranted. There were many anomalies in traffic circulation, due for example to the difficulty of providing an efficient junction network between exchanges in adjacent trunk zones.

Some experiments had been carried out during the early 1900s in working long-distance trunk circuits on an order-wire basis to obtain the maximum paid time per circuit, but in 1912 most of the circuits were operated on the principle of magneto calling, with loop-current clearing where this was technically possible.

After the Post Office assumed full control of the telephone system, it became possible to combine many of the trunk exchanges with the local exchanges. A new traffic-circulation plan was formulated which envisaged a considerable reduction in the number of zones and the establishment of a comprehensive system of direct junctions between exchanges up to 60 miles apart. These junctions would normally be worked on standard C.B. signalling principles and were to be provided in sufficient numbers to give a "no-delay" service. The zone centres would be interconnected by long-distance trunks provided, less generously, on the assumption that some delay could be accepted in the busy hour.

By 1915, 215 of the separate trunk exchanges had been closed down, and the number of zones reduced to nine.

The procedure at this time, and in fact until 1930, was that the local subscriber, on demanding a trunk call, was extended by his local operator to a record position at the trunk exchange. This operator recorded details of the call, and the tickets from the record operators were sorted and passed to the telephonist on the position where the appropriate trunk circuits were terminated. Each trunk operator's position catered for six or less trunk circuits, which were not multipled to the rest of the switchboard. Calls were completed in the order of booking, the trunk operator establishing the call back to the calling subscriber whilst the forward call over the trunk line was being set up.

In London a trunk exchange had been opened in 1904 at Carter Lane; it was equipped with 144 trunk circuits to some 56 provincial centres and two foreign countries, and there were 274 junctions to London local exchanges. By 1921, however, it was necessary to relieve the London trunk exchange of some of the traffic, and a "toll" exchange was established to deal with all traffic to centres within approximately 50 miles of London. This exchange, in turn, could no longer handle the whole of the toll traffic by 1927, so that a new exchange (Toll B) was opened in the Carter Lane premises to deal with incoming toll traffic from the area around London. The original toll exchange was then designated Toll A and dealt mainly with calls outgoing from London to the toll area.

In the years following the First World War there were rapid improvements in long-line transmission but, apart from the introduction in certain centres of a scheme that made possible a better and quicker distribution of calls to record operators, there were no fundamental changes in switching methods. Trunk lines were expensive, and it was considered uneconomic to provide long-distance circuits in sufficient quantity to give an immediate service during short peaks of traffic. The provision of circuits was therefore based on the assumption that there would be an average of 15 minutes' delay on all calls during the busy hour. In 1930, after a study had been made of the methods developed in the U.S.A., it was decided to reorganize the British trunk service so that a large proportion of the calls could be completed on demand. This object was to be achieved without a material increase in trunk circuits, by improving the methods of operation and by alternative routing of traffic. In the meantime, the trunk transmission plan had been reviewed and zones were now divided into "groups." The principal exchange in each group became the "group centre," through which all the long-distance traffic to and from the group was concentrated. Control of all trunk traffic was vested in the operator at the originating group centre. The remaining exchanges were known as "minor" exchanges, or "dependent" exchanges if they obtained access to their group centre via a minor exchange.

The traffic circulation plan made it necessary for each operator at a group or zone centre to have access to all the available outgoing trunk circuits from that centre, and in the interests of speedy completion of calls it was desirable that any one of a number of operators could answer calls on incoming trunks. While an individual trunk circuit was terminated on one position reserved for that and a few other circuits, it was not difficult to adapt the cord circuits on individual positions to meet the special supervisory conditions of the trunk circuits on that position. If, however, the trunk circuits were to become available to a large number of positions, difficulties were foreseen in the design of a cord circuit that would be equally suitable for all trunks terminating at that exchange. It was therefore decided to have a new type of manual board,[28] and to place all the supervisory equipment in the line termination, signalling between the line termination and the position supervisory lamps being effected over the sleeve conductor of the connecting cord. This new switchboard therefore became known as the "sleeve control" switchboard (Fig. 14) and is the present standard equipment for auto-manual and trunk exchanges. The sleeve-control system provided multiple answering facilities, so that incoming circuits could

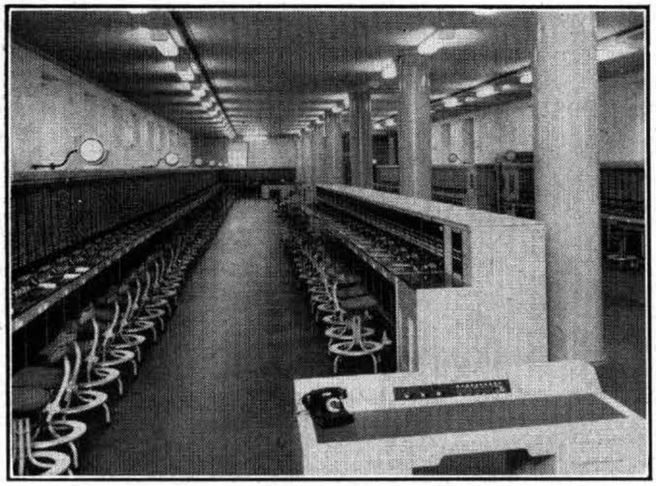


FIG. 14.—MODERN SLEEVE-CONTROL SWITCHBOARD.

be dealt with by the first free operator, and also a system of free-line signals which indicated the first free outgoing circuit in any group. Provision was also made for timing calls automatically,[29] instead of by the insertion of the call ticket in the calculograph as had been done previously. In the first installations facilities were provided for controlling the gain of terminal amplifiers under certain conditions, but this facility was later abandoned. In 1930 an extensive program of conversion from the earlier bridge-control to the new sleeve-control positions was begun.

The decision, in the mid-30s, to permit subscribers to establish calls over the automatic switching network up to a distance of 15 miles,[30] involved the provision of additional routes between automatic exchanges and multi-metering facilities. In director areas, fee determination was obtained by arranging that calls of similar value were routed over the same levels of the code selectors, but for non-director exchanges it was proposed to route all multi-fee calls via one level of the first selectors and associate discriminator-translators with multi-metering relay sets connected to that level. The outbreak of the 1939-45 war stopped this development, and after the war a simplified multi-metering scheme, using the level-control principle, was introduced for non-director exchanges. The overall effect of multi-metering was to reduce very materially the total volume of traffic routed through manual switchboards.

Up to about 1933, generator signalling had been employed on all trunk circuits on which it was not possible to adopt d.c. signalling methods. The absence of automatic supervisory conditions on generator-signalling trunk circuits was very inconvenient in the growing trunk system, and a scheme was developed in which voice-frequency signals (of 600 and 750 c/s) were used to provide the necessary calling, clearing and supervisory conditions automatically on any trunk circuit.[31] During the following years, this 2-V.F. system was introduced gradually at zone centres, and by 1939 plans had been made for the provision of voice-frequency signalling and dialling on all the main zone-to-zone trunk lines.

By the beginning of the Second World War the number of trunk lines over 25 miles long had grown to some 7,000—almost double the number in 1930, when trunk demand working was first introduced.

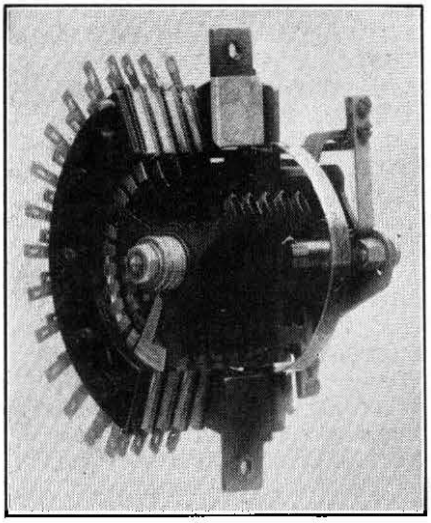
THE WAR PERIOD AND POST-WAR DEVELOPMENTS

At the outbreak of war in 1939 many of the orders placed for new exchanges and for more-modern equipment were cancelled or suspended for the duration of hostilities. Substantially the whole effort of the Post Office and of its manufacturers was concentrated on the provision of communications for the fighting services, for civil defence and for the rapidly expanding war industries. Much of the effort in the early stages of the war was directed to the safeguarding of the existing telephone system. In London for example, five trunk and 11 toll switching centres were established on the outskirts of the city to guard against the possibility of damage to the main trunk exchange or to the cable system in the congested parts of the city. Arrangements were also made for the conversion of the London toll exchanges to automatic working with equipment in protected accommodation. The heavy bombing of 1940-41 caused the destruction of several of the London city exchanges, and it was not possible to provide replacements for several years. The war had interrupted the first stages of the conversion of the Liverpool and Glasgow areas to director working, and had necessitated postponement of the plans for modernizing the Edinburgh system.

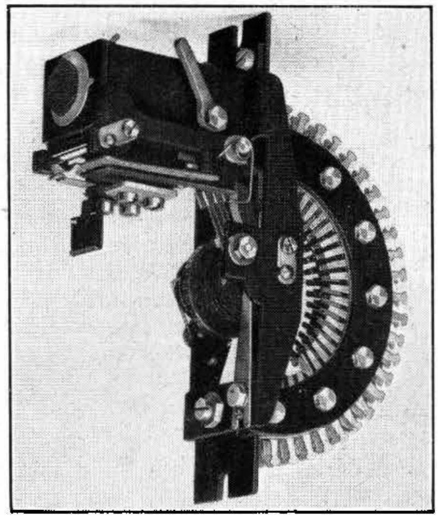
On the cessation of hostilities, the most immediate problem was to provide equipment to meet the pent-up demand for service which had accumulated during the war years. Orders for exchange equipment had risen to a value of nearly £4,000,000 by 1939, but during the war orders rapidly fell to below £500,000 per annum. By 1947 some 210,000 of the outstanding applications for telephone service could not be satisfied due to the shortage of exchange equipment. These arrears could not be overtaken quickly because manufacturers required some time before they could turn round from war products to peace-time production. The post-war problem of providing additional exchange equipment was further complicated by the fact that many of the early automatic exchanges had by then exhausted their design life, and at many other exchanges it was impossible, due to lack of accommodation, to provide further equipment. Nevertheless, during the past ten years, automatic equipment to the extent of 1,600,000 multiple has been ordered, manufactured and brought into service; some 600,000 multiple of this equipment being required to replace existing manual or automatic exchanges. In the London director area alone, 34 manual exchanges have been converted to automatic working, and 29 new automatic exchanges have been opened.

The standard 2000-type automatic switching system had been much developed in the pre-war years. It remains substantially the same apart from a number of comparatively minor improvements which have been introduced during the past 10 years. The first of these was the provision of a new type of uniselector (Fig. 15), designed to give a longer life than the previous standard component. New designs of uniselector racks and group-selector racks have been introduced to permit the grading of trunks on terminal strips at the rear of the racks instead of on separate trunk distribution frames. Improvements have also been made to the detailed design of the 2000-type selector,[32] with the object of reducing the amount of maintenance attention required. A notable feature of post-war design is the rapidly increasing use of p.v.c. as an insulant. Both the physical and electrical characteristics of p.v.c. have been greatly improved during the past few years, and textile-covered wires and cable are rapidly being superseded by p.v.c. insulation and sheathing. Advantage is being taken of these developments to rationalize, as far as possible, the gauges and types of conductors, whilst manufacturing economies are being obtained by the adoption of a simplified colour code which avoids the triple-coloured wires of the old code. A rigid form of white p.v.c. is also replacing phenol resin insulators in selector bank construction, and the tougher nature of the material and the lighter colour are expected to reduce damage in service and facilitate maintenance.

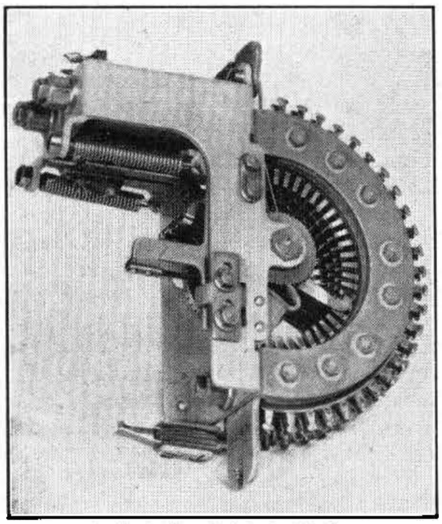
The post-war years have also seen the development of a new and revolutionary form of manual switchboard. One



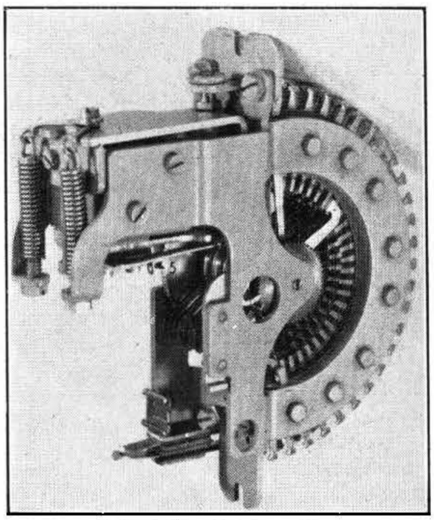
(a) Siemens Bros.' Uniselector No. 1 (1920).



(b) An Early Type of 25-Point Uniselector (A.T.E. Co.).



(c) Post Office Uniselector No. 1.



(d) Post Office Uniselector No. 3.

FIG. 15.—UNISELECTORS.

trial installation of this new cordless switchboard was opened last year at Thanet (Fig. **16**), and a second will shortly be installed at Middlesbrough. The circuits associated with the cordless switchboard provide for the queuing of calls, for the automatic distribution of incoming traffic to disengaged operators, and for the operator to set up (without the use of plugs or cords) any desired call by the manipulation of a digit key-strip on her position. The decision as to whether or not this type of switchboard will be generally adopted awaits the completion of a trial service period of the initial installation.

The more important technical developments in automatic switching since the war have been concerned with the improvement of the long-distance service. The voice-frequency signalling system designed before the war was intended for use only on calls that terminated on the automatic equipment associated with distant zone centres. This, whilst permitting direct dialling by the controlling operators on a high proportion of the total trunk calls, involved the employment of two operators on all calls to exchanges outside the local area of the distant zone centre exchanges. A decision was taken that, as a first step towards complete automatization, arrangements should be made for the originating controlling operator to establish calls to automatic subscribers at any point in the country without the intervention of telephonists at distant centres. Since the war, a new v.f. signalling system has been developed,[33] which permits of dialling through trunk centres, with two or more v.f. links in tandem. The implementation of the plan for single-operator control requires the provision of automatic trunk switching at the zone-centre exchanges, through which distant operators can obtain access to the group and other exchanges within the zone. The first step in the introduction of automatic trunk switching was the opening in 1954-55 of two large automatic trunk exchanges in London. The magnitude of those projects can be judged from the fact that these two exchanges involved a capital investment on switching equipment alone of over £3,125,000—roughly equivalent to the cost of ten 10,000-line local exchanges. Further automatic trunk exchanges will be opened shortly at Chester, Carlisle and Birmingham, and plans have been made to provide single-operator control throughout the whole national trunk-switching system by **1960-61**. The new trunk-switching equipment makes use of the Siemens motor uniselector (Fig. **17**) which, apart from minor improvements, was first introduced in the Siemens No. 17 local exchange system in the early '30s. The switch is particularly suitable for trunk switching because of its ability to provide a large availability on the longer trunk routes where high switching efficiency is required.[34] In addition to the new v.f. signalling system, considerable developments have taken place in the post-war years in direct-current signalling over long lines, and the latest system enables calls to be established automatically, with normal supervision, over physical trunk lines of 100 miles or more.[35] The method utilizes a form of double-current signalling for pulsing, with the supervisory signals obtained via earth-return circuits.

The next stage in the development of the switching system will be the introduction of subscriber trunk dialling[36] and plans have already been made to open the first stage of this service at Bristol in 1959.

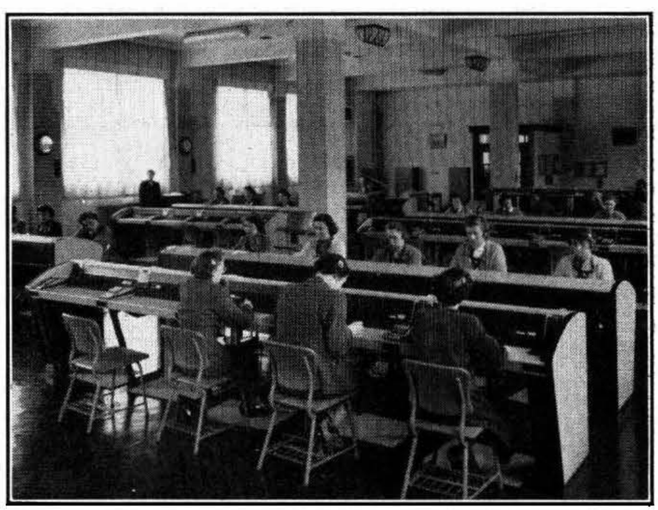


FIG. **16**.—CORDLESS SWITCHBOARD AT THANET EXCHANGE.

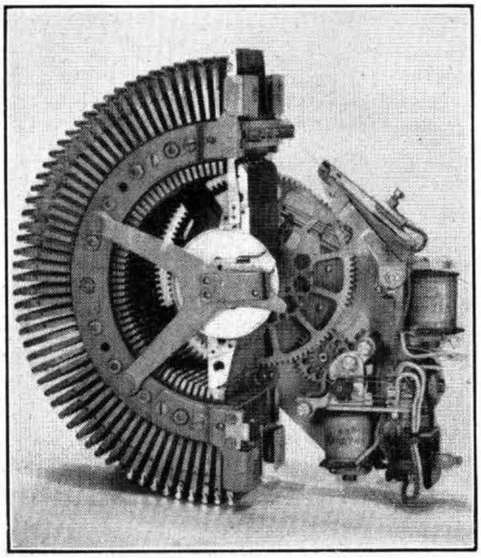


FIG. 17.—SIEMENS MOTOR UNISELECTOR.

Extensive studies are being made of the possible application of electronic methods to exchange switching problems. Trial designs have been produced for fully electronic exchanges, and several models have been made which incorporate advanced time-division multiplex and other techniques. Parallel with this research work, experiments are in progress on electronic equipment which might possibly be integrated with the present electro-mechanical system. At Richmond exchange some electronic directors have now been in service for several years and are giving a very satisfactory performance. Designs have also recently been tried of electronic keysending equipment, which might be used by operators either at main exchanges or possibly at P.B.X.s.

CONCLUSION

The telephone exchange system of the United Kingdom has increased tenfold over the past 50 years, and has now over 6,000 exchanges with more than 7,000,000 subscribers' stations. Some 75 per cent of these have automatic service, in many cases up to 15 miles radius from their local exchange. A large proportion of the trunk calls are now set up automatically by the originating operator, and plans have been made for the completion of the automatic trunk-switching network within the next few years.

ACKNOWLEDGMENTS

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Telephone Instruments and Private Branch Exchanges

During the fifty years since 1906 the number of telephones in the United Kingdom has increased about fifteenfold. The growth in numbers was slow at first, but is now running at some half a million instruments a year. The rate at which technical developments have taken place cannot be reckoned in such precise terms, but the performance of telephones has been vastly improved. This improvement, at relatively small cost, has been made possible only by constant and patient study of technical and manufacturing details, so that nowadays a high-class instrument is produced by modern mass-production methods. Associated with the telephone there are two items of equipment of special interest to the user, Public Call Offices and Private Branch Exchanges.

Introduction

GRAHAM BELL'S original telephones—transmitter and receiver alike—were simple electromagnetic instruments in which acoustic energy impinging on a diaphragm was transformed into electrical energy, and vice versa. A replica of one of these instruments is illustrated in Fig. 1.

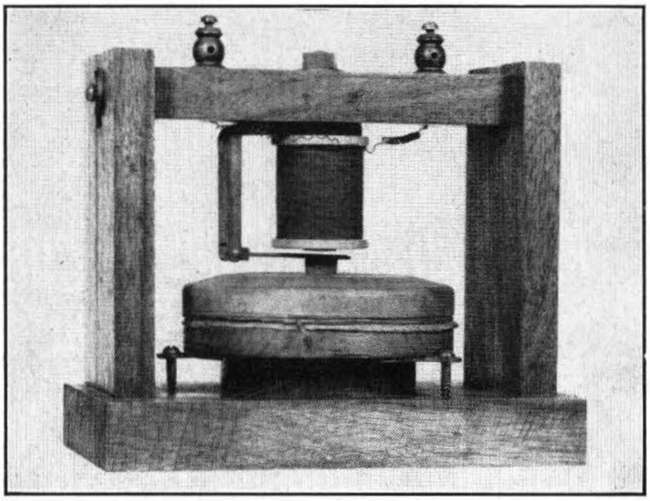

Fig. 1.—A Replica of Graham Bell's Original Telephone.

The output of electromagnetic transmitters is limited by the small amount of energy received by the diaphragm, even if 100 per cent efficiency is achieved, and a change was soon made to variable-resistance transmitters such as Edison's carbon transmitter of 1877. These are inherently amplifying devices giving a very much greater output than electromagnetic transmitters. The simple carbon transmitters were later followed by the carbon-granule transmitter, invented by Hunnings in 1878 and improved by Deckert, and this quickly established its supremacy.

The Bell receiver was inherently simple and reliable; receivers based on other principles of operation were used for a short time, but only to avoid encroaching on Bell's patents.

Although exhaustive study through the years has greatly improved their performance, these two essential components of a telephone system are fundamentally the same to-day as they were in 1880. When the Post Office introduced its first instruments in the early years of the present century, design was, therefore, relatively stable.

Development of Subscribers' Instruments Since 1906

The Post Office commenced its series of central-battery telephones with Telephone No. 1 for wall fixing and Telephone No. 2 for table and desk use. These telephones, illustrated in Fig. 2 and 3, used the solid-back carbon granule transmitter invented by A. C. White, and a Bell receiver connected to line by an induction coil whose only function was the correct matching of the transmitter, receiver and line impedances, the modern anti-side-tone principle then being unknown. The type of handset, previously used on some local-battery telephones, such as

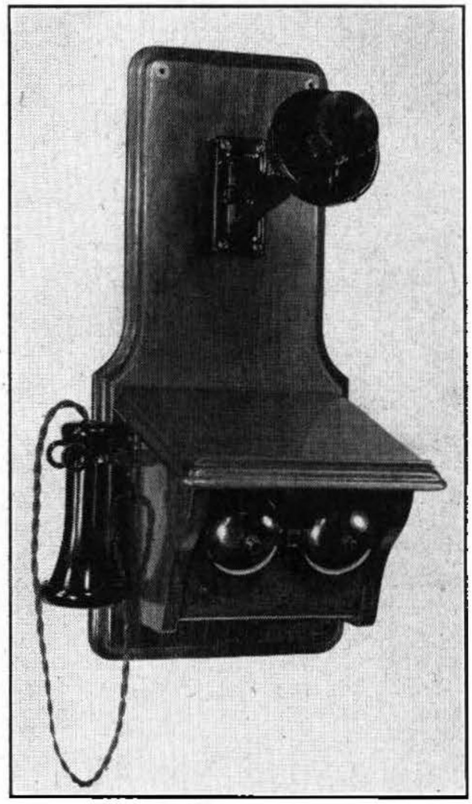

Fig. 2.—Telephone No. 1.

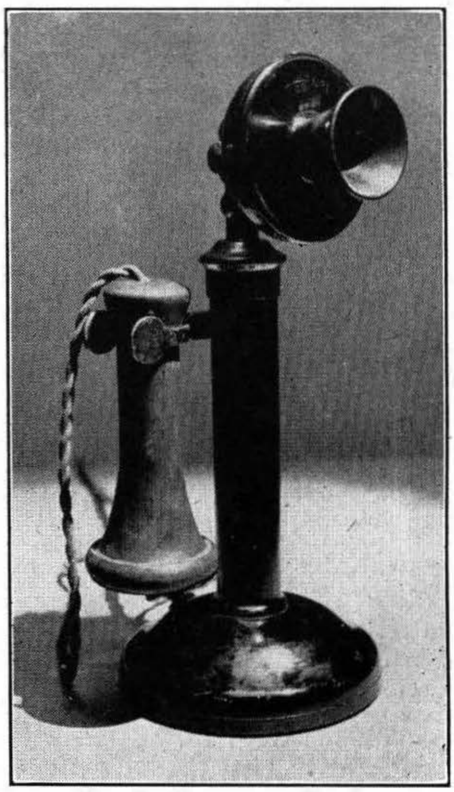

Fig. 3.—Telephone No. 2.

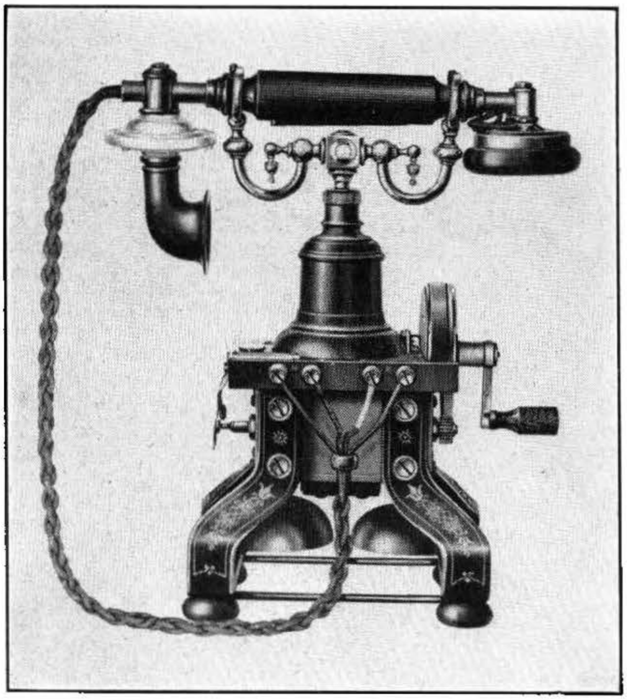

Fig. 4.—Telephone No. 16.

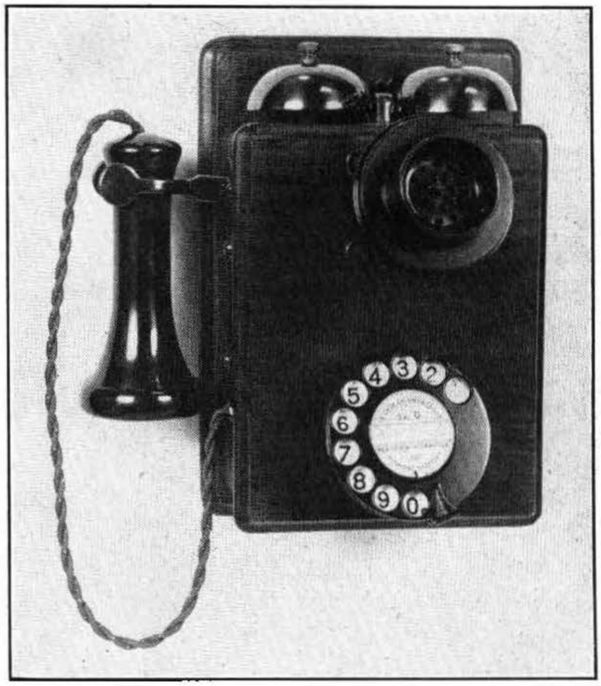

Fig. 5.—Telephone No. 121.

the Telephone No. 16 (Fig. 4), was unsuitable for use on C.B. systems, as the solid-back transmitter only maintained a stable signalling resistance while its diaphragm was nearly vertical. Both Telephone No. 1 and Telephone No. 2 therefore used fixed transmitters. The principal material used in the construction of the wall telephone was wood, while the table telephone was fabricated largely from metal. It is interesting to note, however, that the earpiece and mouthpiece were made of ebonite, one of the forerunners of modern plastics. The wall telephone, including a bell, was completely self-contained but the table telephone had to be used in conjunction with a separate bell-set consisting of the bell, capacitor and induction coil in a wooden case.

The introduction of automatic exchanges from 1912 onwards involved some changes to telephone instruments. The automatic telephone which superseded Telephone No. 2 differed little from it, except that a dial was fitted to the telephone by a bayonet fixing, and could be replaced by a dummy for use on manual systems, thus reducing the number of types of telephone to be manufactured. The wall telephone, Telephone No. 121, was, however, rather different from its predecessor, as will be seen from Fig. 5.

In 1930, the benefits of greater convenience and a controlled speaking distance from the transmitter were secured when the use of handsets for central-battery and automatic systems was made possible by the introduction of the "immersed electrode" principle in transmitter design. In this design, cylindrical carbon electrodes project into the mass of carbon granules so that the total area of contact and the pressure exerted by the granules become substantially independent of the position in which the transmitter is held, and changes of transmitter resistance due to changes of the angle at which it is held are kept within reasonable limits.

The material used for the construction of the range of telephones that incorporated the new handsets, typified by Telephone No. 162[1] (Fig. 6), was a thermo-setting plastic, and the manufacture of telephones, as one of the earliest large-scale uses of this type of material was, in fact, an important early stage in the progress of the great plastics industry of this country. The use of the moulding

Fig. 6.—Telephone No. 162.

Fig. 7.—Combined Telephone and Bell-set.

technique gave the designer freedom to produce shapes both functionally efficient and aesthetically satisfying. The result of this freedom can be seen particularly in the contrast between the 19th-century handset of Telephone No. 16 and the C.B. handset shown in Fig. 6. A matching moulded bell-set was designed which was suitable for mounting on a wall, or for fixing to the bottom of the telephone to form a "Combined Set" (Fig. 7). The telephone could also be combined with a larger bell-set, Bell-set No. 39 (Fig. 8), containing a four-position switch, push buttons and an indicator, to form the master station for an extension plan arrangement.

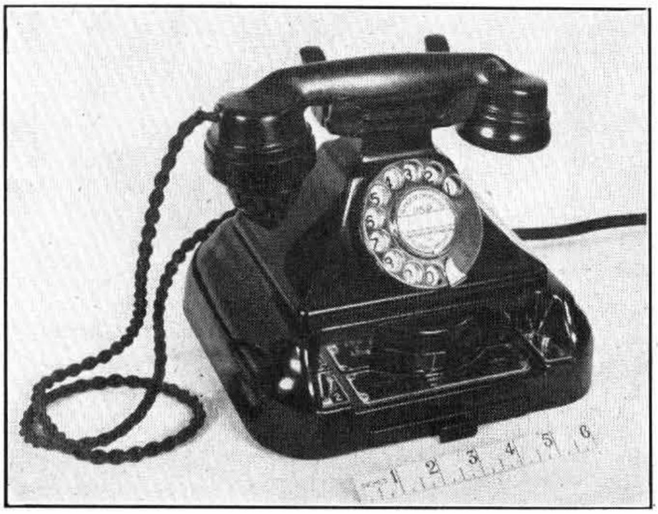

FIG. 8.—TELEPHONE COMBINED WITH BELL-SET NO. 39.

In transmission efficiency the new telephones were a great advance on their predecessors. Loudness alone is clearly not the true criterion of the goodness of a telephone, and articulation and similar subjective methods of testing have been developed which enable quantitative assessments of transmission performance to be made. Important contributions to the transmission of intelligible speech were obtained from better frequency response and from the suppression of side-tone. The latter if present both reduces the signal-to-noise ratio of received speech and causes the user to speak more quietly. The manner in which induction-coil circuits could be designed to reduce side-tone had been shown by G. A. Campbell[2] in 1920, and the circuit of Telephone No. 162 used a separate anti-side-tone transformer to achieve this result.

The next significant change in telephone circuit design was the introduction, in the Telephone No. 232, of anti-side-tone induction coils, which improved the suppression of side-tone without the need for a separate transformer. This was followed by the introduction of the 2P receiver, which still follows in essence the "Bell" principles, but in which improved magnetic materials are used and the frequency response is equalized by the use of appropriate acoustic resonances and damping in the cavities behind the diaphragm.

With the growth in popularity of combined sets, a new one-piece combined set[3] was introduced in 1938. This design is typified by Telephone No. 332, and a valuable feature of it is that up to three push-button keys can be fitted within it to perform auxiliary functions such as those required for extension plan working. The Telephone No. 328 (illustrated in Fig. 9) uses press-buttons for controlling an extension bell, but variations of the switching arrangements in fact permit telephones of the same general type to be used for the whole of the wide range of Post Office extension plans, other than those for which Bell-set No. 39 is used. Since the war, further variants of the design have been introduced for shared service, in which the press-button is used for giving a calling signal to the exchange.

When moulded table-telephones were first introduced, the need for a corresponding wall telephone was avoided by the introduction of brackets for mounting the table telephone on walls. This scheme, though satisfactory with Telephones No. 162 and 232, was not convenient for telephones of the 300-type because, with their differently shaped bases, they would have projected too far from the wall. The introduction of the moulded wall telephone that had been developed to fill this gap was delayed by the 1939-1945 war, during which changes in fashion occurred which led to criticism of its appearance. For this reason it has only been used as a temporary measure for shared-service working, where a combined wall set with a push-button was essential. The newest wall telephone design, meeting current ideas of a pleasing appearance, and destined now for general use, is illustrated in Fig. 10.[4] An innovation in its physical design is the use of a pressure die-casting for the base, upon which the components are mounted without the use of an internal chassis.

FIG. 9.—TELEPHONE NO. 328.

The year 1956 has seen the introduction of Telephone No. 700[5]—the forerunner of another new series of telephones

FIG. 10.—MODERN WALL TELEPHONE.

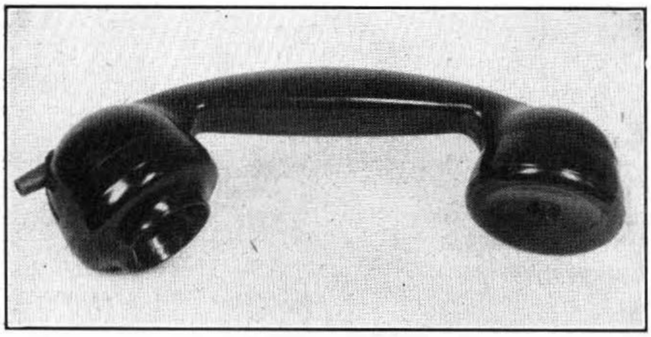

FIG. 11.—HANDSET NO. 1.

of still greater transmission efficiency. These will use the handset illustrated in Fig. **11**, which includes the rocking-armature receiver.[6] The great sensitivity and wide, flat frequency response of this receiver have been obtained by separating the acoustic and magnetic functions so that each may be arranged for maximum efficiency. Striking contrasts between it and the receiver of 1906 are that the magnet weighs one-hundredth of the weight of the Bell receiver magnet, and that measured subjectively the receiver is over 20 times as sensitive.

While acoustic efficiency, convenience in handling and hygiene have played vital parts, the design of the handset, which has a cord tunnel moulded through the handle, has been principally determined by production considerations. Advantage has been taken of all the knowledge and experience accumulated since the previous handset was designed, in the very early days of plastic moulding, to secure a useful reduction in manufacturing costs; for example, by the elimination of all metallic inserts. Telephone No. 700 includes a highly efficient closed-core induction coil and an improved side-tone balance circuit. By the combination of these with the new handset and receiver, this latest telephone operates efficiently on line lengths up to 40 per cent greater, for the same conductor size, than its immediate predecessor, so making possible substantial line plant economies.

CALL OFFICES

From the beginning of the century, it has been possible to make telephone calls, on payment of a fee, from public call offices. At first, public call offices took the form of "silence cabinets" in Post Offices, public buildings and railway stations, and calls could also be made from the private telephones of certain businesses such as restaurants, hotels, or large stores. Initially, only a telephone was fitted and the call charge (1d.) was collected by an attendant or the subscriber. Later, coin-collecting boxes were installed. These took various forms in different parts of the country, but they were all designed for post-payment working, and for making only local calls. The first Post Office pattern was "Box, Coin-Collecting, No. 1," which is illustrated in Fig. **12**. A coin had to be inserted in the slot, after which the turning of a knob deposited the coin and energized a buzzer to signal to the operator. In 1915 a coin box was produced to work to an automatic exchange, but it still accepted only pennies, and was still restricted to local calls.

The first multi-coin box accepting shillings, sixpences and pennies was introduced about 1925; it is a tribute to the soundness of its basic design that, apart from a few refinements, the present-day box is substantially the same. The introduction of a box that would accept silver coins prepared the way for the acceptance of trunk calls from unattended call offices, although until the introduction of demand trunk working in the early '30s the facility was rarely used.

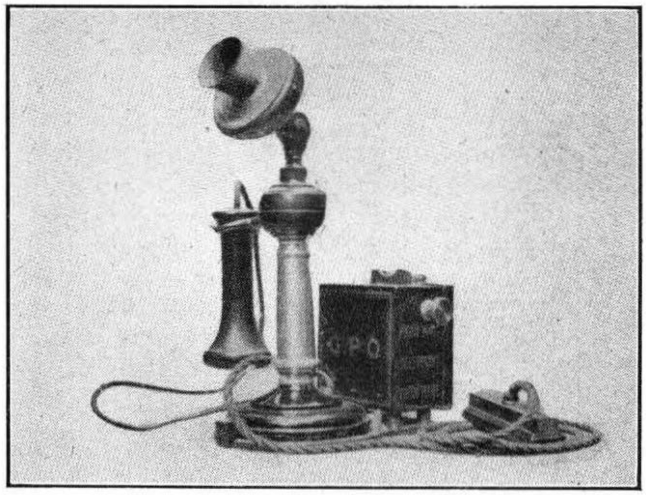

FIG. 12.—THE FIRST POST OFFICE COIN-COLLECTING BOX, WITH TELEPHONE.

As early as 1912, call offices appeared in the streets, housed in wooden kiosks, which, with later modifications, including the use of concrete in 1921, became the Kiosk No. 1 (Fig. **13**). A new cast-iron kiosk (the Kiosk No. 2), designed by Sir Giles Gilbert Scott, R.A., was introduced in 1927, and some 1,500 were purchased for erection in

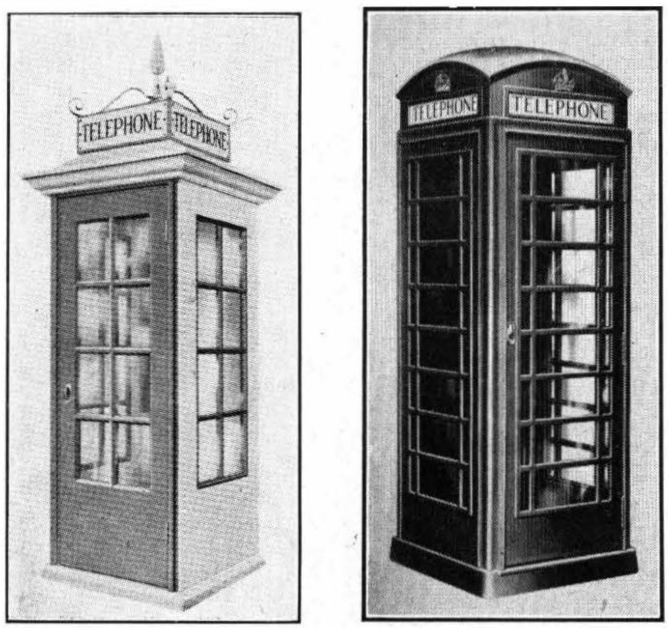

FIG. 13.—KIOSK NO. 1 (LEFT) AND KIOSK NO. 6 (RIGHT).

London and other large towns. A smaller version of the Kiosk No. 2, made in concrete and known as the Kiosk No. 3, followed in 1929, and these were considered more suitable for use in rural areas.

The introduction of cheap night rates for trunk calls, in 1934, greatly increased the traffic from call offices. To meet the growing demand, the present standard call office, comprising a Kiosk No. 6 (Fig. **13**) and black-faced wall-board with stainless-steel notice frames (Fig. **14**), was produced.[7,8] Its introduction was timed to coincide with the Jubilee of King George V (1935) so that it became known as the "Jubilee" call office.

Now, after 30 years of service, the present multi-coin box with its well-known "Buttons A and B" is about to be replaced by a new coin-collecting box without any buttons. The new box will permit direct dialling of trunk calls and will be fully automatic. The introduction of the new coin-

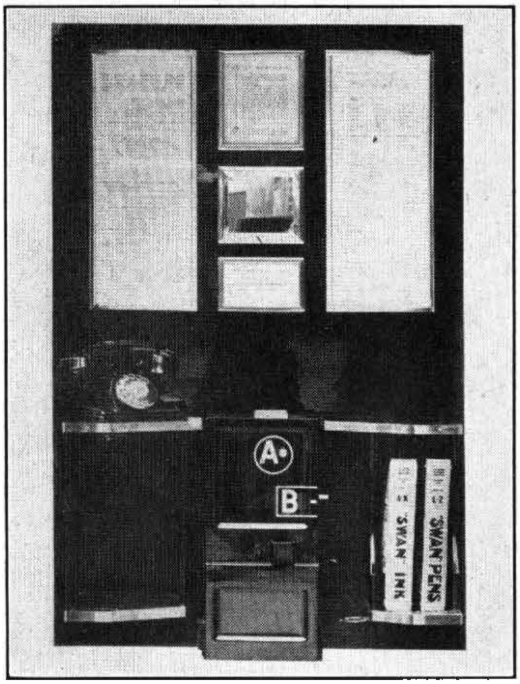

FIG. **14**.—PRESENT STANDARD KIOSK WALL-BOARD.

collecting box will be accompanied by a modified wall-board equipment and a revised layout for completely new installations. The present colour scheme of black with chromium flashing may give place to more subdued colours.

The telephone cabinets, at first the normal housing for a call office, have become less important and now account for only one-sixth of the total installations, the rest being kiosks, mostly Kiosks No. 6. Subscribers' coin-box installations have kept pace with the growth of public call offices and are in fact now slightly more numerous.

PRIVATE BRANCH EXCHANGES

As might be expected, Private Branch Exchanges (P.B.X.s) have followed similar lines of development to main-exchange equipment. The pattern can be traced as: Magneto; C.B.S. and C.B. manual; automatic, with the only difference that the automatic P.B.X. (P.A.B.X.) will not, in the foreseeable future at least, entirely supersede the manual P.B.X. (P.M.B.X.).

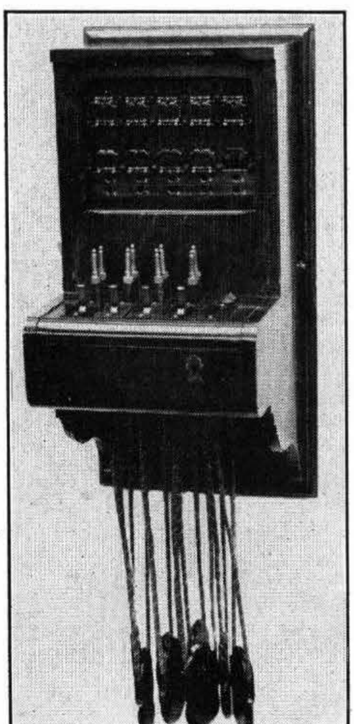

FIG. **15**.—EARLY MAGNETO P.B.X.

Private Manual Branch Exchanges.

The early types of magneto P.B.X. were of cord type, even in the small sizes, as shown in Fig. **15**. All line terminations consisted of a jack and drop indicator, and connexions were made by cords. The indicators were left across the circuit in the speaking condition to provide a simple means of supervision and "ring off" clearing signal. The capacity of these boards ranged from three to 100 lines but the latter were few in number.

The introduction of C.B.S. working allowed further refinements in signalling and supervision. Cordless switchboards were introduced, using key switching in place of cords, for small switchboards. Also, as signalling current was now available, the hand-restored "drop" indicators were replaced by self-restoring "eyeball" indicators, enabling switchhook supervision to be given. The range of single-position switchboards, cordless up to three exchange lines plus nine extensions, and cord switchboards up to 10 exchange lines plus 50 extension circuits, was established, and remains with only minor changes until the present day. A multiple-type board following similar lines to the cord-type single-position boards was also introduced having a capacity of 800 extension circuits.

The introduction of C.B. working brought no fundamental change in the physical design of P.M.B.X.s but it did require the circuit to be remodelled to allow for a C.B. transmission feed. A later development, at the time of the introduction of automatic exchanges in London, was through-dialling and through-clearing from the extension telephone. This was applied to all P.M.B.X. switchboards except for very large installations where main-exchange-type switchboards were used. It was the through-dialling facility which was the most important feature in the early stages, its purpose being to relieve the P.B.X. operator of dialling and control of outgoing calls, but with the introduction of demand trunk working through-clearing also became important, allowing extensions to control the timing on trunk calls.

With the introduction of C.B. working the use of indicators as signalling devices on switchboards in main exchanges was superseded entirely by the use of lamp signals. For P.M.B.X.s, however, the indicator has persisted as a signalling element and is still a standard provision, as indicated by Fig. **16** and **17**; the main reason being that it is a device which will perform satisfactorily with small currents. In the near future we may see a more general change to lamp signalling for P.M.B.X.s of all

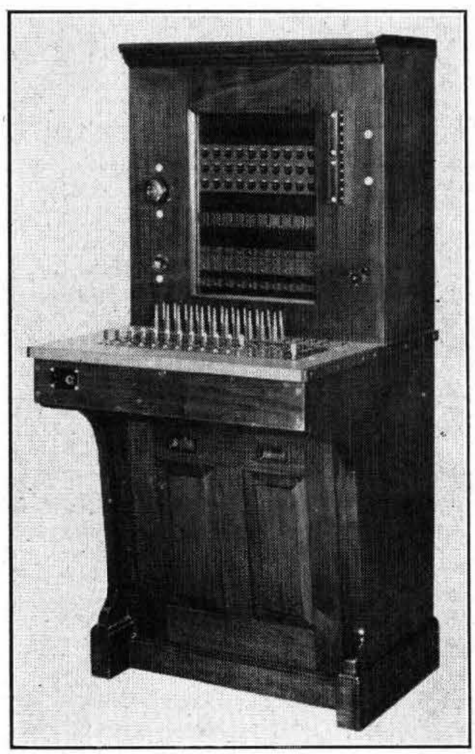

FIG. **16**.—EARLY CORD SWITCHBOARD.

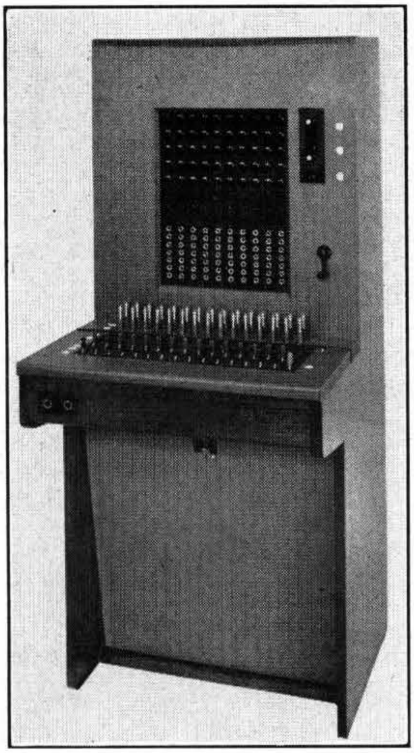

FIG. 17.—MODERN CORD SWITCHBOARD.

types but until now only the larger multiple-type of P.M.B.X. has been so modernized. This modernization started in 1940, when the P.M.B.X. No. 1[9] (Fig. **18**) was introduced to supersede the earlier indicator type. Although it can be used as a single position it was intended primarily for large installations where a multiple suite would be required, giving a maximum capacity of 160 exchange lines and private circuits plus 800 extension circuits. A later version introduced in 1954 gives additional capacity up to 1,200 extension circuits.

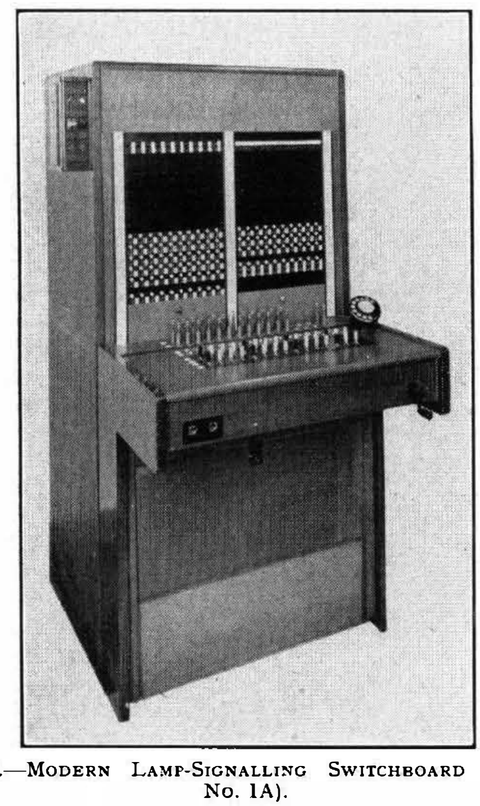

FIG. **18**.—MODERN LAMP-SIGNALLING SWITCHBOARD (P.M.B.X. NO. 1A).

Private Automatic Branch Exchanges.

The history of the P.A.B.X. dates back to the first use of automatic switching systems. It was in 1912 that the first P.A.B.X. was installed, to serve Post Office Headquarters Departments. The equipment used for this and other installations that followed was the early Strowger type using Keith line-switches.

In the 1920s the Relay system became firmly established for smaller installations. In this system mechanical selecting mechanisms were not used; dialled pulses were counted and stored and all connexions made by relays. This form of switching becomes increasingly complicated and expensive for large installations but a few equipments of some 500 lines capacity were installed. Relay P.A.B.X.s formed the greater part of the P.A.B.X. program up to 1927, but a gradual change-over took place in favour of step-by-step systems. Most of the new installations after 1928 followed main-exchange practice in equipment and switching principles, with such variations as were in experimental use at that time.

Although all P.A.B.X. designs had to be approved by the Post Office, there was no approved common design, and, realizing the difficulties this would cause as the number of installations grew, standardization was decided upon. Unfortunately this could not be commenced until about 1935 and, although the final stages of design had been reached and field trials were in progress in 1938, further work was halted by the war. It was not until well after the war that the project was revived.

In 1951 the first standard P.A.B.X. equipments began to appear in the field. These were of unit type (Fig. **19**) and were titled P.A.B.X.s No. 1.[10] Their maximum capacity was 10 exchange lines and 49 extension circuits, and they could be provided in four sizes up to this maximum. The

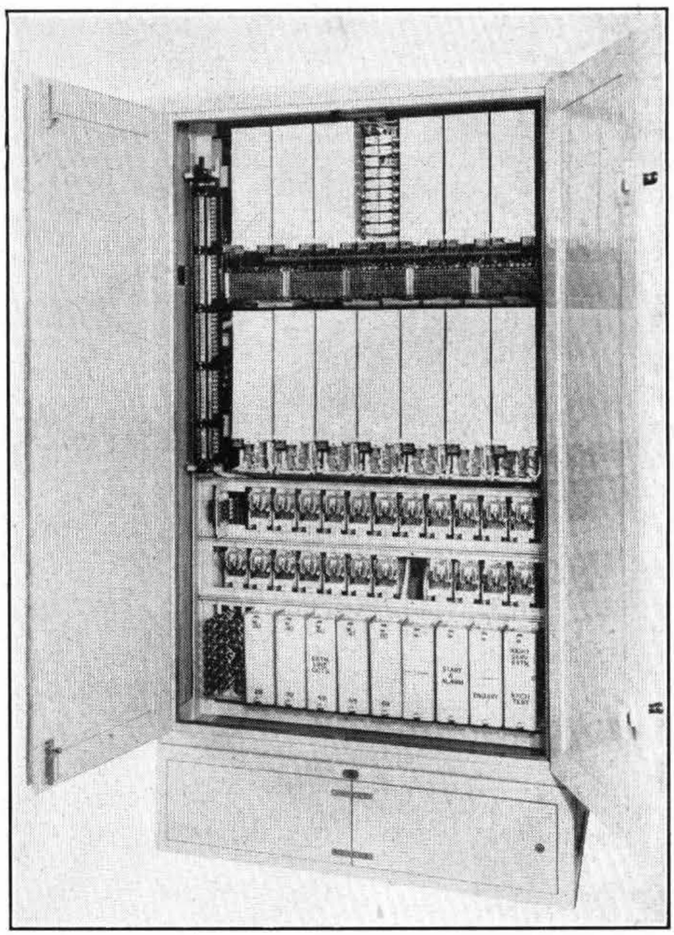

FIG. **19**.—P.A.B.X. NO. 1.

most interesting feature of this development was the improved method of handling exchange calls. It had been the practice previously to provide the equivalent of a P.M.B.X. switchboard, with the automatic equipment, to handle traffic incoming to, and outgoing from, the extensions. With the P.A.B.X. No. 1, however, only a small cordless switchboard (Fig. 20) was provided, having as its main purpose the answering of incoming exchange calls and routing them to the required extension. All other functions could be performed by the extension user, and when the incoming calling rate on the exchange lines was low the operator could be dispensed with entirely, incoming calls being dealt with by any extension user by dialling a code to pick up the incoming call and then routing the call, by further dialling, to the required extension.

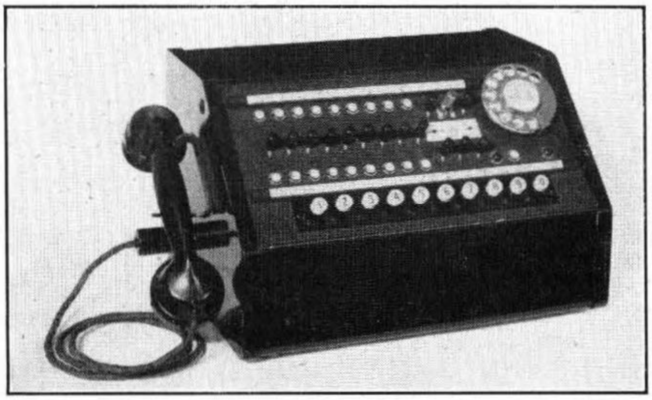

FIG. 20.—CORDLESS SWITCHBOARD USED WITH P.A.B.X. NO. 1.

At the same time as the introduction of the P.A.B.X. No. 1, the P.A.B.X. No. 2[10] was made available for the few cases where the retention of the more conventional manual board was desirable. Apart from this feature the P.A.B.X. No. 2 was identical with the No. 1.

The development of cordless working has been temporarily halted at this maximum of 49 extension circuits but the future may well show further developments.

To provide for larger exchanges the P.A.B.X. No. 3[10] was introduced. Earlier designs were in the field from 1950 but the first standard approved installation was completed in 1952. The design of this P.A.B.X. (Fig. 21) follows similar principles to the non-director main exchange using standard step-by-step equipment, but differs in many details to give those facilities and conditions applicable to P.B.X. working. Conventional manual boards are used for handling incoming exchange traffic, with a manual multiple of extensions. The design was based to a large extent upon the provision of equipment in 50-line units and the maximum originally planned was for 1,200 extension circuits. There was no technical reason for this limit, however, and experience has shown that many installations are required with appreciably more than 1,200 lines. The size of the manual multiple does, however, restrict the upper limit to approximately 5,000 extension circuits, above which different principles will have to be used. The largest installation up to the present is for 4,500 extension circuits.

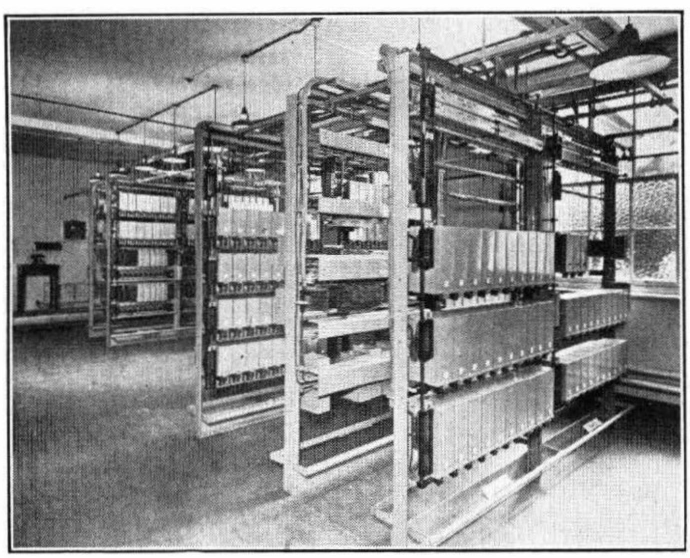

FIG. 21.—TYPICAL 500-LINE INSTALLATION OF P.A.B.X. NO. 3.

Recent additions to this P.A.B.X. have included provision for satellite working, and for tandem dialling arrangements for the more complex networks.

CONCLUSION

The evolution of subscribers' apparatus has been influenced by a number of conflicting factors. The apparatus has to be attractive to subscribers, functionally efficient, reliable and robust, yet at the same time inexpensive. In style the broad trend of public taste has been followed and extravagant extremes avoided, while only well-tried technical features, materials and production techniques have been used. The design policy for the immediate future will be influenced by the same factors, modified by the fact that the transmission efficiency of the latest telephones is such that there is little economic advantage at present in increasing it. Effort will therefore be directed more towards improving the appearance of apparatus, with perhaps greater emphasis on colour, to reducing its size, and to offering the user more facilities. The more distant future holds prospects of revolutionary changes to subscribers' apparatus arising from the development of electronic telephone exchanges. These changes may include the replacement of the carbon granule microphone and the magneto bell by other devices, assisted by transistors.

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Overseas Telecommunications

The development of submarine telegraph and telephone systems is reviewed from the days of the gutta-percha single-core cable to the modern repeatered submarine coaxial cable, and brief details are given of the Post Office fleet of cable ships. Then follows a survey of the country's overseas radio services starting with those to ships at sea and finishing with a short description of the new Rugby short-wave transmitting station. Mention is made of the latest telecommunications service, international telex.

Introduction

THE centre of Post Office overseas telecommunications services half a century ago was, as it still is, London, the source of the great majority of this country's outgoing traffic and the target towards which most of the incoming traffic is directed. Centred on London, there was then a telegraph cable network equal in extent to that which exists to-day, and so well had our forebears built that many of the cables in service then are still in use.

In comparison with telegraphy, which was already more than 50 years old, international telephony was in its very early youth for, although the first telephone cable to the continent of Europe had been laid in 1891, progress had been slow, and by 1906 overseas telephone service was available only between the principal towns in this country and certain towns in France and Belgium. Communication by radio was in its infancy and, like cable telephony, had to await the perfection of the thermionic valve before it could thrive, but a radio-telegraph service to ships in coastal waters had already been established, using spark transmitters and coherer detectors.

Overseas Cable Telegraphy

Although the overseas telegraph cable network at the turn of the century was very much the same as it is to-day, the method of working was very different. On the long cables the syphon recorder, invented by Sir William Thomson 30 years earlier, was still in general use, and a message travelling over a long cable chain—for example, from London to Bombay—had to be read from the recorder tape and manually retransmitted at every intermediate station. On the route mentioned this involved retransmission at no less than six stations: Porthcurno, Gibraltar, Malta, Alexandria, Suez and Aden.

To overcome this slow and expensive method of transmission, relays of various types, among them the Brown drum relay,[1] were invented. The disadvantage of such relays was that the distortion of the first cable was passed on to the second, and it was found impracticable to link more than two cables in this way. This stage was reached about 1905-06, but in 1910 rapid improvements took place following the production of a more robust relay which could operate an automatic reperforator. The perforated tape thus produced was fed into a transmitter and so passed the signals into the second cable with full power and without distortion. More-sensitive relays of various types, among them the Heurtley hot wire and the electrolytic magnifiers,[2] then made their appearance and, because they could deal with still weaker incoming signals, permitted an increase in transmission speed of the order of 25 per cent.

Progress on the shorter continental telegraph cables had been much more rapid owing to their smaller attenuation and distortion, and such well-known systems as Wheatstone, Creed, Hughes and Baudot multiplex were in general use. These continental cables were mainly owned by the Post Office, whereas the long-distance ones[3] were largely the result of private enterprise. This had broadly been the position from the early 1850s, during which period such well-known British companies as the Eastern Telegraph, the Eastern Extension, the Eastern and South African, West African, and Western Telegraph among many others had played their parts, but the Pacific cable which stretched from Bamfield (Vancouver) via Fanning Island and Fiji to Australia and New Zealand was owned jointly by the governments of Australia, Canada, New Zealand and the United Kingdom, and the British Post Office later laid and owned the Imperial cable from Porthcurno via the Azores to Halifax, Nova Scotia.

A map of the British long-distance submarine telegraph cable network as it was in 1906 is shown in Fig. 1, and the network is substantially the same to-day.

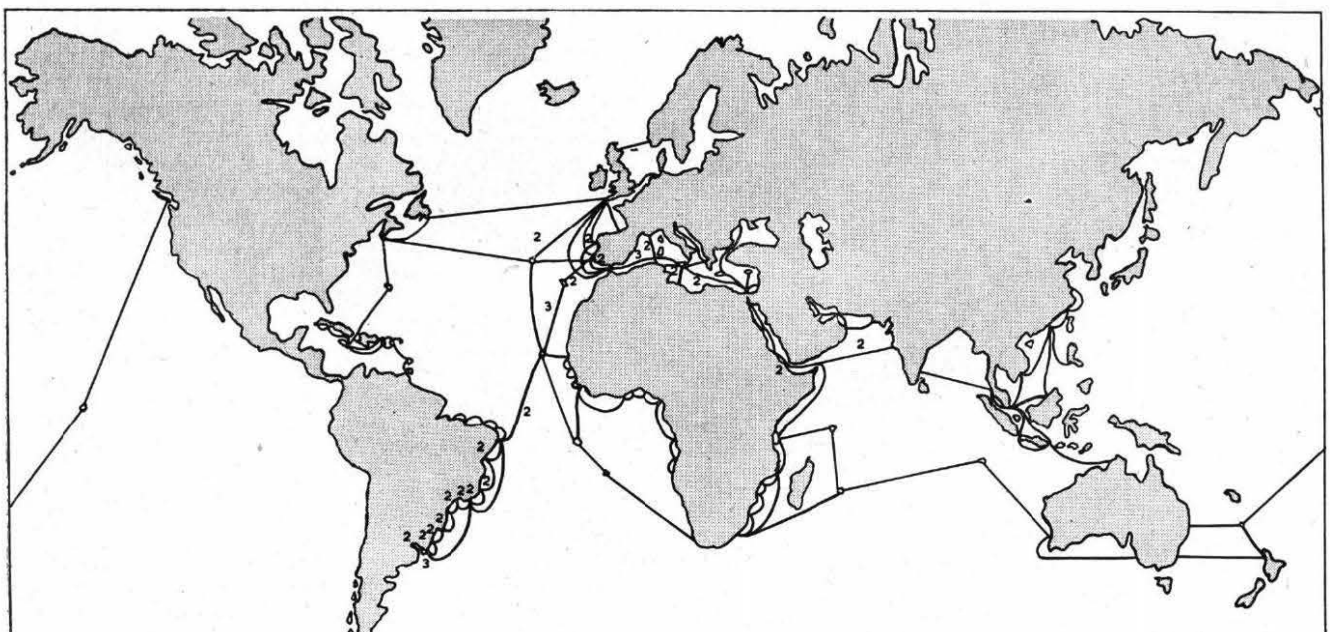


FIG. 1.—THE BRITISH LONG-DISTANCE SUBMARINE TELEGRAPH CABLE NETWORK IN 1906.

The Regenerator System.

The 1914-18 war found the United Kingdom and its Allies in possession of a world-wide network of cables, and during that time both the cables and their staffs were strained to the utmost. The laying of new cables and all experimental work was abruptly brought to a standstill, and it was not until the early 1920s that development could be resumed. In 1923 the Eastern and associated telegraph companies introduced regenerator working,[4,5] and in the space of the next four years the whole network, some 145,000 miles, was equipped. The function of the regenerator, which is used in conjunction with a cable relay or magnifier-cum-relay, was to provide an automatic device which selected each signal at its centre point and retransmitted a perfectly regenerated signal, by means of cams and contacts, into the next cable. This necessitated a very high degree of synchronism between the sending and receiving stations and this was achieved by phonic motors driven from clock-controlled tuning forks. Synchronizing units at the receiving stations took up the difference between the forks at different stations.

The regenerator system, mainly by its accuracy of signal selection, permitted a considerable increase in the safe working speed of cables and the introduction of channelling, in the form of element interleaving, whereby the fast cables could be made to take two or more channels for greater ease of handling. It also permitted the introduction of call devices, by means of which cables could be automatically switched at intermediate points for local or through traffic, and of automatic scrutinizers, which gave audible or visual warning of signal deterioration.

Continuously Loaded Cables.

In 1887 Oliver Heaviside had propounded the theory that the effect of the large electrostatic capacitance of cables could be minimized by increasing the inductance throughout their lengths, but it was not until about 1921, when high-permeability nickel iron alloys were developed, that continuous loading became an attractive proposition. The first telegraph cables having high-permeability alloy wire or tape wrapped over the copper conductor, which increased the maximum sending speed approximately tenfold, were laid in the Commonwealth system in 1926.

The Impact of Radio.

In the middle 1920s short-wave radio began to compete successfully with the cable services, and it quickly became apparent that a merger of the cable and wireless services was desirable. An Imperial Conference was therefore convened and a government-sponsored merger was arranged by which the existing cable and wireless organizations were transferred to a new public utility organization registered in April 1929, and later known as Cable & Wireless, Limited. This company acquired, under authority, the Pacific Cable Board's (P.C.B.) cables, the West Indian cable and wireless system worked by the P.C.B., the Imperial Atlantic cables, the Eastern Telegraph, Eastern Extension, Eastern and South African, West African, and Western Telegraph Companies' systems, and also took over on a lease of 25 years the Post Office beam wireless stations serving the Dominions and India. The company then controlled more than half the cable mileage of the world, some 164,000 miles, and had a staff of 13,000 persons.

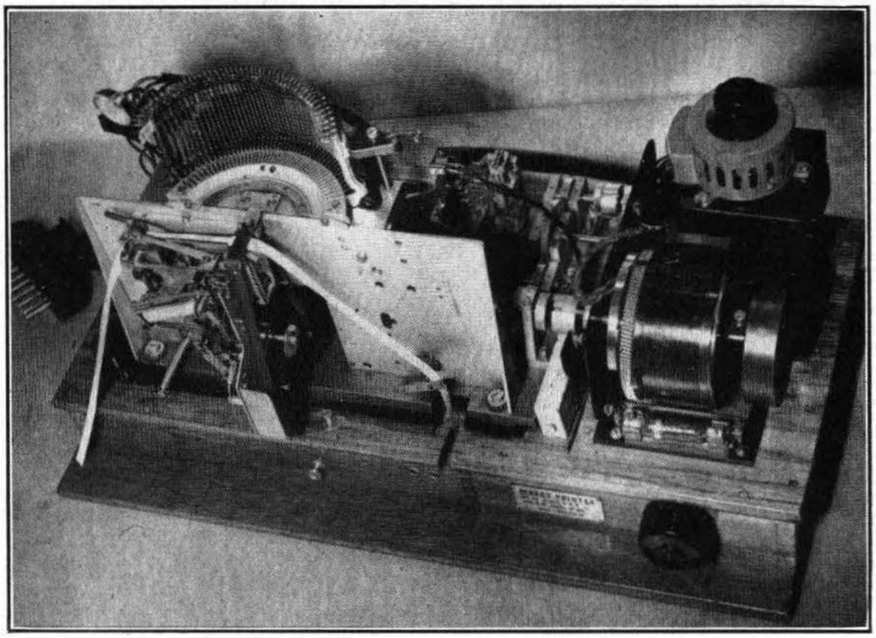


FIG. 2.—THE DIRECT CABLE-CODE PRINTER.

At the same time an Imperial Communications Advisory Committee was constituted to provide a measure of co-ordination of policy on Commonwealth communication matters. This committee was succeeded in 1944 by the Commonwealth Communications Council and, in 1950, when the ownership of the Commonwealth system was divided between the various Commonwealth Governments, it was replaced by the Commonwealth Telecommunications Board[6] with considerably increased functions and powers. The Board to-day meets regularly, usually in London, to advise the partner governments on the various technical, traffic and financial matters that affect the Commonwealth radio and cable telecommunications system.

During the ten years following the merger, developments were mainly concerned with the close integration and most efficient and economical running of this world-wide network of cable and wireless services. Cable code—a three-condition form of the Morse code with the dot, dash and space elements of equal length—had been in general use over the cable network since the "regenerator" was installed, but a two-condition code was more suited to radio operation and ordinary Morse code had been employed on such circuits. To facilitate the inter-working of cable and radio circuits a two-condition form of cable code, known as double-current cable code (D.C.C.C.),[7] was introduced in about 1930, and in the next few years all the main Commonwealth beam radio routes were changed to this form of working. This, in conjunction with the development of a direct cable-code printer (Fig. 2), an instrument which received cable-code signals and printed them directly in Roman characters on tape, facilitated the integration of the cable and radio services and permitted a large reduction in the number and skill of operators. It thus became possible for cables to work directly into radio circuits and vice versa, and gave a flexibility and traffic-carrying capacity undreamed of in the early 1920s. This and the development of radio-relay stations were of the utmost importance during the last war when traffic reached unprecedented heights.

Present-day Developments.

In 1950 the operation in this country of the long-distance overseas telegraph cable and radio services reverted to the Post Office and there is now scope for a closer integration of these long-distance overseas services with those of the continental and the inland telegraph services. The first step towards this goal must be the adoption throughout the Commonwealth system of 5-unit working. Means of achieving this on the radio circuits, with provision for the automatic correction of errors to which radio circuits are at times subject, are already available and are in operation on some routes. Methods of converting the complicated Commonwealth cable system to 5-unit working without loss of traffic-handling capacity are being developed, and this year should see the conversion of the first long-distance telegraph cable chain to this method of working.

Throughout the 50 years reviewed in this article, the cable itself has remained basically unchanged; in fact, most of the telegraph cables in use to-day were laid before 1900. Those laid since that date have differed in design only in that the dielectrics have been improved from gutta-percha to polythene and that, on a few, continuous tape loading has been introduced. To-day the usefulness of these old cables is being enhanced by the use of submerged d.c. telegraph repeaters (Fig. 3), which amplify the

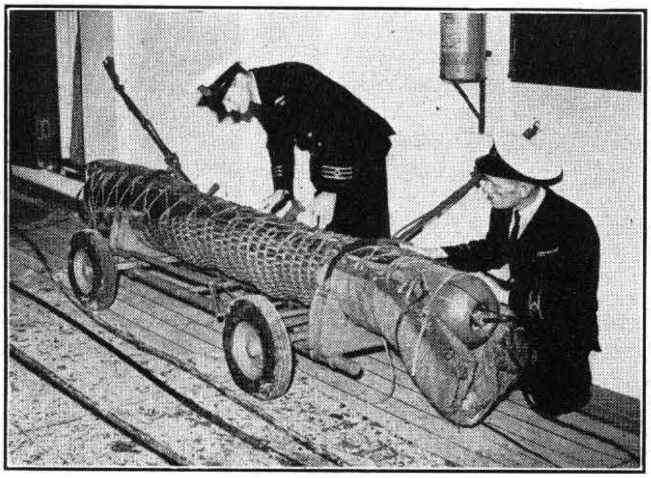


FIG. 3.—THE FIRST BRITISH SUBMARINE TELEGRAPH REPEATER.

received signals just before they enter the shallow water areas, where most noise is picked up. Such repeaters are already in service and consideration is being given to increasing the usable bandwidth by the insertion of audio repeaters at intervals along suitable cables.

Improvements in submerged telephone repeater techniques have increased the capacity and range of submarine telephone cables. On the shorter ones, telegraph channels are derived from a speech circuit by normal inland amplitude-modulation voice-frequency methods, but on the new transatlantic cable maximum use of the frequency band allocated to telegraphs is being obtained by employing synchronous working over frequency-modulation voice-frequency channels. By these means it is hoped to double the amount of telegraph traffic carried in the available bandwidth.

SUBMARINE CABLE TELEPHONY

The history of overseas telephone communication from the United Kingdom begins as early as 1891, when the first submarine telephone cable was laid to France. It consisted of four gutta-percha-insulated wires similar to the cable shown in Fig. 4, and its design was obviously based on existing telegraph practice. The two circuits it provided were extended by heavy overhead copper wires to London and Paris and, having an attenuation of the order of 25 dB, were suitable for conversations between these cities only. By 1906 four such cables had been laid—three to France and one to Belgium—and the service had been extended to the larger and nearer towns in these countries.

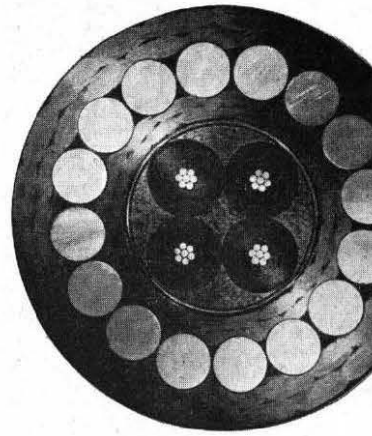


FIG. 4.—CROSS-SECTION OF A 4-CORE CROSS-CHANNEL CABLE LAID IN 1910 (ACTUAL SIZE).

Up to the First World War three further cables to Belgium and France were laid and these are of interest in that two were coil loaded[8] and the third, laid in 1913, was the first continuously-loaded cable laid for telephony. A service to Switzerland, switched at Paris, was opened in 1914, but records show that it was somewhat unreliable, and that telephoning to the Continent was still an adventure requiring patience and spare time.

The Advent of the Telephone Repeater.

The 1914-18 war gave an impetus to the development of the thermionic repeater and after the war means were thus available for providing service over distances hitherto impossible. The next decade was a period of intense activity during which telephone service was extended rapidly. Although the submarine telephone cables had, perforce, to follow short routes to the Continent and continued for the next 20 years to be laid to points on the French, Belgian and Dutch coasts, extension via these countries gradually enabled the more distant parts of Europe to be reached.

This expansion was aided by a notable step taken on the initiative of the French administration in 1923, when a conference on international communications[9] was called which resulted in the formation, in 1924, of the International Consultative Committee dealing with telephone questions (C.C.I.F.). This committee has, since that date, co-ordinated and guided technical, traffic and tariff matters affecting international telephone communications over metallic circuits.

Until 1924 all the submarine telephone cables had consisted of four stranded copper conductors, each weighing about 160 lb/mile, insulated with either gutta-percha or balata, but the advent of the valve amplifier enabled a considerable reduction in the size of the conductor to be made, and a corresponding increase in the number of conductors per cable was possible. The cables laid to Holland in 1924 and 1926[10] represented a major change in design in that they contained 16 and 17 wires, respectively, each line wire being continuously loaded, and in that they employed paper insulation under a lead sheath. The number of circuits obtained from these cables was increased by the use of phantoms, double phantoms, "ghosts" and "spooks," as shown in Fig. 5. Further submarine cables of similar design, but larger capacity, were also laid in the period up to 1930, and in some instances still further circuits were obtained by the use of 1 + 1 carrier equipment.

Carrier and Coaxial Working.

The first submarine cable designed with the requirement for carrier working in mind was laid in 1932 to La Panne in Belgium[11]; it contained 120wires (Fig. 6) and was intended

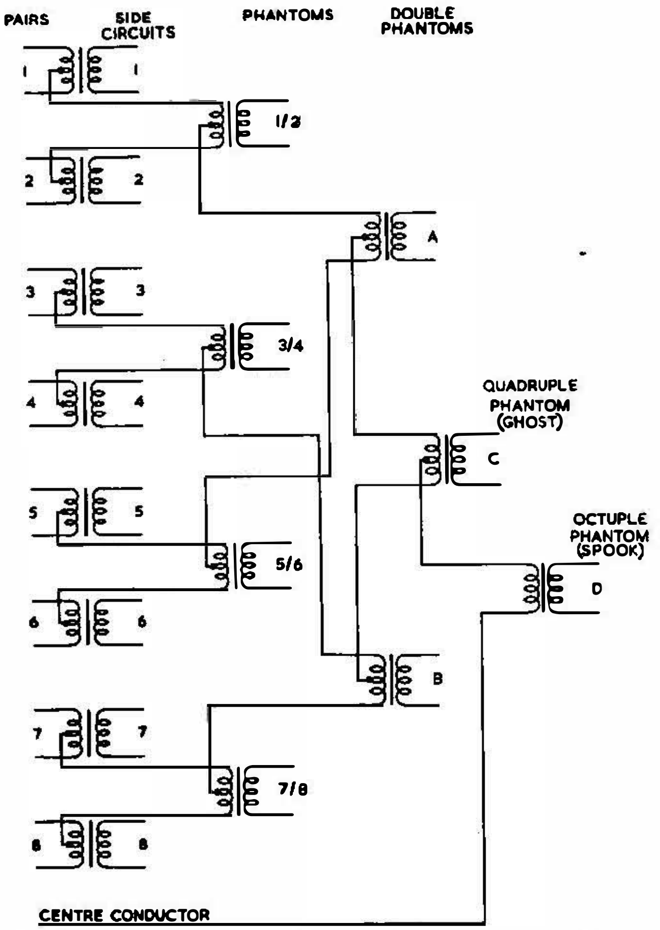


FIG. 5.—SCHEMATIC DIAGRAM SHOWING ARRANGEMENT OF CIRCUITS IN AN EARLY SUBMARINE TELEPHONE CABLE.

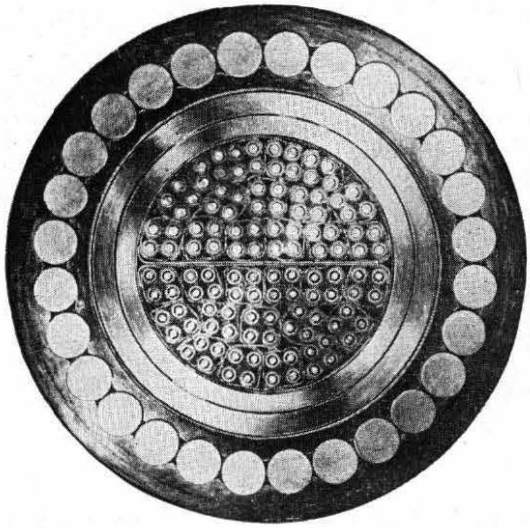


FIG. 6.—CROSS-SECTION OF ANGLO-BELGIAN CABLE OF 1932 (ACTUAL SIZE).

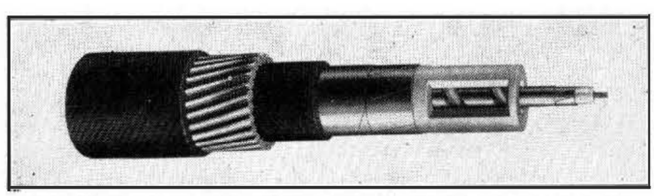
from the start to be worked on a 4-wire basis, the conductors being separated into two groups by a diametrical screen of metallized paper. Each wire was semi-continuously loaded; that is, on each conductor, 400 yd were continuously loaded and the next 400 yd unloaded. The cable weighed 30 tons/nautical mile and was probably the heaviest ever laid. With 1 + 2 carrier equipment it provided 90 telephone circuits.

After a further cable of the type laid to La Panne, another notable advance was made in 1937, when a pair of coaxial cables was laid between this country and Holland[12] and equipped for one 12-channel carrier group, the "go" channels being in one cable and the "return" channels in the other. The diameter of the outer coaxial conductor was 0·62 in., a dimension which has become a standard for submarine use; the dielectric was paragutta.

The introduction of the coaxial type of submarine cable brought about a very great advance in the transmission of speech over submarine cables. The old multi-pair cables required either double lead sheaths or a single lead sheath with a rubber covering, and on the longer routes continuous loading or very heavy conductors had to be employed to reduce the attenuation. Hence, a cable of diameter and weight sufficiently small to be laid and repaired by the normal cable ships contained very few wires. With such cables, it was always difficult to avoid excessive crosstalk after repair and to keep within C.C.I.F. standards. In fact, the requirements for near-end and far-end crosstalk were the limiting factors in determining the attenuation that could be allowed between the two terminal coastal repeater stations. The crosstalk tended to become steadily worse during the life of these cables since, at each repair, very little balancing could be carried out on board ship. The coaxial type of cable, apart from providing circuits generally at a much lower cost, has also the great advantages that it is more easily repaired, and that its electrical characteristics do not deteriorate when a new length is inserted during a repair.

However, very-wide-band amplifiers and terminal modulating equipment had not been fully developed when the requirement came in 1939 for additional circuits to France, and a paper-insulated pair-type cable was preferred. Twelve-circuit carrier systems were then being installed on inland routes and it became practicable to design a London-Paris cable system as a single co-ordinated project. The cross-channel portion of this system differed from the British inland section only in that the "go" and "return" pairs were combined under one lead sheath. A magnetic and electric screen separated the seven quads of the centre from the 16 outer pairs. The cable thus had a capacity of 12 × 14 = 168 circuits. This large capacity was obtainable since the distance across the Straits of Dover is only about 20 miles and wires of relatively small diameter could be used. The cable was laid in 1939 between St. Margaret's Bay and Sangatte and was the last lead-sheathed multi-pair paper-insulated cable laid to the Continent. At that time there were approximately 180 circuits in service, providing direct routes to 34 towns on the Continent.

The years 1944 and 1945 saw much activity in the laying of submarine coaxial cables for invasion operations[13], and telephone contact with the Continent, which had been severed in 1940, was re-established on 8th June, 1944 (D-day plus 2). In all, ten new 0·62-in. coaxial cables similar to the pre-war type, except that the dielectric was polythene instead of paragutta, were laid between this country and France. These cables served to meet the post-war demand for circuits to France and the countries served through France; but to Holland and Belgium, and the countries served through them, capacity additional to that provided by the restoration of some pre-war cables was urgently required and this demand was met by a new design of coaxial cable, in which the diameter of the outer conductor



Note: The hole in the insulation has been cut to show the polythene spiral rod.

FIG. 7.—VIEW OF 1·7-IN. SUBMARINE COAXIAL CABLE.

was increased from 0·62 in. to 1·7 in. and the dielectric was partly polythene and partly air (Fig. 7). On the 80-mile route to Holland,[14] cable of this type provided 84 circuits and on the shorter route to Belgium 214 circuits were obtained.

Submerged Repeaters.

By 1938, wide-band amplifiers and terminal equipment had been developed to meet the needs of the inland coaxial-cable network and the possibility of inserting repeaters in submarine coaxial cables had also been considered. Work on this important problem continued during the war years and in 1943 the first submerged repeater (Fig. 8)[15] was

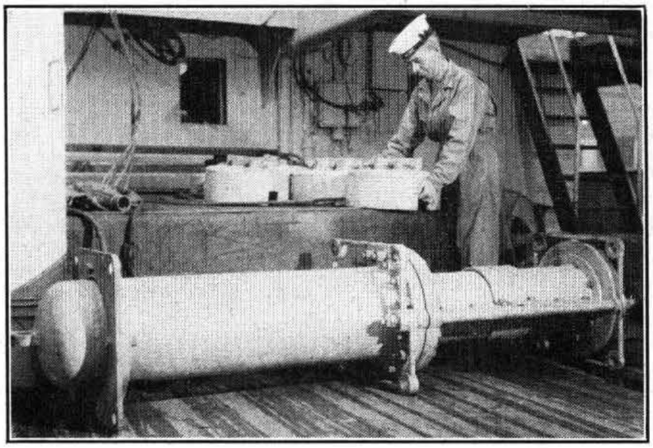


FIG. 8.—SHALLOW-WATER SUBMARINE TELEPHONE REPEATER.

inserted in a 0·62-in. submarine coaxial cable between Anglesey and the Isle of Man, increasing its capacity from 24 to 48 circuits. In 1946 the second submerged repeater was inserted in the 200-mile cable between this country and Germany. Both these repeaters amplified one direction of transmission only, that using the higher frequencies, and work continued on the design of two-way amplifiers and on repeaters that could be operated in tandem. This work culminated in the insertion, during 1950 and 1951, of four repeaters in each of the two 0·62-in. coaxial cables existing between this country and Holland, giving one supergroup of 60 bothway circuits on each cable. Similar 60-circuit schemes involving two to four repeaters were provided on new cables laid between 1952 and 1955 to Ireland, the Channel Islands and Holland.

These submerged repeaters were suitable only for the shallow water surrounding the British Isles and were designed primarily for insertion in existing cables. Following the successful use of this design thoughts were turned to a repeater suitable for deep sea use, capable of being operated with a greater number in tandem and designed for laying at the same time as the cable. A new pattern of repeater was evolved, seven of which were successfully laid in 1954 in a cable over 300 miles long between this country and Norway to provide 36 circuits.

This development and similar work in the U.S.A. paved the way for a project which had for long been exercising the thoughts of engineers on both sides of the Atlantic—a transatlantic telephone cable. After many technical discussions an agreement was signed in November 1953 between the American Telephone and Telegraph Company, the Canadian Overseas Telecommunications Corporation and the British Post Office to provide, jointly, a 36-circuit scheme across the Atlantic from Oban in Scotland to Clarenville in Newfoundland, and thence to the mainland of Canada, with extensions from the cable heads to New York, Montreal and London. This project is now approaching completion, and by the time this article appears in print the system should be in operation and thus form a fitting climax to the 50 years of telephone progress that have been reviewed.

International and Continental Exchanges.

Until 1933, the United Kingdom end of overseas circuits had been terminated in a special foreign section of the London inland trunk exchange, but at that date a separate International Exchange[16] of 121 sleeve-control positions, equipped for 480 continental trunks, was opened in the same building as the inland trunk exchange, Faraday Building.

The exchange catered for radio as well as cable circuits, but due to the continued growth of overseas traffic of both types the exchange outgrew its accommodation and it became necessary in 1947 to separate the two units, the radio exchange going to Wood Street, where it became known as International Exchange,[17] and the cable circuits remaining at Faraday Building with the title of Continental Exchange.

Generator signalling was employed, though earlier forms had been modified to suit amplified circuits and to give greater immunity to false operation by speech currents. The well-known 500/20 c/s ringer was evolved and, in fact, remains the standard for international manually-operated circuits to this day.

No further advance in methods of signalling on overseas circuits was made until 1952 when, under the aegis of the C.C.I.F., trials of 1-v.f. and 2-v.f. dialling and signalling systems were made. The trials established that these systems of signalling can meet the needs of international semi-automatic working, whereby the operator at the originating end can establish connexion automatically with the subscriber in the distant country. These systems will also permit the ultimate adoption of international subscriber-to-subscriber dialling. The trial equipments remain in use to a number of countries, and additional equipment to convert most of the continental routes to this method of operation is being engineered.

POST OFFICE CABLE SHIPS

The Post Office first became interested in cable ships in 1870, when the private telegraph systems operated in the United Kingdom were formally transferred to the Post Office and the few cables belonging to various telegraph companies were taken over, together with a small paddle ship of some 500 tons gross, named *Monarch*, used for repairs. It is interesting to recall that that *Monarch* was the first cable ship that grappled for a lost cable and successfully carried out a repair; aboard her was fitted the first cable-picking-up engine ever made, and the present technique of cable repairing originated in her. From this modest beginning the Post Office has built up a very efficient cable fleet capable of undertaking any cable-laying operation or repair, not only around the British Isles but in any part of the world.

In 1883, the second *Monarch* was specially built as a cable ship for the Post Office to replace the first ship of that name and a few years later the *Alert*, a small paddle ship, (Fig. 9) was acquired. These two ships maintained for many years the network of cables serving the Continent and the islands around Great Britain. Submarine cables at that time were mainly of the single-core and four-core types and their repair was a simple operation. The cable ships seldom steamed at night and repairs were generally effected during daylight.

During the First World War the Post Office cable ships were immediately on active service and enemy-owned cables were cut in the Channel as soon as war broke out. *Monarch* was, unfortunately, sunk in the Straits of Dover

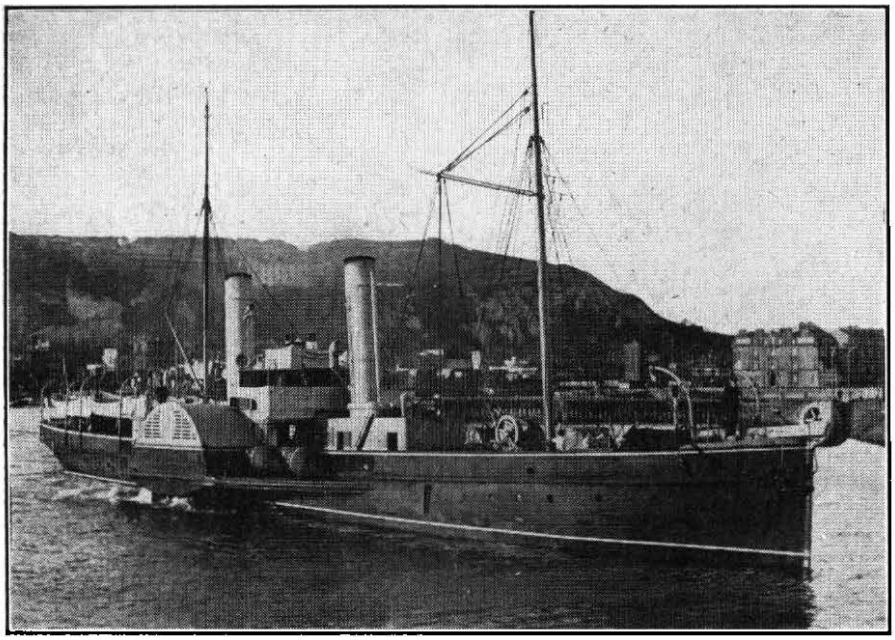


FIG. 9.—H.M.T.S. *Alert* (ABOUT 1900).

by a mine in 1915, and *Alert* was condemned; but these two ships were replaced by modern cable ships, also named *Monarch* and *Alert*,[18] which continued to maintain the Post Office cables until 1940.

On the outbreak of the Second World War a third cable ship, *Ariel*, 1,500 tons gross, was being built to assist in the maintenance of the rapidly expanding telephone cable network and, to cope with additional war work, a sister ship, *Iris*, was ordered immediately *Ariel* had been launched. These two ships[19] came into operational use during 1940.

Submarine cable-repair operations had not changed very much during the years before the war and, apart from the development of the echo-sounder, there had been little advance in electronic aids to navigation.

During the war years, 1939-45, in mined and submarine-infested water, in areas constantly subjected to attacks by aircraft, the cable ships sailed to maintain essential lines of communication. Post Office cable ships were also able to render assistance in the early stages of development of what was to become so well known as "Pluto."

The preparations made for "D-day" will always be of interest. Immediately the beach at Longues was cleared of the enemy, the splice to the U.K. shore end was made and *Iris* and *Alert* proceeded to lay the first cable. All went well, and 25 hours after starting, the cable end was connected to a mobile repeater station on the Normandy beach and telephone communication was re-established with the Continent.

When the break-through in Normandy came and the Allied Armies swept through France to the Rhine the cable ships followed up the Channel closely in support laying telephone cables as and where required. The Post Office cable ships had not so far been too unfortunate having regard to the many risks which they had to take in their work during the five years of war, but the last few months of hostilities were to see them suffer grievous loss. H.M. Telegraph Ship *Alert* was sunk, and although an extensive search was made, there were no survivors from the entire ship's company of 55 officers and men. This loss was soon followed by that of *Monarch*, which was also torpedoed. Fortunately, the weather was fine, so that it was possible to rescue 69 out of a total complement of 72 men. V.E.-day came in May without further loss to ships or personnel.

During the war the only large British cable ship, the *Faraday*, owned by Siemens Bros. Ltd., had been sunk off the Welsh coast. The loss of this fine ship was a serious handicap in view of the large British interests in submarine cables, so it was decided that the Post Office should build and maintain a large cable-laying ship capable of maintaining the high prestige that had been built up by such fine cable layers as *Faraday* and her predecessors *Dominia* and *Colonia*.

From the design and specification prepared by by the Engineer-in-Chief of the Post Office, Messrs. Swan Hunter and Wigham Richardson built H.M. Telegraph Ship *Monarch*[20] (Fig. 10), the fourth ship in Post Office service to bear that name. *Monarch* is 480 ft overall, 55-ft beam and can carry about 2,600 miles of deep-sea submarine cable. She is oil-fired and has every modern scientific device to enable cable faults to be located and the ship to be navigated to the required position in the most efficient manner. *Monarch* is the only cable ship to be fitted with electrically-operated cable machinery. The particular requirements of the cable engines made it desirable to provide a form of drive very similar in performance to that given by a steam-engine, and use has been made of the constant-current system in which one or more generators are so controlled that they deliver a perfectly steady current—in this instance of 300A—no matter what the load. This novel application of the system to cable engines has proved to be a great success.

With the great advances in radio aids to navigation during and since the war, it is now possible to navigate in any weather in the vicinity of the British Isles, the North

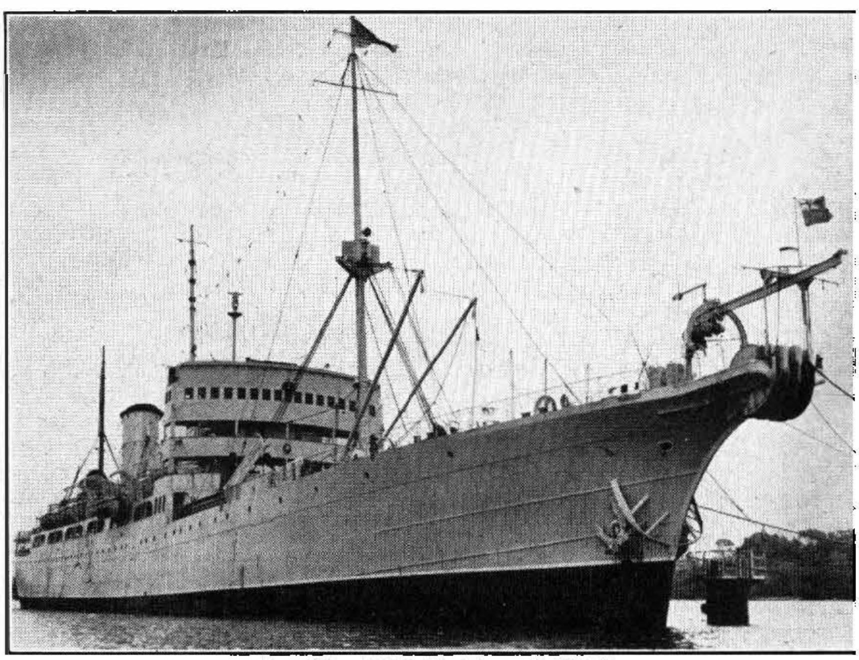


FIG. 10.—H.M.T.S. *Monarch* (1955).

Atlantic and the Eastern seaboard of North America.[21] Radar is fitted in all Post Office cable ships, enabling them to proceed in fog with reasonable safety.

The principal system of radio navigation is the Decca, by which the exact geographical position of a ship can be found at any time from radio signals, continuously emitted from four shore-based transmitting stations. The Decca system, which is comparatively short-ranged (about 300 miles), is installed in all Post Office cable ships and has proved of immense value. *Monarch,* when working in the North Atlantic outside the range of the Decca system, uses the Loran system for position finding, a long-range system which has proved most valuable during the laying of the transatlantic telephone cables.

Radio Communications

Shorter-Distance Ship-to-Shore Communications.

At the beginning of the 50 years under review, radio services (as distinct from experimental circuits) were almost non-existent except for an established telegraph service to ships at sea, the value of which, in cases of distress, had been spectacularly shown on several occasions. The Post Office was responsible for the collection, transmission and delivery of ship-to-shore and long-distance messages and, in 1909, took over control of the British coastal stations for working with ships in coastal waters. The service was reorganized between 1909 and 1913, and a well-founded ship-to-shore service was built up with a chain of coastal stations equipped with Marconi synchronous spark transmitters, such as that shown in Fig. **11**. The Washington Radio-telegraph Convention, 1927, abolished spark working by coast stations, and the transmitting equipment was completely replaced between 1932 and 1935 by new valve transmitters. At the same time new receivers in keeping with the then existing practice were installed. In general, each coast station was equipped with a main and an emergency transmitter and a minimum of two receivers, and had a range, by day, of approximately 300 miles. By night the range was much greater. The transmitting and receiving aerials were erected on the same sites and only simplex working was possible.

Bellini Tosi direction-finding equipment was first introduced in 1924, and by 1932 equipment had been installed in six more stations ; by 1939 all but one of the stations were equipped with the Bellini Tosi system and one with that of Adcock. During 1932, about 6,000 bearings were given to ships, but this number has fallen since as a large number of ships carry their own direction-finding equipment and a comprehensive marine radio-beacon system has been established. Nevertheless, direction-finding by coast stations remains of great importance during distress working, and a plan has been drawn up for the installation of modern Adcock systems at each station, for use in the 500-kc/s and 2-Mc/s bands: so far three stations have been so equipped.

Up to 1932 the services provided by the coast stations were all conducted by radio telegraphy, but in that year fishing vessels and other small ships began voluntarily to carry radio-telephone apparatus, and suitable equipment was also installed at certain of the coast stations. At first the commercial services given by radio telephony were similar to those given by radio telegraphy, but in 1934 a link service between small ships and inland telephone subscribers was introduced on a simplex basis. Since the end of the 1939-45 war there has been a great expansion in the short-range radio-telephone link service (in 1955, 70,000 link calls were handled), and a comprehensive re-equipment and expansion program has been taking place at the coast stations, of which there are now 12.

In general, each coast station has a minimum of three modern medium-frequency transmitters of Post Office design, used for radio telegraphy and radio telephony, and suitable apparatus to permit duplex working in the radio-telephone link service. A view of a typical receiving room is given in Fig. **12**. The transmitting aerials are located at the station, the receiving aerials (including those for direction-finding) being located at remote sites and connected to the station by balanced transmission lines and coaxial cables.

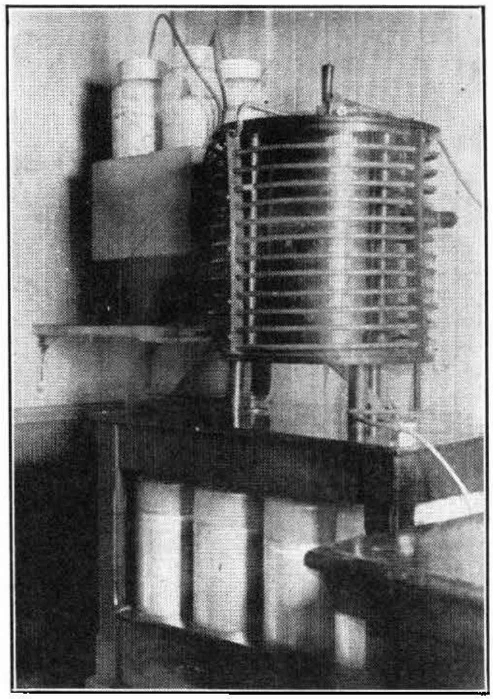


Fig. **11**.—An Early Spark Transmitter at Cullercoats Radio Station (1914).

The most important function of the coast stations remains, however, their contribution to safety of life at sea, and the stations maintain continuous watch on the telegraph and telephone distress-frequencies, 500 kc/s and 2,182 kc/s, respectively.

Long-Distance Ship-to-Shore Communications.

In 1920 the Post Office supplemented the coastal service to ships with a long-distance telegraph service in the band 110 to 160 kc/s from a station at Devizes in Wiltshire.[22]

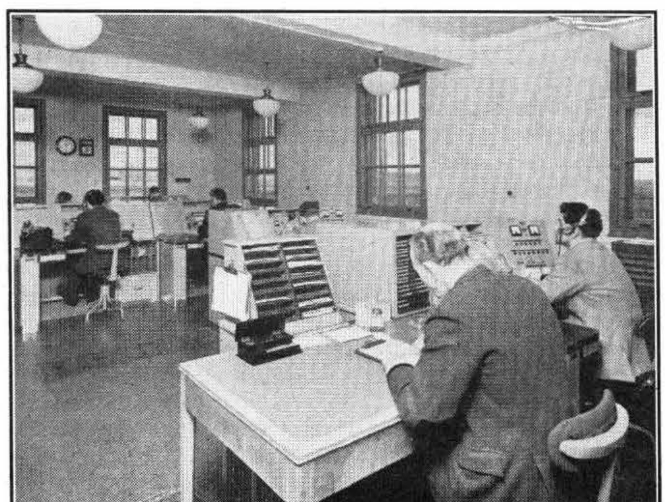


Fig. **12**.—The Receiving Room at Wick Coastal Radio Station.

The range covered was of the order of 2,000 miles. By 1925 separate transmitting and receiving stations became necessary to permit simultaneous operation of several channels in the band. The new stations were provided at Burnham-on-Sea for reception, and at Portishead, 19 miles distant, for transmission, and keying was effected over land-line connexions between the two points. The service was extended to high-frequency (h.f.) bands in 1926, and by 1938 six such transmitters were in service and the traffic handled was three million words per annum. After the Second World War an additional facility was introduced whereby messages to and from British ships in distant parts of the world were routed via a number of stations overseas, the world being sub-divided into areas, each with its area station.

To cope with the steadily increasing traffic the Burnham station was enlarged and re-equipped during the period 1946 to 1948.[23] In addition to omni-directional aerials, on which most calls are initially received, a fan of rhombic and vertical Vee aerials with a distribution and selection system were provided to enable each operator to obtain the benefit of high-gain aerials in the reception of messages from any ship to which he may be working no matter where its position at sea. These aerials can be used simultaneously by any or all of the operators without interaction. Low-frequency (l.f.) reception is provided by an aerial system incorporating crossed loops giving directional or omni-directional facilities for simultaneous and independent use at the four l.f. positions. Twenty-eight h.f. and four l.f. positions are provided, each incorporating a modern communications-type receiver. Ten h.f. and two l.f. transmitters at Portishead and a third l.f. transmitter at Criggion are available. Traffic in 1955 had grown to ten million words.

With the development of h.f. telephone services from Rugby-Baldock, primarily for fixed services, which are referred to later, a service was provided from these stations to large passenger liners. At first used chiefly by the very large transatlantic liners the service is now available to suitably equipped ships anywhere in the world. The service was originally provided solely on double-sideband equipment, but for the past ten years either double-sideband or single-sideband working has been available, according to the equipment fitted on the ship.

Point-to-Point Telegraph Services.

The early work of the Marconi Wireless Telegraph Company resulted in a limited commercial service across the Atlantic in 1907. In 1913, provision of a series of radio-telegraph stations throughout the world was approved to form an Imperial chain of communications. However, construction was interrupted by the First World War, and only temporary service was available from Egypt until 1921, when permanent bothway service was established, using Poulsen arc transmitters at Abu Zabal and Leafield.[24] The next step was the erection by the Post Office, between 1923 and 1925, of a 500-kW v.l.f. transmitting station at Rugby[25] (Fig. 13) with its aerial system supported from 12 820-ft lattice masts. The transmitter incorporated high-power water-cooled valves and a high-stability tuning fork for frequency control, both of which were novel features.

To supplement the v.l.f. service a series of h.f. directional services was planned, and in 1924 an agreement was concluded between the Postmaster-General and the Marconi Company, for the provision of h.f. beam stations[26] to work at 100 words/min with Canada, India, South Africa and Australia. These stations, which were brought into service in 1926-27, gave 10 to 15 kW output, and the transmitters were adjustable to any frequency between 7·5 and 20 Mc/s, the bandwidth of the receivers being 20 kc/s to accommodate possible frequency drift of the transmitters. High-gain

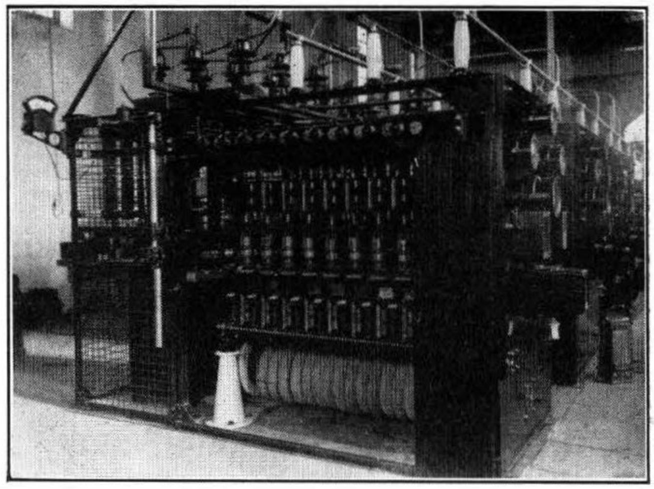


FIG. 13.—THE HIGH-POWER STAGES OF THE RUGBY V.L.F. TELEGRAPH TRANSMITTER (1925).

transmitting and receiving aerials of the Franklin pattern were employed, and are still giving good service to-day.

As already recorded, competition between these new radio circuits and the existing cable system led to a merger of the two services, and in 1929 control of the beam-radio stations passed out of Post Office hands, until 1950, when the operation of both the cable and radio services became again the responsibility of the Post Office.

Although telegraph service is now available by cable or radio to almost every country in the world, the demand for channels is still increasing, but the emphasis is more for telex and leased channels requiring five-unit working. This has led to a need for channelling equipment to enable fuller use to be made of the available bandwidth, and for automatic error-correction systems to minimize the incidence of printed errors due to poor radio conditions.

Point-to-Point Telephone Services.

Shortly after the establishment of the v.l.f. telegraph service at Rugby, a long-wave telephone service[27] was developed in conjunction with the American Telephone & Telegraph Company and opened for traffic in 1927. It is interesting to note that single-sideband technique with suppressed carrier was employed and that the same frequency was used in both directions. The United Kingdom transmitter was located at Rugby and the receiving station at Wroughton, and later at Cupar in Scotland, where the highly-directional receiving aerials on a mean frequency of 60 kc/s (5,000 metres wavelength) occupy several square miles.

As with the telegraph service, this transmitter was quickly supplemented with high-frequency services and a group of h.f. transmitters and aerial arrays was constructed at Rugby with a complementary receiving station at Baldock. Double-sideband receivers incorporating automatic gain control were used and, to facilitate frequency changing, the h.f. amplifying stages were originally provided in duplicate. The first h.f. telephone service was opened on the transatlantic service in June 1928. Two additional channels were provided in 1929, and circuits to Australia, Buenos Aires, Capetown and Cairo were opened in 1930 followed by circuits to Canada and India in 1932. At this time London could truly be said to have become the world's trunk exchange.

The h.f. double-sideband transmissions were capable of being received on any h.f. telephone receiver, and it was necessary to provide radio-telephony systems with some form of privacy. Various types of privacy equipment,[2] starting with inversion of the speech frequencies, were used in conjunction with periodic variation of the carrier frequency. More elaborate privacy equipment is now used in which each speech channel is split into five frequency bands, and the position of the bands interchanged at intervals of 20 sec or so.

By 1934, single-sideband working was practicable for h.f. circuits, a low-level pilot-carrier being radiated and used to control the oscillators in the receiver, and in collaboration with the American Telephone & Telegraph Company, conversion of all the circuits between London and New York was put in hand.[29] The transmitting facilities were then extended so that two independent speech channels of 5-kc/s bandwidth could be translated into single-sideband signals, one above the pilot-carrier and one below, and applied to one transmitting amplifier, with complementary facilities at the receiver. From 1939 to 1945 the public radio-telephone service from the United Kingdom was closed down and on reopening after the war it grew rapidly until to-day 73 radio-telephone circuits exist to 45 overseas terminals in 40 different countries. On resumption of service new independent sideband equipments were introduced with a bandwidth of 6 kc/s, and by combining two-speech channels in this range, up to four channels could be applied to one transmitter.

Attempts to improve the directivity of aerials led to the development in 1935 of the multiple-unit steerable array (M.U.S.A.)[30] for reception. This array, by providing sharp directivity, steerable in the vertical plane, permits discrimination between the waves arriving at different down-coming angles and so reduces selective fading due to wave interference. Between 1937 and 1939, the M.U.S.A. technique was applied to h.f. telephone circuits between the U.S.A. and this country.

Technical control and supervision of long-distance radio-telephone circuits are provided at the Radio Telephony Terminal (R.T.T.). The first R.T.T.[31], located in Faraday Building, had by 1949 been equipped to control simultaneously 13 circuits, but it has since been superseded by a new R.T.T.[32] at Brent Building, in north-west London, where equipment for the simultaneous control of over 70 circuits has been installed. The equipment at the R.T.T. includes privacy equipment and constant-volume amplifiers in the go and return paths to maintain the average modulation of the transmitter at a high level and to counteract the effects of selective fading. This equipment, together with signalling equipment, singing suppressors, etc., is rack mounted; operation is controlled from suites of low operating positions (Fig. 14) equipped with comprehensive test facilities and located in an adjacent room.

Fig. 14.—Two Suites of Operating Positions and Associated Control Positions at the Radio Telephony Terminal, Brent.

The circuits finally terminate at the International Exchange at Wood Street,[17] in the centre of London, where over 100 low-type sleeve-control positions are provided, the radio circuits terminating on multiple jacks and being switched two-wire. Order-wire facilities are provided on each circuit between the traffic and technical operators, and "state of circuit" lamps advise the traffic operators when the radio circuits are of commercial quality.

Broadcast Press Services.

Reuters were quick to appreciate the use of radio for a broadcast news service and, in 1923, rented facilities from the Post Office for a long-wave broadcast news distribution service in morse to Europe. By 1928, a world broadcast news service in code was commenced, using Rugby GBR on 16 kc/s, and in 1931 the service was extended for uncoded messages by the addition of two h.f. transmitters at Leafield, still using omni-directional aerials. In 1935, an experimental supplementary service to Europe was started on a Leafield l.f. transmitter, using the Hellschreiber direct-printing system, in which the characters are not printed from type-face but are built up by a series of marks in a frame, seven elements wide and seven elements deep.

From shortly before the Second World War, h.f. broadcasts have been undertaken for a number of Press agencies, including Reuters, using broadly-beamed aerial-systems, which together provide almost world-wide coverage. In view of the practical difficulties of making frequency changes at short notice on a one-way multi-destination service, successful operation depends on accurate propagation forecasts, and the Post Office extended its work on this subject for this purpose. Morse and Hellschreiber transmissions still provide the greater part of these Press broadcasts, but they are disappearing in favour of teleprinter transmission. This requires greater efficiency in the transmitting and receiving arrangements, particularly the latter, and the services are being replanned to employ the latest practices.

Photo-telegraphy by Radio.

Radio photo-telegraphy on a commercial basis can go back only 30 years, and from its inception, in 1926, progressed very slowly for many years. The crude "dot-modulator" system,[33] then employed, keyed in telegraph fashion a long-wave transmitter which radiated dots at varying speed, controlled by a light spot scanning a picture placed on a drum rotating at constant speed. These dots produced an illusion of tone graduations at the receiving end when recorded on the telephoto equipment, as shown in Fig. 15.

This method gave way to the constant-frequency variable-dot principle,[33] which again keyed the radio transmitter in telegraph fashion, but varied the size instead of the frequency of the dot and built up a more pleasing pattern on the received picture, being very similar in appearance to a newspaper reproduction. Both systems had the quality of partially defeating radio-fading variations, which made direct amplitude-modulation transmission impracticable.

In those days, the London terminal for extra-European radio pictures handled on an average about 120 pictures a year, and this remained the figure until 1939, when an improved system, known as sub-carrier frequency modulation,[33] was introduced. In this system the picture intelligence is contained in the frequency variations of an audio tone which modulates a radio transmitter operating on radio-telephone principles. With the introduction of this system, radio picture transmission was speeded up considerably, but poor terminal equipment was a limiting factor and, with the expansion of airways, picture traffic was not greatly increased.

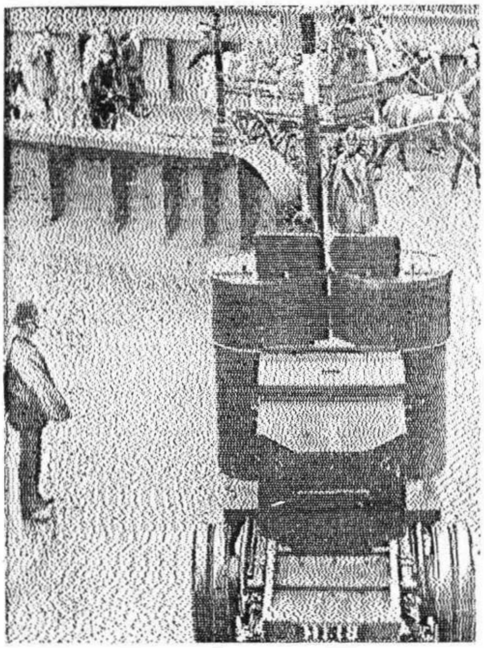


FIG. 15.—A PICTURE TRANSMITTED BY RADIO IN 1926 USING THE DOT MODULATOR SYSTEM.

During the Second World War, propaganda radio-pictures were broadcast, and after the war, improved telephoto equipment was introduced and some 15 countries were served from London, with an annual turnover rising to 3,000 pictures.

In 1950, further improvements were made and the most modern equipment installed. In addition, to speed up delivery, direct transmission to the customer by line from the London telephoto terminal was arranged, in place of some 30 minutes' delay, which previously was required for photographic processing and production of prints for sending out by messenger. For this, the customers, mostly press agencies and newspapers, require to have their own telephoto equipment. To-day, a customer can rely on a reasonably quick clearance, and the press can often receive a picture, directly transmitted to their London office, within 30 minutes of the event being photographed in, say, Australia, Japan or the U.S.A.

In 1953 the London terminal handled 7,000 pictures; in 1954, 9,000; and in 1955 the figure rose to 10,800, serving 31 countries by radio.

The New Rugby H.F. Transmitting Station.

No article on overseas communications would be complete without reference to the latest Post Office radio-transmitting station recently completed at Rugby.[34] This station contains equipment for world-wide telephone and telegraph radio transmissions between 4 and 27·5 Mc/s, and the 28 identical transmitters it houses are suitable for independent or double-sideband operation on telephony, and can carry up to four telephone channels or multi-channel telegraph systems. Single-channel telegraph signals, with frequency-shift keying or amplitude modulation, can also be radiated.

For the two-channel and four-channel telephone systems each pair of channels is assembled in London and transmitted to Rugby over a land line, having a bandwidth of 6 kc/s and carrying the two speech channels of 250 to 3,000 c/s.

The transmitters of 30-kW peak envelope-power are designed for remote control and are operated and supervised from a central control position (Fig. 16). One man at this position can start and stop any transmitter, switch it to any one of six predetermined frequencies and to the required

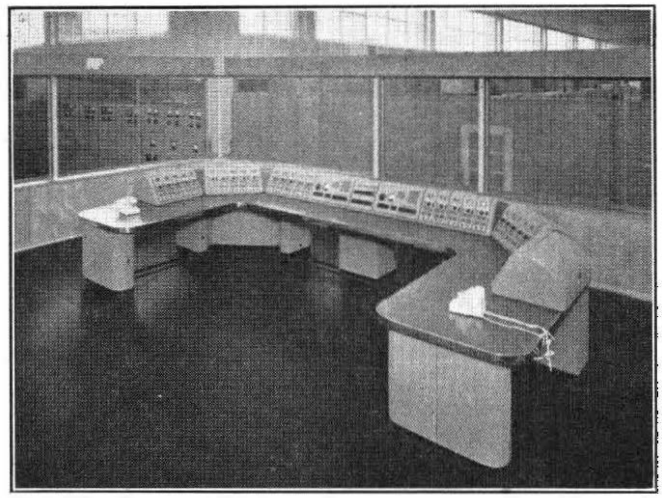


FIG. 16.—CENTRAL CONTROL POSITION AT THE NEW RUGBY B TRANSMITTING STATION.

aerial, and can monitor any transmission. A number of indicators operated by automatic monitors show whether normal operating conditions are being maintained or not and, when conditions are not normal, the monitors operate alarms grouped into urgent and non-urgent categories.

INTERNATIONAL TELEX

Teleprinter exchange service, or telex as it is known throughout Europe, is the latest telecommunications service to be offered to the public. When it was first introduced in the United Kingdom as an inland service, calls had to be established initially as telephone connexions, the subscribers then switching to teleprinter operation. International service on this basis was opened in 1936, to Holland and Belgium, and extended to Germany in 1937, but when the international service was reopened after the war, it was operated as a purely telegraph network, using channels in voice-frequency telegraph systems. Recently the inland system has been converted to this method of operation and now full interconnexion between the inland and overseas circuits is provided.

By 1952, access to 14 European countries was available, and on seven of the routes the London operator could obtain the distant telex subscriber automatically by direct dialling. In that year the first extra-European circuits, to New York, were connected. These provided a number of problems because American teleprinters work at $45\frac{1}{2}$ bauds as against 50-baud operation, which is standard in this country and throughout Europe, and because the automatic correction of errors due to interference or fading experienced on the radio path had to be catered for. Later, when the system was extended throughout America further complications arose due to the different keyboards, etc., in use in the different companies' systems in that continent. But these problems have been overcome, and to-day it is possible for a subscriber in London to communicate by teleprinter to telex subscribers in over 30 countries abroad, and the service is rapidly expanding.

FUTURE DEVELOPMENTS

It would be rash to endeavour to predict the course of events for the next 50 years, but the pattern for the more immediate future is naturally clearer.

In the telegraph field the Post Office is pledged to play its part in the conversion of the Commonwealth cable and radio network to 5-unit operation. The plan as seen to-day is for the short-distance cables and the easier radio circuits to continue to work 5-unit on a start-stop basis at standard teleprinter speed. Longer-distance telephone cables will carry v.f. telegraph channels, but these will be worked synchronously to conserve band width. Some of the older telegraph cables will remain with d.c. signalling, but will be converted from cable code to 5-unit working, whereas others will be equipped with submerged repeaters and worked by v.f. methods. The more difficult radio circuits will be operated on a synchronous 5-unit basis with automatic error-correction.

When the overseas circuits are converted to reliable 5-unit operation, there appears to be no insuperable difficulty in linking together the overseas and inland networks to avoid the re-transmission of messages. This could be achieved on an automatic or semi-automatic basis, using known methods and apparatus but, with the advent of magnetic storage devices, it might be attractive to dispense with punched tape as the storage medium and develop new techniques. Printing would be on a page basis, monitor copies being taken at control points as required. The automation of the overseas telegraph office would reduce the "office drag" and should effect considerable savings in the cost of handling the overseas telegram.

On the telephone side, the h.f. radio spectrum is becoming so crowded that one must look elsewhere for alternative means of providing additional circuit capacity, and it is from the use of repeatered submarine coaxial-cable that the more immediate relief may be obtained. Present techniques have shown that it is possible, using well-tried components, to provide 36 circuits over a 2,000-mile ocean span. With later types of valve and with cable insulation capable of withstanding higher voltages for the power supply, it should be possible to increase the available bandwidth very considerably. Frequency conservation devices may be perfected which allow more circuits to be obtained from a given bandwidth, and new types of cable, cheaper than existing types and yet more suitable for laying in, and lifting from, great depths of water, may shortly be evolved. The transistor may also provide the answer to a number of these problems. The next decade or two may therefore see a considerable extension of the long-distance repeatered submarine coaxial-cable network.

So far as land circuits are concerned, radio and cable again seem gradually to be changing their roles for, just as the repeatered submarine cable is tending to replace radio for transoceanic communication, so are microwave relay systems tending to supersede land cables for intra-continental services.

As regards the long-distance radio services there will, without question, be significant developments of the many types of equipment ranging from high-power h.f. transmitters to receivers handling very weak signals. The initial communications, which were restricted to telegraph signals on low frequencies, have been rapidly supplemented by signals on frequencies up to 20 or 30 Mc/s. Still higher frequencies, of hundreds or thousands of megacycles/second, are attractive in enabling bandwidths of one or more megacycles/second to be used on each transmission. Systems making use of ionospheric scatter, on frequencies of 25 to 100 Mc/s with relatively narrow communication channels, are already being installed for single-hop transmissions of 1,000 miles. Frequencies of 1,000 Mc/s or so are being proposed for distances of 100 to 300 miles to provide circuits capable of handling signals of 100 kc/s bandwidth or more. Fifteen years ago frequencies above 50 Mc/s were considered to be useful for just more than line-of-sight transmission. As has been the rule with radio, the applications now seem wider than at first envisaged, and it may well be that international exchange of television programs, already of regular occurrence over a large part of Europe, will become a daily occurrence on an inter-continental basis.

Finally, the process of automatizing the inland trunk telephone and telex networks will undoubtedly be extended to include links overseas so that every subscriber in the United Kingdom will be able to dial directly into the national networks of at least the nearer continental countries. To extend the range further may involve accounting and administrative difficulties, but if there is a public demand for the service it is certain that engineering means will be found to meet it.

ACKNOWLEDGMENT

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Transmission and the Trunk Network

Fifty years ago, the paper-core lead-covered cable was already in use in subscribers' networks, but long-distance transmission was by heavy overhead wires. The advent of the loading coil made possible cable transmission over limited distances, and the thermionic amplifier extended this distance indefinitely. Carrier operation on pair-type cables, and later on coaxial cables, greatly reduced the cost of long circuits. Microwave radio links show promise as a medium for the transmission of large groups of circuits and are finding their place in the trunk network. Television relay circuits are provided either by cable or microwave radio. Forthcoming developments may reduce the distance beyond which carrier is more economical than audio transmission. In the local line networks conductor gauges have been progressively reduced as telephone instruments of improved performance became available.

The Beginnings of a Trunk Network

When, in January 1878, Graham Bell demonstrated his telephones before Queen Victoria at Osborne House, Isle of Wight, his demonstration included connexions to Southampton and to London. This was the first example of long-distance telephony in Britain. In November 1878, speech was transmitted experimentally over a private line between Norwich and London, a distance of 115 miles. On both occasions single-wire earth-return telegraph circuits were appropriated for the purpose.

Public telephony in Britain began with entirely local telephone systems in various towns with no means of telephone communication between them. Late in 1884, however, the various private telephone companies were granted new licences which removed territorial restrictions hitherto imposed on them and permitted them to go ahead with inter-town communications. This they did with vigour where trunk lines were certain to be profitable—as for example between Liverpool and Manchester, and between Edinburgh and Glasgow. All the circuits were overhead, sometimes earth-return, sometimes metallic loops. In 1888 a project was mooted for telephone communication between London and Birmingham (and thence to the Midlands in general) but wayleave difficulties impeded completion until July, 1890. Four pairs of 150-lb/mile wires were erected, the plan being to terminate two circuits in Birmingham, one in Manchester and one in Liverpool.

The need for a unified system led to the Telegraph Act of 1892, which made provision for the purchase of the existing trunk lines by the Postmaster-General and for the development of trunk communications by the Post Office, which went ahead immediately with the planning and construction of a comprehensive network based on 800-lb overhead copper wires for the main routes, such as between London and Glasgow; 600-lb copper wires for secondary routes such as Cardiff–Birmingham; and 400-lb wires for shorter routes such as London–Brighton. The scheme was largely completed, and the purchase of the independent lines concluded, by 1896.

These aerial lines consisted, generally, of copper wires spaced 12 in. apart, the pairs of wires forming one circuit occupying diagonally opposite corners of a 12-in. square. Crosstalk and interference were reduced by rotating the square; later, a systematic transposition scheme was introduced. The high quality of transmission attainable on these lines was often impaired by the need to introduce short lengths of underground cable through towns.

By 1904 overhead trunk routes were large enough, in some instances, to justify order-wire working.[1] A scheme of call-wire working, using a telegraph circuit superimposed on the trunk circuits, was also introduced.

By 1910 there was serious congestion of aerial routes on main roads, particularly around London. A scheme was prepared for direct cross-country lines consisting of steel towers carrying large numbers of conductors, but just at this time the long series of experiments with loaded lines led to the conclusion that future development could be better catered for by underground cable.

Between 1905 and 1910 the trunk-network wire-mileage increased from about 113,000 to 227,000, of which about 85 per cent was overhead.

The air-spaced, paper-insulated, lead-covered cable had been developed in the early nineties and was extensively used in the subscribers' network, chiefly with 20-lb conductors. Underground cables could not, in the early years of the century, take the place of open wires in the trunk network. Until the advent of the loading coil and the introduction of cable balancing, cable transmission was not practicable between towns much more than about 50 miles apart; and only with the coming of the valve repeater did open wires finally become obsolescent for transmission over distances exceeding about 200 miles.

The First Trunk Cables.

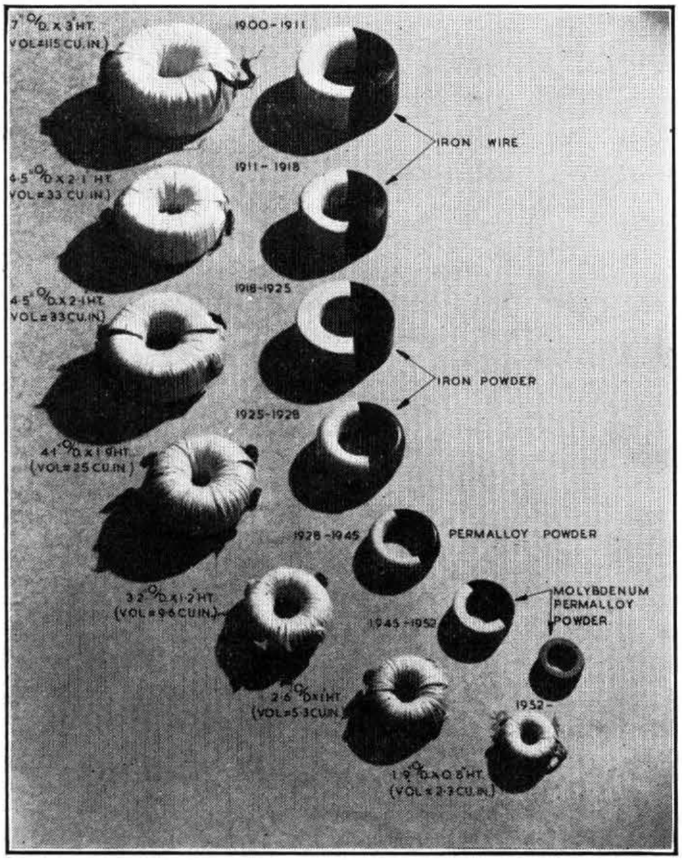
A few long-distance cables were laid about the turn of the century—notably the London–Birmingham No. 1, laid between 1897 and 1898; the Liverpool–Manchester, laid 1902-04; and the London–Chatham, laid 1905-06. Those early cables made use of conductors of gauges up to 150 lb/mile, were frequently of composite structure (i.e. contained pairs of different gauge) and indeed were provided much more for telegraphy than for telephony. The London–Chatham cable, for example—a section of the first London–Canterbury cable—consisted of four 150-lb pairs, 28 100-lb pairs, 30 100-lb single conductors screened with copper tape, and seven 40-lb single conductors similarly screened. Much experimental work was done on telephone transmission over cable pairs, notably on the London–Birmingham cable,[2] which was for many years used for telegraphy, but after later reconditioning is now very successfully meeting certain high-grade circuit requirements.

The Introduction of the Loading Coil and Cable Balancing.

The benefit of added inductance in the line circuit was pointed out by Oliver Heaviside in 1893, and the early practical development was carried out in the U.S.A. by Prof. Pupin and Dr. G. A. Campbell between 1899 and 1903.[3] The first British cable to be loaded for practical purposes was the Liverpool–Warrington section of the Liverpool–Manchester cable of 1902-04. Solenoidal air-cored coils of 45-mH inductance were used. A Newcastle–Stockton cable, laid 1906-07, included 20 pairs loaded for telephony; the loading consisted of 136-mH coils at 2·3 miles spacing. The first loaded cable of major importance, devoted entirely to telephone circuits, was the Manchester–Liverpool No. 2, laid in 1910. This was a 104-pair, 70-lb, multiple-twin cable, with loading coils of 136 mH at 2·3 miles spacing. Multiple-twin construction was to become standard for trunk and junction cables, practically throughout the world, for many years.

The earliest air-cored coils were soon replaced by iron-wire-cored coils imported from the U.S.A. These cores were toroidal, made from mild-steel wire of 0·004 in. diameter. The most common loading consisted of 136-mH coils at 2·6 miles spacing; but much heavier loadings were used—up to 250 mH at 1·25 miles spacing. Multiple-twin construction was intended to provide for phantom-circuit operation and this was general. The loading inductance was about 60 per cent of that of the side circuits.

Wire-cored coils, whilst satisfactory for their purpose, were not free from distortion, were not constant in inductance and were not of sufficiently uniform performance. An improved core material, compressed powdered iron, was introduced in 1916 and used in Britain for the first time in 1921-22. Wire cores became obsolescent from about 1924. Nickel-iron powder cores, first used in 1929, very much reduced the size of coils, and later improved materials have progressively reduced the size to about one-tenth that of the early wire-cored coils (Fig. 1).



Photograph by Standard Telephones & Cables Ltd.

FIG. 1.—LOADING COILS, FROM 1900 TO 1956.

Loading was introduced with the sole object of reducing the volume-loss of transmitted speech, the aim being a loss comparable with that of an overhead line in its best condition. The unavoidable disadvantages of low cut-off frequency and low velocity of propagation were accepted as the price that had to be paid to attain this end. Later realization of the importance of these shortcomings led to the use of lighter loadings. In the meantime, in spite of low cut-off frequency and relatively high loss, loaded underground circuits found favour because of their reliability and comparative freedom from noise; trunk circuits could now, over limited distances, be provided much more economically and the consequent better grade of service led in turn to more traffic.

The low noise level of cable circuits was achieved only after the introduction of cable balancing. The need for some system of cancelling out induced e.m.f. over successive lengths of cable was early realized, and about 1899 Martin and Tremain made an exhaustive investigation on the Birmingham–London No. 1 cable,[2] and found that crosstalk could be very much reduced by a system of wire and pair crosses at roughly five-mile intervals to meet an empirical rule that no two pairs should be adjacent for more than 10 per cent of the total route length. Principles based on these tests were followed until about 1912, when it was found that they no longer sufficed for loaded cables, and that joint use of cables for telegraphy and telephony was becoming impossible. Much study was devoted to problems of cable design and balancing and the Post Office developed a technique[4] which involved capacitance measurements and wire or pair crosses at every 176-yd jointing point. The Leeds–Hull cable of 1913 was the first to be so balanced. At first a simple resistance-capacitance bridge was used, measuring only resultant capacitances between wires, but in 1915 the double bridge was introduced by Hay and Werren and this, with some modifications, is still in use.

The rigorous system of test and selection obtained until 1930, when the work was simplified by the introduction of "systematic jointing" whereby the position of each four-wire core in relation to its neighbours was changed over successive lengths of cable according to a systematic plan and the number of joints actually test-selected in the field was reduced to three per loading-coil section. Field operations were further simplified by the introduction of a 15-position switch to give the essential connexions required for testing.

Development up to the First World War.

In 1912-13 an extensive scheme of main trunk cables was planned, mainly in and around London, generally of multiple-twin cables with 70-lb conductors, but the war of 1914-18 intervened, and out of some 18 main cables begun before the war only two were completed by the end of 1914. A London–Birmingham–Liverpool cable was started in 1914 and completed in March 1916; it had only 52 pairs but was notable because of the size of its conductors, which ranged from 100 lb to 300 lb. It was loaded with Western Electric coils spaced 2·5 miles apart, 135-mH coils being used on all pairs and 82-mH coils on phantom circuits on the 150-lb and 200-lb pairs. Each loading-coil case was buried on its side in the ground, with its top projecting through the manhole wall into the manhole. The intention was to use the lighter-gauge pairs for calls terminating in the "home" areas of the three zone centres, and to reserve the heavier pairs for longer-distance communications. The "equated lengths" of the circuits, as planned for use, ranged between 9 and 12 miles of standard cable (m.s.c.).

Many of the projected schemes were never carried out and there were no major developments until 1919-20 when a post-war drive to overtake heavy arrears began.

THE INTRODUCTION OF THE AUDIO AMPLIFIER

The first effective use of amplifiers occurred immediately after the great storm of 27th March, 1916, which severed all overhead lines between London and the North, leaving as the only line of communication the new London–Birmingham–Liverpool cable, completed only a fortnight before. It was important to restore communication to Ireland, and Research staff installed two repeaters in Liverpool Head Office between cable pairs and their overhead-plus-submarine extensions to Dublin, and to Belfast via Glasgow. Because of the considerable unbalance between cable and overhead line, continuous monitoring was necessary.

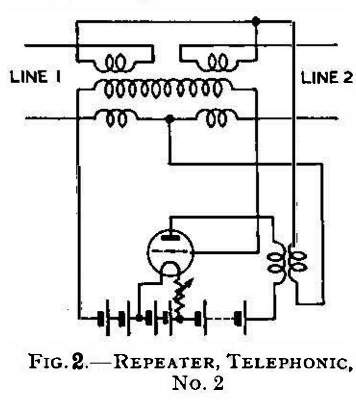


FIG. 2.—REPEATER, TELEPHONIC, No. 2

This effective demonstration was followed in May 1916 by the first permanent installation, when four repeaters were inserted at Birmingham in 200-lb unloaded phantoms in the same cable, reducing the overall loss to the equivalent of about 12 m.s.c. The two-wire repeater,[5] which made use of "round" Marconi valves, became known as

"Repeater, Telephonic, No. 2" and the circuit is shown in Fig. 2. The conditions stipulated for the use of this repeater were that (*a*) the line loss must not be less than 20 m.s.c., (*b*) the line on each side of the repeater must have the same characteristics, and (*c*) the loss between each end and the repeater must not be less than the gain of the repeater.

These conditions were met by the London–Liverpool circuits amplified at Birmingham but the limitations of this repeater led in 1918 to the production of the more stable double repeater with balancing networks (Fig. 3).

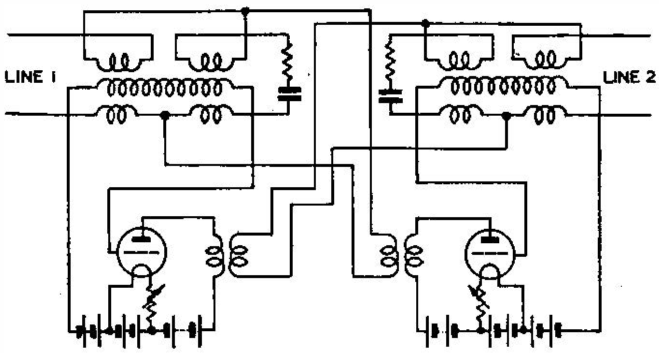


FIG. 3.—DOUBLE REPEATER.

The "hard valve" superseded the "soft valve" in 1918 and repeaters were by this time recognized as a commercial proposition. The possibility of using four-wire repeatered circuits was recognized but the Post Office concentrated on the two-wire type for field use. In 1921 the accepted standard was that up to four repeaters could be operated in tandem, each giving a gain equivalent to the loss of 16 m.s.c., and circuits were considered workable with a minimum residual equivalent of 12 m.s.c., which was necessary to minimize echoes and ensure stability.

The effect of the introduction of repeaters was soon evident in cable design. A London–Manchester cable similar to the London–Liverpool cable would have followed that cable immediately, but for the war. When the project was revived, 40-lb conductors loaded at 1·6 miles spacing with 176-mH coils on side circuits and 106-mH on phantoms, and with repeaters at Northampton and Derby, met requirements. A cable of 160 such pairs provided up to 240 circuits, and used only 84 per cent of the copper, as compared with 42 circuits in the 200-lb type of construction.[2] The cable was completed in 1922, although the repeater stations were then temporary.

The old, heavy-gauge cables were now obsolescent. The Post Office proceeded to install two-wire repeaters at Guildford, Fenny Stratford and Derby, and a series of repeater stations was planned for the northern and western main trunk routes, to be installed by the Western Electric Company and the General Electric Company, respectively. By 1926 some 24 repeater stations were in operation, containing 320 four-wire and 1,100 two-wire repeaters, and over one-third of this equipment was already in service. These early installations derived their power from batteries at 130V for anodes and 24V for heaters, the 4V heaters operating in series at a controlled current. Double batteries were used on a charge-discharge basis. At first a separate battery provided grid bias, but later self-biasing from the series heater circuit was adopted.

Signalling on trunk circuits was generally at 17 c/s with signalling relays at each repeater. By 1925, however, a voice-frequency signalling system had been developed jointly by the Post Office and the Western Electric Company, using a frequency of 500 c/s modulated at 20 c/s. The use of a signalling frequency in the speech band dispensed with the need to by-pass repeaters, and the 500/20-c/s system has since been extensively used for circuits beyond the range of d.c. signalling

By 1925 the underground cable system had been extended as far as Edinburgh by the completion of the Leeds–Newcastle–Edinburgh cable and its associated repeater stations (Fig. 4). This was a composite cable of

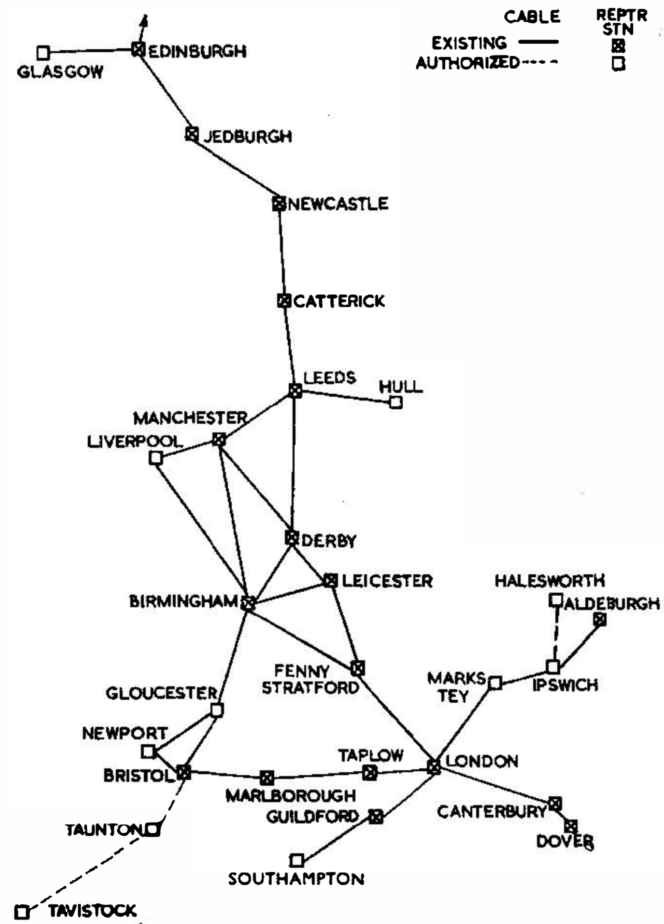


FIG. 4.—EXISTING AND AUTHORIZED REPEATER STATIONS, 1925.

122 20-lb and 90 40-lb pairs, diminishing to 38 20-lb and 82 40-lb pairs at the Edinburgh end. Repeater stations were located some 50 miles apart at Leeds, Catterick, Newcastle, Jedburgh and Edinburgh.

Between 1920 and the end of 1927, practically 5,000 miles of trunk cable were laid, and by 1929 the total mileage in service was 9,200.

Until about 1932 there was a period of steady expansion based on 20-lb and 40-lb loaded cables and four- and two-wire repeaters. The inherently better stability of the four-wire as compared with the two-wire repeater had led to its development for the longer trunk circuits, with 500/20-c/s signalling and adjustable equalizers to render the gain sensibly constant over the working range of frequencies. The longest circuits were so equipped; circuits up to 200 miles in length—for example London–Derby, London–Leeds, Newcastle–Glasgow—continued to employ two-wire repeaters and 17-c/s signalling. Gains were about 40 dB for four-wire, two-stage repeaters; 25 dB for four-wire, single-stage; and 20 dB for two-wire, single-stage repeaters. Cord-circuit repeaters were tried over a period of about 10 years, and finally discarded about 1928.

The number of repeater stations increased from 18 in 1924 to 45 in 1932. Cost studies led eventually to the almost universal adoption of 20-lb conductors—though the last long-distance audio cables to be laid, namely the London–Liverpool and Liverpool–Glasgow, completed in 1935, had 25-lb conductors. One notable change was made in cable design: the multiple-twin formation was superseded by the star-quad form of construction.[6] The phantom circuits of the star-quad formation were inferior to those of the multiple-twin formation, but this was of little consequence because by this time phantoms were being increasingly used to provide d.c. signalling channels.

It was no longer necessary to plan loading to give the greatest possible reduction in attenuation. It was recommended by the C.C.I.F. at Düsseldorf in 1930 that international trunk circuits should transmit frequencies up to 2,400 c/s. The Post Office consequently reduced its standard loading to 120-mH coils at 2,000-yd spacing, giving a theoretical cut-off at 3,300 c/s and a working limit of 2,500 c/s. Then, in 1934, the C.C.I.F. recommended an extension of the working bandwidth to 2,600 c/s, and 88-mH coils were adopted by the Post Office as the future standard. In 1938 it was further recommended that international trunk circuits provided on coaxial or other multi-channel carrier cables should transmit effectively a band of frequencies from 300 to 3,400 c/s. Since it was planned to provide all long-distance trunk circuits within the United Kingdom by carrier means no further alteration of audio-cable loading standards has been introduced.

Units, Amplifying.

In 1932 the first of a series of repeaters of simple design—known as "Units, Amplifying"[7]—was introduced. These single-stage units on a 3½-in. base-plate were designed for quantity production and were relatively inexpensive. The circuit provided for d.c. signalling on the phantom. There were no arrangements for line equalization, which was provided separately if necessary. The Unit, Amplifying was the first item of transmission equipment to be designed for mains operation. The filament supply was a.c. at about 4·2V and the anode supply was 130V derived from the smoothed output of a dry-plate rectifier. On mains failure both filaments and anodes were switched to batteries, normally trickle-charged, with capacity sufficient for four hours' use.

An object successfully achieved by the use of Units, Amplifying was to cheapen the shorter four-wire amplified circuits and much extend their field of use.

The last of the series was Unit, Amplifying, No. 20A, current until 1940. By this time the principle of negative feedback[8] with its outstanding advantages had been incorporated in Amplifier No. 32[9] which, with a stable and uniform gain of 27 dB over the whole working range up to 6 kc/s, superseded the earlier units and is still standard for general service. Well over 100,000 are in use to-day.

Carrier Operation

The first carrier system to be successfully applied (Carrier System No. 1)[10] was installed in 1932-33, and provided a single carrier circuit on one pair of overhead wires. The equipment was mains-operated and was only suitable for use where intermediate amplifiers were not necessary.[11]

In 1934 a system providing three carrier channels and an audio channel on a pair of overhead wires (Carrier System No. 3)[12] was introduced and examples of this system are still in service, chiefly in northern Scotland. These systems were produced in pairs, the carrier frequencies in the two systems differing by a few hundred cycles in order to effect an improvement in crosstalk between the two systems when applied to pairs on the same overhead route. More than two systems on a route were permissible provided that the transposition scheme was designed with sufficient care.

The first successful system applied to cable pairs (Carrier System No. 2) was in service in 1935 and provided one carrier plus one audio circuit on a four-wire basis. Copper-oxide rectifiers were introduced in place of valves in the modulators and demodulators, which were of balanced type giving 30 dB carrier suppression. The carrier frequency was 6 kc/s, the lower sideband being transmitted.[13] The system was first applied to certain old cables, including the Northern Underground telegraph cable, in which pairs were loaded with 10-mH coils at 2·5-miles spacing, and later to groups of pairs specially allocated in the new London–Liverpool and Liverpool–Glasgow cables. These pairs were loaded with 22-mH coils at 2,000-yd intervals. In the Liverpool–Glasgow cable two well-separated groups of pairs, initially left unloaded, were subsequently loaded with 6-mH coils at 1,000-yd spacing, giving a working range up to 16 kc/s and an attenuation slightly under 1 dB/mile at that frequency. Carrier System No. 4,[14] applied to these pairs, yielded five speech channels each of bandwidth 300-2,600 c/s, using the lower sidebands of frequencies 6,000, 9,200, 12,500, and 16,000 c/s. Systems installed between Liverpool and Glasgow in 1937-38 are still in service; elsewhere their use has largely ceased.

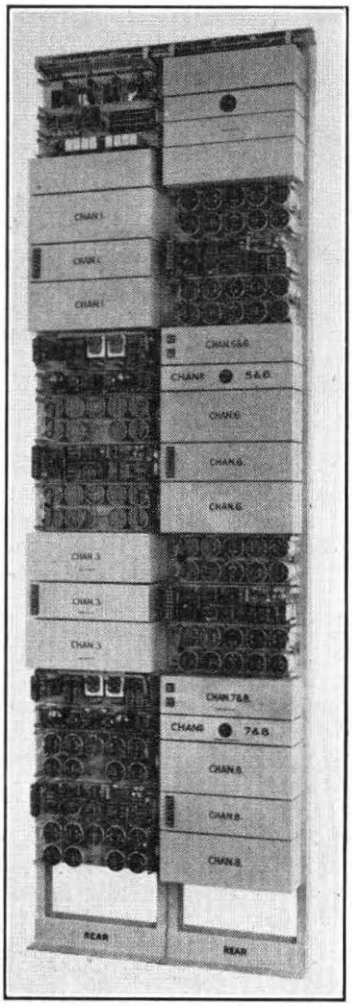


Fig. 5.—Carrier System No. 5—Channel Equipment.

The "go" and "return" groups of carrier pairs were separated by two complete layers of audio pairs in the cable, but even so, with repeater section lengths equivalent to 30 dB loss, the desired near-end crosstalk limits could only just be met.

It was apparent that this represented the limit to which single-cable working could reasonably be developed and that the next step had to be a two-cable scheme. Thus was evolved the two-cable, 12-channel carrier system[15] based on 12-channel groups, the channels having 4-kc/s spacings between 12 and 60 kc/s.

The first 12-channel system (Bristol–Plymouth) made use of 19-pair cables with the pairs in simple twin formation, but thereafter a 24-pair quad-type cable became standard, the inherent symmetry of the quad construction more than compensating for the slightly more complicated balancing procedure. In the early systems, the balancing networks were located in huts at the mid-point of each repeater length; in later systems it was found practicable to install the networks at the "receive" end of each section.

Successive 12-channel systems have been designed and installed. Thus Carrier Systems No. 5 (Fig. 5) and No. 6,[16] developed respectively by Standard Telephones and Cables and the General Electric Company, employed coil-and-condenser filters, modulators based on the copper-oxide rectifier, frequency generation by master oscillators with subsequent derivation of channel frequencies, and synchronization by means of tones transmitted over the line. Three-stage line amplifiers with negative feedback gave a gain of up to 65 dB; the effective channel width was about 300-2,600 c/s. The introduction of the negative-feedback amplifier, with its freedom from harmonic and intermodulation distortion, its remarkable stability against the effects of variation in supply voltage and valve characteristics, and its high working output level, was a major contribution to carrier development.

In 1938 the C.C.I.F. recommended that the 12 60 kc/s 12-channel carrier band should be assembled from the upper sidebands of channel carriers spaced at 12, 16 ... 56 kc/s; and that the effective speech-band transmitted should be 0·3-3·4 kc/s. A subsequent C.C.I.F. Sub-Committee meeting recommended that for coaxial cable systems—which were by this time developing—the basic group should be in the range 60-108 kc/s with the channels assembled as lower sidebands of carriers at 64, 68 ... 108 kc/s.

The existing Carrier Systems No. 5 and 6 did not meet these recommendations and a new design of channel equipment was put in hand in which the channels in the basic group band of 60-108 kc/s were assembled by a single modulation process using quartz crystal filters. Arrangements were made for the modulation of the group band 60-108 kc/s against 120 kc/s to provide a 12-60 kc/s 12-channel carrier group that would comply with C.C.I.F. requirements. The new equipment became known as Carrier System No. 7.[17]

During this period it was demonstrated that 24-pair, 40-lb star-quad cables would economically permit of carrier working up to 108 kc/s with repeater stations at about 14-miles spacing instead of the 22 miles for 12-channel operation. The additional 60-108-kc/s group would be provided directly from the 60-108-kc/s channel equipment, the combination and separation of the two groups being effected by means of special "24-circuit" filters. Recent extensions to the carrier network have, for the most part, been equipped for 24-channel operation, and most of the early 12-channel routes have been similarly re-equipped, additional repeater stations having been built where necessary.

As carrier systems developed and the trunk system grew in size and complexity, the problems of power supply increased. To enable maximum use to be made of existing power plant, heaters and anodes operating at 24V and 130V respectively were generally retained in all carrier systems up to and including Carrier System No. 7. The first development at terminal stations was the introduction of simple battery-float systems, followed by self-operating plants, incorporating automatically started and controlled prime movers as a safeguard against mains failure, with motor generators or dry-plate rectifiers. This system overcame the increasingly difficult problem of providing adequate standby with a battery of relatively small capacity, since the battery capacity could be reduced provided that it was sufficient to cover the starting and switching cycle of the plant.

The Development of Coaxial Cable Systems

In the meantime a radically new approach to the problem of multi-channel cable design had developed. If the symmetrical twisted pair were replaced by a "pair" consisting of an inner conductor centrally located within a conducting tube, the inherent screening properties of the construction would ensure that crosstalk would be negligible at frequencies above about 60 kc/s. Attenuation/frequency characteristics would be such that, with repeaters of suitable design at relatively close spacing, some hundreds of channels could be transmitted over each coaxial tube.[18]

The first coaxial cable, the London–Birmingham No. 3, was in service by 1938.[19] This cable contained four coaxial tubes of 0·45 in. diameter. Repeaters of 53 dB nominal maximum gain were spaced between six and eight miles apart. Automatically-switched standby repeaters were provided, and power supply at 350V a.c. was fed over the coaxial tubes from main to intermediate repeater stations.

In the original installation, eight channels at 5-kc/s spacing were assembled to form a "group" in the band 60-100 kc/s. Quartz crystal filters were used in the channel equipment. The basic "supergroup" was assembled from five such groups, in the range 300-500 kc/s. The line assembly was planned as eight supergroups in the range 500-2,100 kc/s.

Assembly in two stages—groups and supergroups—has remained as standard throughout the development of coaxial systems, but the original eight-channel group was soon superseded by the C.C.I.F. 12-channel group as generated by the Carrier System No. 7. Supergroups were made up of five such groups, the basic supergroup covering the range 312-552 kc/s, and the 10-supergroup system operating in the range 60-2,540 kc/s on $\frac{3}{8}$-in. tubes, with repeater stations at nominal 6-miles spacing, has been practically standard up to the time of recent developments.

The earliest group and supergroup translating equipment was of Post Office design, but after the completion of the first London–Birmingham coaxial cable and its extension to Manchester a design developed by Standard Telephones & Cables was adopted and this equipment has remained the standard until recent years.

Coaxial cable practice had, from the start, taken cognizance of the probable need to relay television programs over considerable distances. The first major requirement of this kind arose in connexion with the opening of the B.B.C. transmitter at Sutton Coldfield. With possible future requirements for colour or other wide-band systems of television in mind, a new London–Birmingham cable[20] was laid that included two 1-in. diameter coaxial tubes for experimental purposes, four $\frac{3}{8}$-in. tubes and audio pairs. In the meantime the tubes have been equipped with repeaters at 12-miles spacing, and are in use for the transmission of normal television programs between London and Birmingham in the band 3-7 Mc/s.[21] Elsewhere, television programs are relayed over main coaxial cable links through the normal $\frac{3}{8}$-in. tubes, in the frequency range 0·5 to 4 Mc/s[22]; for short, studio connexions video-frequency and 3-7 Mc/s carrier systems have been used.

Coaxial Line Repeaters.

The majority of the line installations, known as "Unit, Bay, 1B" and "Coaxial Equipments, Line, No. 1 and 2," are based on Post Office designs dating from about 1938.[23] In their standard form they transmit the frequency band 60-2,852 kc/s, which is more than sufficient for 10 supergroups. Main and standby line amplifiers of 48 dB flat gain are fitted with automatic change-over initiated by the failure of a 300-kc/s line pilot. Temperature equalizers are switched in along a route to keep the cable loss constant with seasonal changes in temperature. Power at 350V a.c. is fed to two dependent stations on each side of a main power-feeding station.

Coaxial Equipment, Line, No. 3.—This is an equipment specially designed for television over the 1-in. tubes of the London–Birmingham No. 4 cable with repeater stations at 12-miles spacing. It was brought into use in 1950. A number of short television links on $\frac{3}{8}$-in. tubes have been provided with this form of equipment, or a simplified equivalent.

Coaxial Equipments, Line, No. 4 *and No.* 5.—The No. 4 equipment was introduced in 1951. It is a development of the No. 2 equipment having amplifiers and equalizers that provide for either television or telephony in the band 60-4,340 kc/s over standard ⅜-in. tubes, with repeater stations at 6-miles spacing. The six-stage amplifiers, main and standby, have a rising gain/frequency characteristic which compensates for the loss in six miles of cable, the amplifier output being flat over the transmitted band.

For television the line signal is assembled as a vestigial-sideband asymmetric signal on a 1·056-Mc/s carrier. The Birmingham–Manchester and London–Wenvoe television links use this line equipment, produced to the Post Office design. For telephony applications 16 supergroups (960 circuits) can be transmitted between 60 and 4,028 kc/s. Coaxial Equipment, Line, No. 5 is a simplified version of Coaxial Equipment, Line, No. 4, for short television links.

*Coaxial Equipment, Line, No.*6.—This is an automatically-regulated line system designed by Standard Telephones and Cables, covering the band 60-4,092 kc/s with repeater stations at 6-mile intervals on ⅜-in. tubes. The line repeater has an output with a rising gain/frequency characteristic, while the input signal received from the preceding station has a falling characteristic. Variations in the attenuation of the preceding repeater section are corrected in each line amplifier by a regulator, operated from a 4,092-kc/s pilot, which introduces an appropriate correction which varies as the square root of frequency over the frequency band, the assumption being that the normal variation is due to temperature effects on the cable. Single three-stage amplifiers, with the valves and a number of other components provided in duplicate, are used at the repeater stations, and power-feeding up to six stations on each side of a main station is possible. The system will, alternatively, transmit television as well as 16-supergroup telephony.

The coaxial network now extends to about 3,500 miles of cable. The most recent major extension was to Oban, in the west of Scotland, the landing-point for the transatlantic telephone cable.

Recent Developments in the Design of Transmission Equipment

In 1945, the Post Office carried out development work on new channel, group and supergroup translating equipment, together with carrier generating equipment (Carrier System No. 8). The aim was to produce a compact design operating from a.c. mains, and a limited amount of this channel equipment was installed. In 1948, work was suspended since contractors' designs of improved construction and higher capacity promised to become available.

Discussions were initiated with Standard Telephones and Cables and the General Electric Company, with a view to introducing alternatives to the use of quartz crystals in channel filters, increasing rack capacity and designing equipment suitable for mains operation.

Considerable work was carried out on the growing and processing of ethylene diamine tartrate (e.d.t.) crystals[24] and it was demonstrated that satisfactory e.d.t. channel filters for the range 60-108 kc/s could be produced. This development, together with consideration of the cost, number of valves required, heating problems and general complexity with coil-and-capacitor double-modulation equipment, led to the decision to retain single-modulation crystal-filter designs. Because of cost and production difficulties further work on e.d.t. crystals was stopped and quartz crystals were used for the filters.

A complete range of equipment was ultimately agreed and installation started in 1953. The carrier generating equipment was developed by the General Electric Company, who produced a design based on high-stability 124-kc/s crystal oscillators and which avoided common equipment in main and standby paths. The new equipment is known under the general title of "Carrier System No. 9" (Fig. 6).

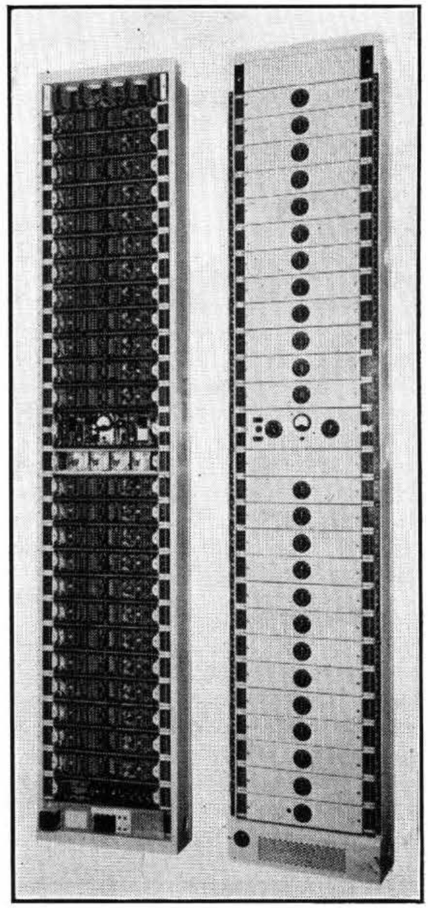


Fig. 6.—Carrier System No. 9—Channel Equipment.

The physical design of the equipment is based on Standard Telephones and Cables' "new equipment practice," known in the Post Office as "51-type" equipment. The rack framework is of pressed steel construction and the panels, which are mainly in the form of two horizontal rails on which cans or small components can be mounted, jack into the rack, connexion between panel and rack being by special multiple U-links and sockets. As a result of the redesign, four groups of channel equipment can be mounted on a double-sided 9-ft rack—yielding more than four times the capacity of the No. 7 design.

The U-link form of connexion facilitates testing and line-up work and enables panels to be changed quickly. The current range of equipment is notable in that soldered-in valves are generally employed; wires are welded to the normal valve pins and soldered to special valveholders.

Group and supergroup equipment developed under the Carrier System No. 9 project follow C.C.I.F. recommendations for the band of supergroups 1-10.

Developments in the Supply of Power.

The original coaxial installations were operated directly from the mains via a series voltage-regulator. In case of failure, the mains supply was replaced by the output from an automatically-started engine-alternator set, the transmission path being subject to interruption for 7 to 15 sec during the time taken to start the engine.

It was later decided that the break in the transmission path due to the starting time of the prime mover was unacceptable, and a number of interim designs were developed which, while they generally provided power supplies giving an uninterrupted transmission path, were liable to cause unacceptable variation in supply voltage for a short time under extreme conditions.

Subsequently, as a result of the recommendations of a committee set up to study broad-band systems, it was decided that the power plant for a.c.-operated coaxial and carrier equipment should provide a continuous a.c. supply, and in addition should provide protection for the equipment against possible surges in the public supply network. The plant evolved to meet these requirements consists of a composite a.c. motor-alternator set, d.c. motor, battery, and automatically-started engine-alternator set. With conditions normal, the a.c. motor runs from the mains and the alternator feeds the transmission equipment. Upon failure of the mains supply the drive is transferred to the d.c. motor, which is supplied from the battery, and the start signal is given to the engine. With the engine-alternator set running at full speed, the a.c. motor again takes over the load. Upon restoration of the mains supply the plant automatically reverts to normal running conditions. A variant on this design, in which the energy required to bridge the gap in supply is stored mechanically in a flywheel instead of electrically in a battery, is in use and is being further investigated, primarily because it offers advantages both in initial cost and in running charges.

Present Direction of Development in Line Transmission

The useful frequency bandwidth that can be handled by coaxial cable depends on the tube diameter and the repeater station spacing, subject to limits fixed by valve and amplifier design. Present coaxial systems with $\frac{3}{8}$-in. tubes and 6-miles repeater spacing are generally equipped for 600 channels (Fig. 7) but are capable of handling 960 channels or a television signal corresponding to a 3-Mc/s video band. Work is now in hand on a 12-Mc/s line system to handle about 2,500 channels (or 1,200 channels plus a 5-Mc/s television channel) with $\frac{3}{8}$-in. tubes and 3-miles repeater station spacing.

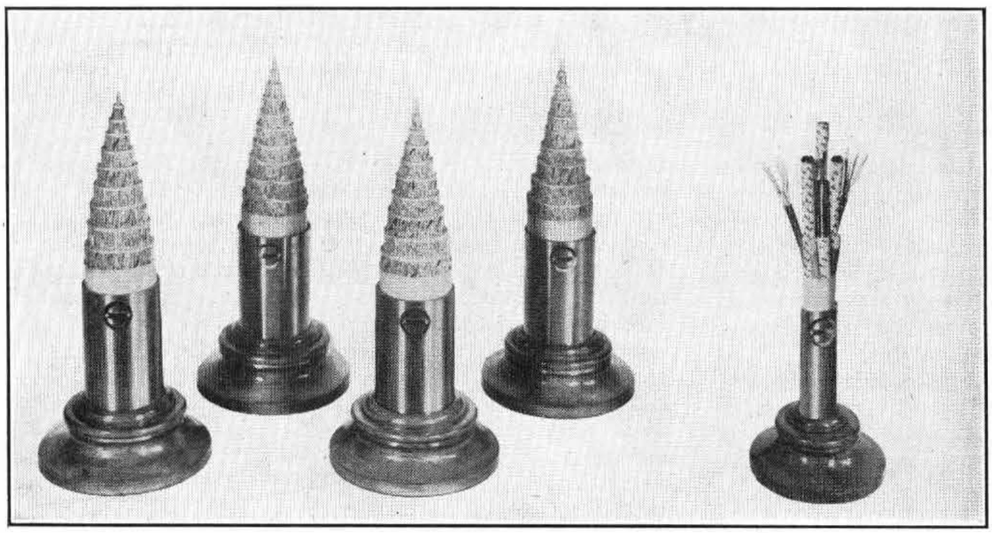


Fig. 7.—Cable Progress—Coaxial Cable on the Right will provide more Circuits than the Four Audio-Frequency Cables on the Left.

With the extension of the coaxial line frequency-band for a capacity of 40 or more supergroups, corresponding developments are being planned for the assembly of the supergroups at the terminal stations and for suitable television translating equipment. In this connexion the concept of a "master-group" made up of five supergroups has developed and it is probable that this unit will be used in building up the line assembly above the band of supergroups 1-16.

In the field of twisted-pair cables, arrangements are now in hand for the installation of 60-channel systems operating on low-capacity 14-pair cables with repeater stations at about 12-miles spacing, the frequency band, 12-252 kc/s, being obtained from the basic supergroup (312-552 kc/s) by a suitable translating process. The new systems will be a.c. operated and the possibility of feeding power over the cables is being examined.

Trials are also in hand of a modified form of channel equipment[25] in which the standard group band of 60-108 kc/s is divided into eight channels of 6-kc/s bandwidth. Each channel caters for the usual speech band of 300-3,400 c/s plus signalling. The new channel equipment has inbuilt static relays and signalling receivers and provides means for extending d.c. signals over the carrier link. From the experience so far gained it is now considered that the required facilities could be given by equipment using a 4-kc/s channel spacing and further work on these lines is in hand.

An experimental carrier system for use on unloaded pairs in audio-type cables is under trial.[25] This provides 12 channels, the go and return transmission paths being over the two pairs in a quad, with repeater stations at about 7-miles spacing. The aim is to produce a system that will prove economic over distances of about 20-100 miles.

In the audio field considerable attention has been paid to the design of compact "canned" units covering the range of transformers, equalizers, terminations and amplifiers suitable for mounting on 51-type racks and panels. Trials are in hand of transistor audio amplifiers; there is little doubt that these will be successful, and will in due course offer the prospect of considerable savings in power plant and accommodation and will greatly simplify the installation of amplifiers in the smaller telephone exchanges.

Field tests have been made on negative impedance repeaters of the shunt and series types. The requirement that stability must be retained when the ends of the circuit are either open-circuited or short-circuited limits the practicable reduction in loss. Thus a circuit of 12 dB loss unamplified might be operated with a loss of about 5 dB when amplified. A number of such circuits have given satisfactory service under traffic conditions but further work is planned with a shunt/series type of unit which should avoid reflection effects. Interest in devices for amplifying two-wire circuits has prompted renewed study of conventional two-wire repeaters and these appear at this stage to be more amenable to development for general use than do the negative impedance units.

Some Statistics of the Main Line Network

Table 1 shows the growth in miles of the main trunk cable network over the years.

TABLE 1

Year (31st March)	1908	1930	1935	1940	1945	1950	1955
Audio cable ..	505	10,064	11,756	15,311	24,516	25,683	29,644
Carrier cable ..	—	—	—	2,430	6,040	6,582	7,385
Coaxial cable ..	—	—	—	379	1,284	1,962	3,263
Total mileage	505	10,064	11,756	18,120	31,840	34,227	40,292

The pair-mileage of audio trunk and junction cable in 1951 was 6,766,000; the present figure would be of the order of eight million pair-miles. A study in 1955 showed, at that time, an availability of 3,843,000 channel-miles in the carrier cable network and 2,571,000 channel-miles in the coaxial cable network; it is evident that the total carrier-type mileage will soon surpass the audio-type mileage.

Table 2 shows how, over the years, technical developments have resulted in very considerable reductions in the amount of copper and lead needed per circuit-mile.

TABLE 2

Type of circuit	Approx. year of use	Typical maximum circuit capacity	Weight of copper per 100-mile circuit (tons)	Weight of lead per 100-mile circuit (tons)
Overhead wire 600 lb/mile	1896	—	56	—
150-lb/mile cable with phantom circuits	1914	82	9·3	17·1
40-lb/mile cable (P.C.M.T.) two-wire repeaters	1922	160	3·7	8·4
20-lb/mile cable (P.C.Q.T.) four-wire repeaters	1926	271	3·7	4·9
Carrier (V + 1) on lightly loaded pairs of P.C.Q.T. (audio) cable	1935	—	1·8	2·5
12-circuit carrier on carrier quad cable	1936	288	0·63	2·4
24-circuit carrier on carrier quad cable	1948	576	0·31	1·2
600-circuit coaxial	1938	600	0·09	0·29
960-circuit coaxial		960	0·06	0·18
Developments in prospect:				
60-circuit carrier on two 14/40 lb cables		840	0·12	0·71
2,500-circuit coaxial		2,500	0·02	0·07

The use of Radio Links in the Inland Network

Until very recently, the radio link was regarded primarily as an alternative to the submarine cable.

Thus, the first radio-telephone link to be used commercially as part of the Post Office trunk telephone network was set up experimentally in 1932 across the River Severn between Cardiff and Weston-super-Mare. This 13-mile link provided a single channel on a frequency of 60 Mc/s, and remained in service for two years. In 1934, the first system providing several radio-frequency channels was introduced using substantially the same design of equipment, to give six trunk circuits over a distance of 39 miles across the North Channel between Scotland and Northern Ireland. Multi-channel systems of this kind required several radio channels in each direction and this necessitated fairly extensive aerial structures, as each channel required an independent Koomans array comprising as many as 128 elements. Two years later a nine-channel system was installed across the North Channel; this made use of a single radio-frequency carrier in each direction and combined the speech channels in a 150-300 kc/s baseband.[26]

The performance of radio links was improved through the introduction of crystal-controlled transmitters and superheterodyne receivers with crystal-controlled local oscillators. Concurrently, improvements in valve technique led to the development of high-power anode-modulated amplifiers giving transmitter output powers of 250W. These features enabled a commercial circuit to be established in 1936 over a long, non-optical path, about 85 miles in length, between Chaldon and Guernsey.[26] Two-channel operation was employed; one audio channel was inverted and the other was displaced to the band 6·4-9·6 kc/s.

The eventual adoption of horizontal rhombic aerials considerably simplified aerial structures and eased maintenance problems. The number of speech channels carried per pair of radio channels increased, first to 12, then to 24, assembled in normal 12-channel groups. Transmission was in the band 156-184 Mc/s and frequency modulation was employed. By the early years of the war, about 14 such v.h.f. links were in operation, spanning distances of about 40 miles, all across water. Recent developments now enable 48 channels to be transmitted on a single r.f. carrier.

Microwave Developments.

The period since the recent war has seen notable developments in the 1,000 to 10,000 Mc/s band, which is, as yet, comparatively unexploited. Microwave radio has characteristics that make it attractive for use in an inland network. It offers the possibility of transmitting a very wide band of frequencies. The energy may be transmitted in a narrow beam by means of aerials in the shape of parabolic "dishes," which function over a wide range of frequencies. Repeater stations may be spaced up to about 30 miles apart, but an "optical" transmission path is required, and automatic gain control is provided to counteract the effects of fading.

The first use of microwave systems by the Post Office was for the transmission of television programs; the Sutton Coldfield station of the B.B.C. was initially linked to London by a radio-relay chain in 1949,[27] and the Kirk O'Shotts station has been served by a system from Manchester since 1952.[28]

Radio transmission systems have now been developed capable of carrying several hundred telephone channels. Three such systems, for 120-channel or 240-channel operation in the frequency bands 1,700-2,300 Mc/s or 3,780-4,200 Mc/s, are now in course of installation and will come into service in 1956 or early 1957.

Technical developments in the United Kingdom and abroad indicate the possibility of a considerable increase in capacity per radio-frequency carrier—up to the equivalent of 600 or more speech channels or 625-line monochrome, or 405-line colour, television. The Post Office has, therefore, issued specifications describing in detail the system characteristics and performance requirements for such radio-relay systems. For telephony, the 600 channels in each direction of transmission will be assembled in frequency-division-multiplex in the baseband 60 kc/s to 2,540 kc/s. The arrangement of channels and the frequency and gain-stability characteristics will conform with C.C.I.F. requirements. For television, the performance characteristics will conform with the recommendations of the C.C.I.R. and C.C.I.F. for monochrome, and will meet the requirements that have been stipulated by the Post Office for the transmission of colour television. Effects of fading on transmission performance will be taken into account, although over a land path fading is negligible for 95 per cent of the time and most of the remaining 5 per cent, when fading occurs, is during the night and early morning.

An important feature of the new radio-relay links will be the possibility of multiplexing a number of radio-frequency channels on a single aerial system. Thus a radio repeater station with only two aerials in each direction of transmission will handle up to six broad-band channels, each of which will carry one television or 600 telephone channels. A still further development may be the use of a single aerial to carry two or three groups of six broad-band channels.

The first embodiment of a system designed to the new Post Office specifications will be a main radio link between London and Scotland with branches at intermediate points. The main link will carry six broad-band channels in each direction; one or two of the broad-band channels would be for use as a standby.

Following hard on the heels of the above "backbone" system will be the development of radio-relay systems for up to 2,000 telephone channels, or about 1,000 telephone channels together with one television channel.

Traffic Circulation and the Transmission Plan

A rational system of telephone traffic circulation is necessary to ensure, among other things, that when two subscribers anywhere in the national network are connected, the grade of transmission afforded will not be worse than some specified standard.

The apportionment of transmission losses among the switched links in the trunk, junction and local chain of connexions constitutes the "transmission plan."

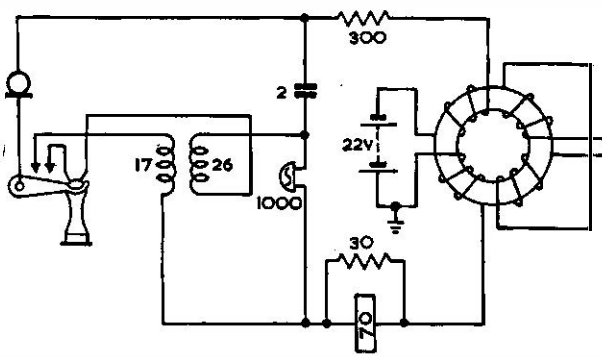
For the purpose of the plan it is necessary both to set a standard of transmission performance, and to devise a transmission unit by means of which quantitative assessments may be made of the extent by which the actual performance departs from standard in any particular case.

In 1904 the American Telephone & Telegraph Company's standard unit of assessment—the "mile of standard cable" (m.s.c.)—was adopted. This was the equivalent of a mile of dry-core cable-pair of loop resistance 88 ohms/mile and mutual electrostatic capacitance $0{\cdot}054\mu$F/mile. An inductance of 1 mH/mile and leakance of 1 micro-mho/mile were later included in the definition of the British reference standard.

The basic standard, against which practical combinations of line, instrument, etc., were judged, consisted of a pair of telephones, suitably specified, with their appropriate circuits (Fig. 8). In this context, "circuit" included not only the induction coil, capacitor and other equipment normally associated with the telephone, but also a 300-ohm non-reactive "line" to the local exchange and its termination (transmission bridge) therein.

A standard of performance could be set by stipulating a value, in m.s.c., for the line connecting the two test circuits thus specified.

Early tests by the Post Office and the National Telephone Co. led to the conclusion that speech would be commercially acceptable up to the limits represented by two telephone circuits connected over a line of 46 m.s.c., and an agreement of 1905 imposed standards to be observed and to which plant should conform. Briefly, between two telephones in the same "transmission area" and not more than 50 miles apart, the standard of speech was to be no worse than that between the two test instruments of Fig. 8 separated by



Note: Principal component t pes are: (a) Receiver, similar to Western Electric Company (W.E.) T pe 2657A; (b) Transmitter, solid back with No. 7 Button, similar to W.E. Type 2617A; (c) Induction coil, similar to W.E. Type 2203; (d) Supervisory relay, similar to W.E. Type 1007P; (e) Re ting coil, similar to W.E. No. 25C.

FIG. 8.—TRANSMISSION TEST CIRCUIT, 1904.

30 m.s.c. (20 m.s.c. if the telephones were under 10 miles apart); and the standard of speech between a subscriber and the point of connexion with the Post Office trunk system was to be normally no worse than that between two test instruments separated by 5 m.s.c. On this basis it was expected that transmission between areas having a substantial community of interest would be within the stipulated limit of 46 m.s.c.

By 1908 a system of "zoning" had been introduced, the country being divided into 43 zones, each one a commercial rather than a geographic entity. About 280 Post Office trunk exchanges had been established, the predominant trunk exchange n each zone becoming the "zone centre," and trunk lines were established where justified between these centres. The use of zone-to-zone links in tandem was accepted practice.

By 1915 the growth of the national network called for a reconsideration of the transmission plan. The great majority of the trunk exchanges had been united with local exchanges, and the country was now divided into nine zones, with zone centres at London, Bristol, Cardiff, Birmingham, Cambridge, Manchester, Leeds, Glasgow and Dublin. These were to be interconnected, so far as reasonable, by direct trunk circuits of the highest possible efficiency. From each zone centre, trunk circuits would radiate to secondary centres, known as controlling centres, and from each controlling centre trunk circuits would radiate to a lower order of exchanges to be known as minor exchanges. It was now admitted that in order to achieve commercial speech over circuits having a loss of 46 m.s.c. between terminal points, conditions had to be very favourable and a working limit of 35 m.s.c. was considered desirable.[29] To meet this standard new targets were set; e.g. (*a*) zone centre to any exchange in the zone not to exceed the equivalent of 10 m.s.c., and (*b*) zone centre to controlling centre not to exceed the equivalent of 4 m.s.c.

Around 1922, considerations of traffic circulation and control, and of line engineering, led to the division of the telephone system into "groups" within the "zones." This system of subdivision still obtains to-day; the number of zone centres has increased only slightly, but the number of group centres considerably, in 34 years. Traffic could be divided into the components which would circulate via the zone centres, group centres, etc., and it was proposed to classify trunk circuits according to the type of traffic they would carry and to grade them to give the requisite transmission performance.[30] At this time every circuit longer than a "fee junction" was classed as a trunk circuit.

It was decided that the standard grade of transmission should be improved—not that a better standard could be met at once, but planning should aim towards it. The standard was, therefore, set in terms of a circuit consisting of two standard telephones with zero local loops connected by circuits of total loss equivalent to 35 m.s.c. It was postulated that, provided local line networks were designed to a line limit of 300 ohms, a loss of 12 m.s.c. could be taken as representative of the sending-plus-receiving allowance in respect of the subscribers' lines. This left a main-line allowance equivalent to 23 m.s.c. for the sum of junction, trunk, and switching losses, the latter being assessed at 1·5 m.s.c. at each switching point. For trunk circuits connected to a zone centre, or used for trunk traffic via a zone centre, a standard of loss that varied with line length was adopted, the standard being based on 40-lb and 70-lb unamplified cables and on 150-lb and300-lb overhead wires.

In 1933, growth in the volume of trunk traffic and developments in operating methods and in line plant practice led to a further review of the transmission plan.[31] Repeater technique was now well established, and the use of four-wire circuits was becoming widespread. A new telephone instrument of superior performance—the handset Telephone No. 162—was coming into service. Sleeve-control switchboards had been introduced, and "delay" working was giving place to "demand" working.

A proposal was made to upgrade all four-wire zone centre to zone centre circuits to zero loss. This was to be achieved by introducing a 600-ohm closing impedance on the two-wire line in the idle condition, together with the use of echo suppressors.[32] It was planned to "line up" all circuits to the sleeve-control termination, thus eliminating exchange losses. At the same time, the concept of the "mile of standard cable" as a unit of assessment was becoming outmoded, and the now familiar decibel was accepted, in line with extensive practice abroad, as the unit for all day-to-day assessments.

With these points in mind, it was decided to adopt a new transmission standard, as follows:—

"The audibility shall not be worse than that obtained from two standard telephones (i.e. Telephones No. 162) each with a 300-ohm subscriber's line, via specified feeding bridges, and a nominal line loss of 15 dB in the chain of trunks and junctions between terminal exchanges."

To meet this standard it was proposed that the various links in the main trunk network should comply with the following requirements—

Zone centre to zone centre	zero loss
Zone centre to group centre (and to "foreign" group centre)	3 dB
Group centre to minor or dependent exchange, normally	4·5 dB
Group centre to minor exchange in a multi-exchange area	6·5 dB
Minor exchange to minor exchange for terminal traffic only	12 dB

This transmission plan remains substantially in force at the present day. The implication in the plan that switching losses would ultimately be included as a component of the line losses has not been realized and the concept of zone-to-zone circuits of zero loss has been somewhat modified. All zone centres are now linked by high-velocity carrier circuits; echo problems are of little consequence and echo suppressors are not now fitted. Circuits are lined up to "zero stability" as distinct from "zero loss." This implies, in practice, a loss of about 1½ dB, but against this may be set the benefits of the wider bandwidth and lower noise-level of carrier circuits.

Local Line Transmission

The test circuit of Fig. **8** was primarily a reference circuit, and the inclusion of a 300-ohm resistance between exchange transmission bridge and telephone did not—in the National Telephone Company's system at any rate—imply that local line networks were designed to this limit. For many years local networks were considered together with the appropriate links in the junction and trunk chain in assessing the transmission limits for local lines, and standards were set more by what was technically achieveable than by what was desirable.

The national transmission plan agreed in 1905 between the Post Office and the National Telephone Company had, however, enabled conductor gauges to be reduced and 10-lb cable began to be used in the local line network.

The 1922 revision of the transmission plan apparently envisaged local line networks planned to a 300-ohm limit but it was not until about 1930 that design limits for local line networks were specified without relation to the trunks and junctions in that area.

As early as 1910, transmission allowances had been assigned for lines of different lengths, for P.B.X. equipment, exchange cabling, local battery installations, and even protective devices. Published figures include an allowance for "extra receiver, using both ears."

Comparisons between practical assemblages of transmitter, receiver, line and other equipment were made on a simple volume ("loudness") basis, and took no account of frequency response or other refinements.

The various allowances were added to and revised from time to time but the basis of assessment was unchanged until 1933, when, following the introduction of the Telephone No. 162—the "non-astic" handset—and the revision of the national transmission plan, a revision of the basic "reference circuit" took place.

The new reference circuit consisted of a Telephone No. 162 with Bell-set No. 1, connected through a 300-ohm non-reactive resistance to a 22-V repeating-coil transmission bridge. The new reference circuit was also adopted as the maximum proportion of the overall transmission loss that could reasonably and economically be conceded to the subscribers' network—i.e. the "local line allowance."

Transmission bridges operating from 50-V batteries had been in use since the introduction of automatic exchanges, and new equivalents were issued for all necessary combinations of instrument, line, transmission bridge and other equipment. The limit of 300 ohms continued to apply in 22-V C.B. areas, but for 50-V automatic-exchange areas a planning limit of 600 ohms was now permissible—irrespective of conductor gauge.

Soon after the Second World War, the simple volume basis of assessment was discarded and "Transmission Performance" took the place of "Volume Efficiency." The effects of improved frequency response and side-tone characteristics in the newer telephones were thereby given due weight.

At the same time, a new reference circuit was adopted, consisting of a Telephone No. 162, a Bell-set No. 25 and a line of 2·557 miles (450 ohms) of 10-lb cable fed from a 50-V non-ballast transmission bridge. The performance of this circuit on a volume-efficiency basis approximated to that of the previous circuit, and it became the new embodiment of the "local line allowance."[33] New types of telephone incorporating anti-side-tone induction coils and improved receivers showed up favourably under the new method of assessment—especially when used on the lightest-gauge cable conductors. Typical line limits were now 600 ohms (in certain circumstances 720 ohms) and 400 ohms for 50-V ballast and 22-V C.B. feeds, respectively, with 6½-lb cable pairs; and 750 ohms and 450 ohms, respectively, on 4-lb pairs.

In 1953, consequent upon the growing use of the newer types of telephone (Telephones No. 232 and 332 with the anti-side-tone induction-coil and the 2P receiver) the line limits were further raised to 860 ohms for 50-V ballast and 580 ohms for 22-V C.B. exchanges with 6½-lb cable pairs; and in recent months, in view of the impending introduction of a new telephone of even better performance, it has been decided to plan new exchange areas (with certain reservations) to figures of 1,000 ohms for 50-V ballast and 700 ohms for 22-V C.B. exchanges.

Hitherto, all telephones in use by the Post Office have been freely used in the network irrespective of length of line. With the new high limits, it will be necessary for the first time to restrict the use of certain older types to the shorter lines.

Improvements in telephone instrument design have made possible very considerable economies in line plant. In 1906 the underground local line network consisted mainly of 20-lb cable, with some 10-lb cable; to-day's additions consist predominantly of 6½-lb and 4-lb cables. There may in fact now be a field of use for cables of even lighter gauge.

Future Trends

The present standard ⅜-in. coaxial tube seems likely to be retained much in its present form for main lines despite the technical attraction of larger tubes and the theoretical possibility of reducing attenuation by the use of laminated conductors.

At the present time the planning of coaxial line systems for a 12-Mc/s bandwidth (about 2,500 channels) is in hand and with continuing improvements in valves and the continuing development of high-frequency techniques an increase in this bandwidth may be expected to follow. Nevertheless, the advantages of twisted-pair carrier cables in providing circuit flexibility in relatively small units (24, 60 or even 120 circuits) will probably justify their further use on selected routes. For the shorter and less heavily loaded routes, composite cables (audio pairs plus a few carrier pairs or small-diameter coaxial tubes) may be introduced as a means of serving local and through traffic.

The need for flexibility in routing blocks of circuits is a strong reason for the retention of the present method of circuit assembly based on the 60-108 kc/s group for all carrier and coaxial systems.

By the use of high-quality components and with sufficient care in manufacture, faults in transmission equipment could be reduced to such a low level that automatically-switched standby units would hardly be justified; their omission would simplify power feeding and control arrangements. However, the cost of equipment of this calibre is very high and for the immediate future on inland routes the fault liability of cables and power plant would probably nullify the advantages of very special repeater equipment. These conditions may not hold when plans mature for the use of gas pressure on cables, and for engine sets that offer absolute continuity of power supply. The tendency to reduce repeater station spacings, and the difficulty of acquiring sites, may lead in due course to manhole or cabinet repeater installations; a thoroughly reliable sealed unit would then be particularly attractive.

There is much to be said for the provision of completely separate spare lines, fully equipped, on busy routes; the special "fault-free" equipment would not then be so necessary and cover would be given against long-duration breakdowns.

Audio equipment using transistors is becoming established and there is no doubt that in the near future carrier equipment using transistors will become available.

There may be developments in transmission systems in which the line spectrum is derived from time-division multiplex equipment, or from normal frequency-division multiplex equipment followed by a frequency modulation process.

Speech bandwidth compression and similar schemes may find an application for deriving the maximum possible number of channels from very expensive links such as long submarine cables.

The extent to which radio links are used in future will depend on operating experience, costs, and local conditions, which may influence choice. It is too early to generalize; present indications are that there will be a field of use for both cables and radio links in the main network. The waveguide, operating at very high frequencies with low attenuation, and capable of transmitting large bandwidths, may in due course become a competitor and may open up a wide prospect of cheaper terminal equipment.

In the field of local line transmission the forthcoming "1,000 ohm" standard may mark the limit beyond which it is uneconomic to reduce copper costs by increasing line resistance. It is conceivable, though it appears at the moment unlikely except perhaps for a minority of long rural lines, that a simple form of carrier operation could be economically applied to the subscribers' network. The situation may change if electronic exchanges come into use; high-frequency paths used both in the exchange and in the line might point the way to a new conception of what a local line network might be.

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The Development of Radiocommunication in the Post Office

The Post Office has always taken the keenest interest in the practice of signalling without wires. Early experimenters in this field were encouraged, and substantial contributions have been made to the technology of radio communication in its successive stages of spark, arc and valve operation. A logical development has been the provision of communication services to off-shore islands—both telephony and telegraphy—which would have been difficult and uneconomical to provide by any other means. These services are provided on frequencies akin to those used for television broadcasting. Then a further development, resulting from experience with microwave frequencies during the war years, resulted in the provision of microwave radio-relay systems for the transmission of television programs and multi-channel telephony.

Early Experiments

Sir William Preece's interest in electromagnetic induction led him to start, in 1884,[1] a long series of experiments in communication between two points, without interconnecting wires, that culminated in actual commercial links to outlying islands. This form of communication probably depended largely on the local induction field of the transmitting loops, or on the finite conductivity of the earth. Between 1900 and 1904 there were many attempts to provide wireless telephone circuits to lighthouses, and Sir Oliver Lodge co-operated with the Post Office in a successful attempt to establish communication between Anglesey and the Skerries lighthouse, off Holyhead.

Hertz made use of the true radiation field in his classical experiments with dipoles in 1888, and in 1889 he demonstrated theoretically the difference between the local and the radiation field of the dipole, but the significance of this work in relation to Preece's experiments does not seem to have been fully appreciated until the early part of this century. The much lower rate of decrease of the radiation field with distance, compared with that of the "local" field, finally led to the discarding of all "wireless" systems not primarily employing radiation fields.

Although Preece was engaged on his own system of "wireless," he welcomed Marconi in 1895 with his important invention of the earthed elevated-aerial system, which enabled large radiation fields to be obtained at wavelengths long compared with those used by Hertz. By May, 1897, Marconi had, with the co-operation of the Post Office, communicated over a distance of eight miles across the Bristol Channel. Experimental co-operation between the Post Office and Marconi ended with the formation of the Marconi Wireless Telegraph Company, but Post Office engineers continued experimenting on their own account, transmitting over a distance of 25 miles across the Bristol Channel in 1900.

Other inventors were also encouraged in the radio field. A full account of the early experiments has been given by J. E. Taylor.[2]

Radio Telegraphy from 1906 to 1939

Fifty years ago there was already an established telegraph service to ships at sea, operated by the Marconi Co. and Lloyd's under licence from the Postmaster-General. In 1909 the Post Office took control of the coastal service, and by 1913 a chain of stations was in operation, using Marconi synchronous spark transmitters. Magnetic detection was employed in the earlier receivers but became obsolete with the introduction of crystal detectors; later, thermionic valve amplifiers became available and were used to improve sensitivity.

By 1920, the thermionic valve was being used for detection as well as amplification. Coastal transmission was still by spark, at powers not exceeding 10 kW, the range being 150-300 miles. A long-distance telegraph service to ships had begun from Devizes, Wiltshire, using continuous waves in the band 110 to 160 kc/s with a range of about 2,000 miles.

Fixed telegraph services, originating with the Marconi Co.'s limited transatlantic service in 1907, had received a setback on the outbreak of the First World War, but soon after it ended long-wave stations using high power and continuous waves, generated by Poulsen arcs (Fig. **1**), were

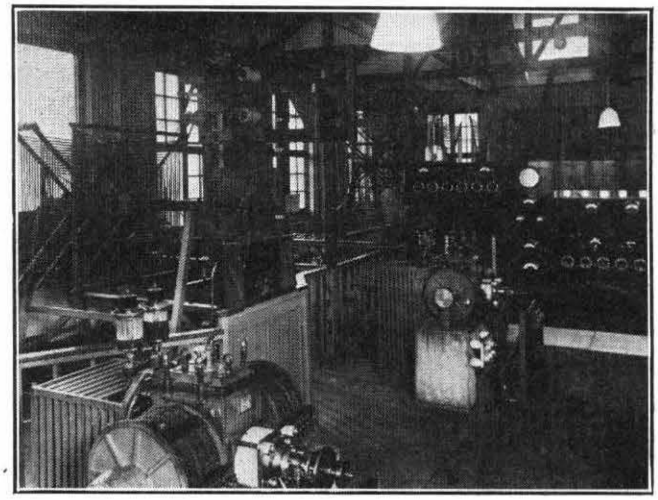

Fig. 1.—Northolt Radio Station: Poulsen Arc Transmitter, with Valve Transmitter in the Background.

established at Leafield, Oxfordshire, and Northolt, Middlesex, and some experimental links were set up, such as that between Stonehaven, Kincardineshire, and Berlin. A permanent bothway service to Egypt commenced from Leafield in 1921. By 1923 a valve transmitter was in operation at Stonehaven, and by 1924 water-cooled valves were being tested at a station at Northolt. Also in 1924, an inductive coupling was introduced at Leafield between the arc generator and the aerial.[3] Previously, the arc had been directly connected to the aerial, and the high-power arc station at Leafield had caused interference in the ship-shore communications operated at Devizes. A problem typical of the times was the provision of a capacitor for the primary circuit; this was satisfactorily solved by constructing four steel-tank units containing aluminium plates immersed in oil, each of 6,500 pF capacitance, which were connected in parallel. The entire capacitor contained 5,000 gallons of oil and weighed 25 tons. Under normal conditions the power handled was about 18,000 kVA at the frequency of 24·3 kc/s.

Arc transmitters became obsolescent and passed out of use in the middle 'twenties.

The Rugby Radio Station.

In 1923 the Post Office embarked upon what was possibly its greatest single project up to that time—the design and construction of the long-wave, high-power radio station at Rugby,[4] which was opened for traffic on 1st January, 1926. The site covered 900 acres, and the range of the main transmitter GBR (Fig. **2**), working at a frequency of 16 kc/s and designed for an aerial power of 500 kW, was expected to include the more remote parts of the world, beyond the range of the transmitters at Leafield and Northolt.

The aerial system was designed, within the limit of

FIG. 2.—ORIGINAL LONG-WAVE TELEGRAPH TRANSMITTER (GBR) AT RUGBY RADIO STATION.

structural possibilities, to give the best attainable radiation efficiency, the principal requirements being high effective height, high capacitance to earth, and low earth resistance. The aerial system consists of twelve 820-ft masts (considerably higher than any masts previously constructed) spaced at ¼-mile intervals and supporting cage aerials 12 ft in diameter. Each mast rests on a ball joint, insulated by 12 stacks of 9-in. "cheeses" of porcelain on a 5-ft 6-in. cube of Swedish granite. The choice of insulating materials, porcelain and granite for the mast insulators and whitewood for the coil formers, was based on the results of tests made at a voltage of 15,000 V and a frequency of 50 kc/s. For these tests a 100-kW steam-electric plant was installed to run an electric arc and oscillating unit.[5] The masts, stayed in three directions at five levels, were designed as continuous beams constrained at the stay points (taking account of the elasticity and curvature of the stays) and loaded with a maximum pull of 10 tons due to the aerial. The masts are of braced-steel construction and of non-tapering triangular section with 10-ft sides, and the maximum working load on the base is 400 tons. At each mast, adjacent spans of the aerial are electrically connected and supported by the halyard via a series-parallel arrangement of four 3-ft long insulators; the working voltage across these insulator assemblies is about 150 kV r.m.s. Where the aerial feeders leave the building the lead-out takes the form of a 2-ft diameter "torpedo" passing through the centre of a 7-ft square glass window, the wooden framing of which is protected by earthed guard-rings.

The earth system consists of copper wires ploughed into the ground 6 in. below the surface and extending 820 ft on each side of the aerial.

The aerial system has remained substantially unmodified over a period of 30 years, and only now has the time come for the renewal of the stays, a striking confirmation of soundness of judgment in a design which necessarily involved new techniques.

The tuning coils of the transmitter were wound with cables consisting of 6,561 strands of No. 36-S.W.G. copper wire, each strand insulated with enamel and one covering of cotton or silk. The formers were hexagonal spiders of American whitewood (canary), the external side being 7 ft 9 in. in the largest former, and the turns were 6 in. apart. Five spiders of eight turns each formed the aerial coil, three spiders of four turns each the primary, and one spider of two turns the coupling coil.

Five power-amplifier units were provided, each consisting of 18 10-kW water-cooled valves in parallel, with arrangements so that any of the units could be put in parallel. The five amplifier units allowed for one 500-kW transmission with two units spare, or two separate 300-kW transmissions with one unit spare. For the high-voltage supply to the power units, whatever apparatus was installed had to be capable of withstanding a short-circuit with impunity. After consideration of various possibilities, three sets of machines were installed, each consisting of a motor driving two d.c. generators. Each generator could develop 250 kW at 3,000V, and all generators could be put in series, thus giving 1,500 kW at 18,000V.

When the station was first put into service the frequency of the emitted signal, 16 kc/s, was controlled by a valve-maintained tuning fork, vibrating at a frequency one-ninth of the signal frequency. The method of control has been modified from time to time to keep abreast of progress in frequency control, e.g. by the use of quartz crystals, as described later.

The Introduction of High-Frequency Working.

With improved technology, better methods of frequency control and wider knowledge of the performance to be expected at various wavelengths, interest began to centre on the commercial use of higher frequencies. In the early 'twenties the theoretical advantages of high-frequency transmission were appreciated—in particular the possibility of concentrating the transmitted field in specified directions by the use of suitable aerial arrays. By 1925 experimental short-wave transmitters of only 1½ kW were in use at Dollis Hill, dealing with traffic for Cairo and Halifax, Nova Scotia. Similar transmitters were also in use at Leafield.

The "Empiradio" beam stations.—Following an agreement, in 1924, between the Post Office and the Marconi Wireless Telegraph Co., the company commenced the construction of a number of beam stations for short-wave point-to-point radio-telegraph links between the United Kingdom and Canada, South Africa, India and Australia.[6] This agreement provided for guaranteed signalling speeds (using on-off keying) of 100 words/min, to be attained during specified average percentages of the daily operating periods. Transmitting stations were set up at Bodmin and Grimsby, with complementary receiving stations at Bridgwater and Skegness. Frequencies of about 9 and 19 Mc/s were used on each service, with the exception of the Australian service which used 12 Mc/s. Highly-directional tuned aerial-arrays (Franklin arrays) were provided at the transmitting and receiving stations, and connected to the radio equipment by concentric tube feeders. Means of reversing the direction of transmission of the Australian arrays was provided to enable the long or short route to be used. Master oscillators, using specially designed valve circuits, controlled the carrier frequencies of the transmitters. The power input to the final stage of the transmitters was about 10 kW, metal-and-glass, oil-cooled valves being used.

The receivers used the double superheterodyne principle, the 1st intermediate frequency being about 185 kc/s and the 2nd 30 kc/s, and the intermediate frequency bandwidths were 10 kc/s and 5 kc/s, respectively.

Ship-to-Shore Traffic.

In due course the volume of long-distance ship-to-shore traffic outgrew the capacity of the station at Devizes. Moreover, closer frequency spacings demanded physical separation between sending and receiving points, and in 1925 new stations of greater range were opened at Portishead, Somerset, and Burnham (Fig. 3), 19 miles distant, for sending and receiving, respectively. Successful experience with short-wave operation quickly led to its adoption at these stations, and their capacity was thereby increased over a period of years.

FIG. 3.—RECEIVING ROOM AT BURNHAM RADIO STATION.

Between 1932 and 1935, coastal stations were converted to valve operation as a result of the international decision taken in 1927 that spark transmission should be abolished.

Direction-finding (d.f.), previously carried out only by the Admiralty, was introduced at Post Office coast stations in 1924, when a Bellini-Tosi system was installed at Niton Radio Station. By the end of 1932 the Post Office was providing d.f. services at six coast stations ranging from Niton to Wick, each using the Bellini-Tosi system. By 1939 all coast stations were similarly equipped, with the exception of one station at which an Adcock system was used.

RADIO TELEPHONY TO 1939

Radio telephony, because of its dependence on principles of modulation and amplification, had to await the development of the thermionic valve for its realization. With the coming of the triode valve, radio telephony entered the laboratory stage, and under the stimulus of the 1914-18 war, development was rapid. The immediate need was for mobile communications, and by the end of the war radio telephony of limited range was a practical proposition.

Post Office staff had contributed to the war-time developments, and in the early post-war years their attention turned to the commercial applications of radio telephony. The most promising field of use was that of transoceanic telephony, since, at that time, speech transmission by cable was a technical impossibility, and the shortcomings of radio (liability to interference and to fading, and lack of secrecy) could therefore be tolerated.

Transatlantic Telephony.

Soon after the First World War the Post Office and the American Telephone & Telegraph Company co-operated in experiments in radio telephony between the United Kingdom and America. Following these tests, the first two-way telephone contact was established in February, 1926, on a frequency of 60 kc/s.

The 200-kW transmitter, at Rugby, operated on a single sideband, with the carrier suppressed—probably the first use in this country of a system now universally employed in carrier working on telephone lines. The receiving station was originally at Wroughton, Wiltshire, and employed a Beverage long-wire aerial five miles long. Later, in order to reduce noise on the circuit, a receiving station was installed much farther north, at Cupar, Fifeshire (Fig. 4); again a Beverage aerial was used, but it was subsequently replaced by loops extending over an area of several square miles.

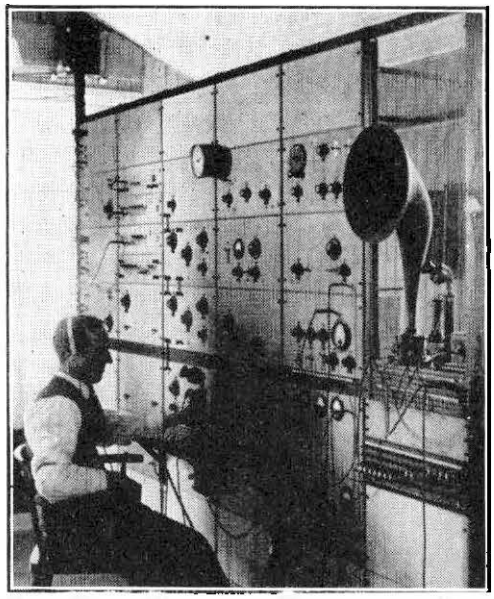

FIG. 4.—LONG-WAVE TELEPHONY RECEIVER AT CUPAR RADIO STATION.

The two directions of transmission operated on a common frequency, and the consequent tendency for the circuit to sing around the local transmitter-receiver loops was eliminated by using singing suppressors at the two terminals; the A.T. & T. Co. used a mechanical relay system and the Post Office an electronically operated device. At the terminals two-wire extensions were taken into the American and British telephone networks. Commercial operation began on 7th January, 1927.

As with telegraphy, this long-wave system was quickly supplemented by high-frequency services. Transmitters and aerial arrays were installed at Rugby with complementary receivers and aerials at Baldock (Fig. 5). At that

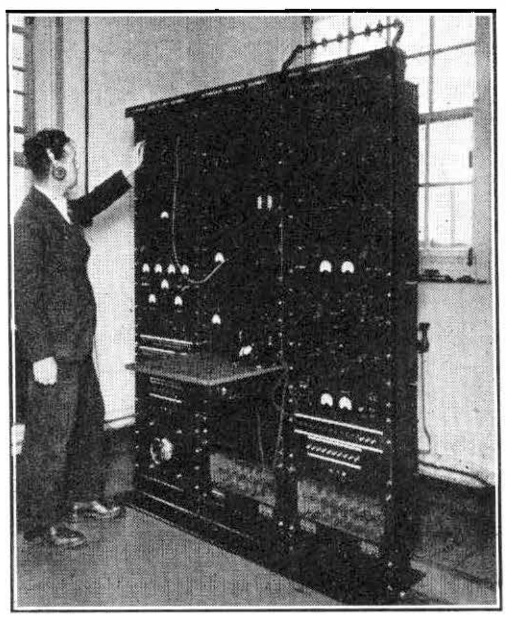

FIG. 5.—SHORT-WAVE TELEPHONY RECEIVER AT BALDOCK RADIO STATION.

time, although the merits of single-sideband operation had been well proven, it was not possible to control the frequencies of h.f. oscillators with the necessary precision, and double-sideband operation was therefore used. Superheterodyne receivers were designed which provided the necessary band-pass characteristics in the intermediate-frequency amplifier and incorporated automatic gain control to limit output-level fluctuations caused by the wide variations of received signal strength. To facilitate frequency-changing, the h.f. amplifying stages were originally provided in duplicate. Various types of privacy equipment were used.

The first high-frequency transatlantic link was opened for traffic in June, 1928; others followed in 1929, and during the ensuing few years other long-distance point-to-point services were inaugurated. With the use of high frequencies, problems in the design of aerials and transmission lines for such frequencies led to the development by the Post Office of equipment for impedance measurements; the use of this equipment led in turn to improvements in constructional methods.

Single-sideband operation on high frequencies.—In 1930, following accounts of successful tests between Paris and Madrid on a single-sideband (s.s.b.) h.f. system in which a low-level pilot carrier was radiated and used to control the oscillators in the receiver, the Post Office embarked on further trials of s.s.b. operation in collaboration with the American Telephone & Telegraph Company. As a result of these tests it was agreed to convert the U.K.–U.S.A. high-frequency circuits to s.s.b. working. The transmitters were redesigned to comprise a drive unit which produced a s.s.b. signal at a fixed low radio frequency, a modulator or frequency changer, and a linear high-power transmitter. The receivers (Fig. 6) included automatic frequency control

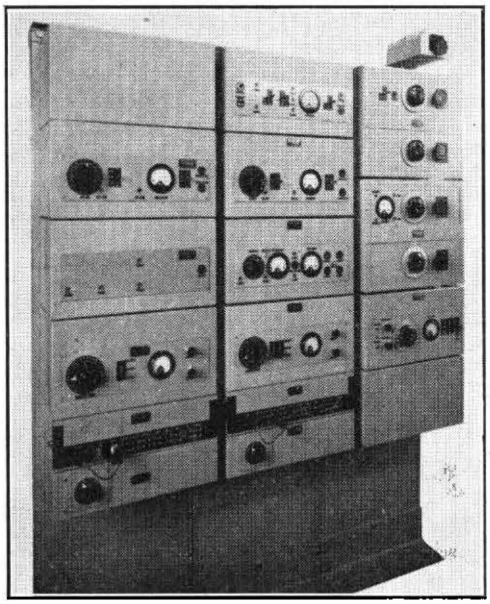

FIG. 6.—EARLY SHORT-WAVE SINGLE-SIDEBAND RECEIVER.

and used quartz crystal filters to separate the low-level pilot carrier from the sideband.[7] All the equipment for the United Kingdom end of these circuits was developed by Post Office staff. A subsequent development was that of translating two independent speech-channels of 5 kc/s bandwidth into single sidebands, one above and one below the pilot carrier, for transmission over a single radio channel. Following the successful operation of these circuits, others were converted to s.s.b. operation,[8] and s.s.b. reception was employed even where the transmission remained double-sideband.

Telephony to Ships.

From about 1932, small ships began to be equipped for telephony, and equipment was installed at certain coastal stations to provide radio-telephone service, and to connect these radio links with the inland telephone network. Within a short while telephone service was extended to the larger passenger liners; at first it was operated from Rugby-Baldock on double-sideband equipment, but later provision was made for either double-sideband or single-sideband operation, as required.

The Multiple Unit Steerable Antenna.

A development of the middle 'thirties was the Multiple Unit Steerable Antenna (M.U.S.A.). Aerial arrays of this type possess a high degree of directivity which is "steerable" in the vertical plane; the predominant down-coming angle of the received waves can therefore be selected with discrimination against unwanted transmissions and noise, and results in a reduction in selective fading due to wave interference.

Between 1937 and 1939, the M.U.S.A. system was applied by the British and American administrations to the h.f. transatlantic circuits. The British installation, at Cooling Marshes, near Rochester,[9] consists of 16 rhombic aerials equally spaced along the line of arrival of the signals, and steering is effected by adjusting the phase of the signals from the aerials so that, when combined, they add in phase for one particular, preferred, vertical angle of arrival. In the British installation, entirely electronic phase-shifting equipment was used to combine the aerial outputs, whereas the American phase-shifters were mechanically operated. Fig. 7 is a view of the general monitor and control positions.

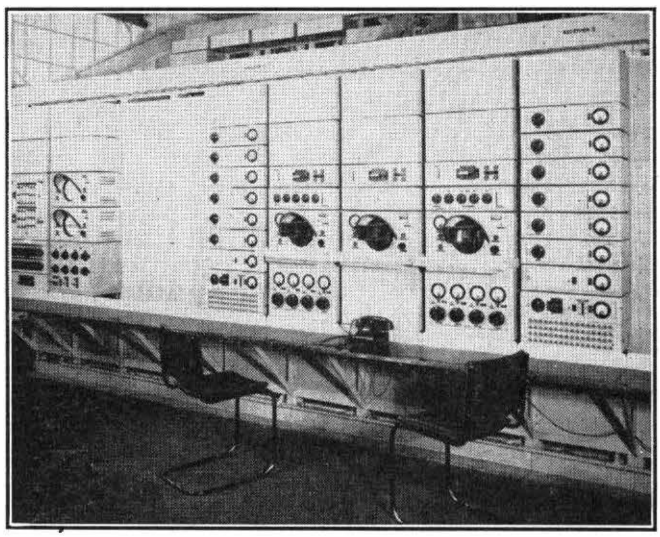

FIG. 7.—GENERAL MONITOR AND CONTROL POSITIONS OF M.U.S.A. RECEIVING SYSTEM.

Ultra-Short-Wave Radio Links.

The first ultra-short-wave radio telephone link used as an extension of the inland telephone network was set up in 1932, over a distance of 13 miles across the Severn Estuary, and was followed within a few years by links across the North Channel and to various off-shore islands. The frequencies used were in the band 50 to 75 Mc/s (wavelengths of 6 to 4 metres). The first links used self-oscillating transmitters and super-regenerative receivers, with Koomans aerials sited to take best advantage of topographical features. In 1934, a 6-channel system was provided across the North Channel (39 miles), comprising six single-channel links on separate carrier frequencies.

The introduction of crystal control (first tourmaline, later quartz) for the transmitters and the application of the superheterodyne principle to the receivers brought improved performance, and progress in valve techniques and circuit design made possible transmitter powers as high as 250W (which were, however, seldom used). These developments enabled a commercial circuit to be established in 1936 between Chaldon and Guernsey, on a non-optical path about 85 miles long. Koomans arrays were used in the original installation but were later replaced by rhombics. Several radio channels were used, each providing two telephony channels, one inverted and the other displaced by about 6 kc/s. The same year saw the installation over the shorter North Channel path of a 9-channel system in which the speech channels were combined in a 150-300 kc/s base-band, which modulated a single carrier frequency in each direction.[10]

Frequency Control and Selection.

The expansion of the radio services and the consequent greater likelihood of interference necessitated improvements both in the frequency stability of transmitted signals and in the selectivity of receivers; particularly was this so with the trend towards the use of higher frequencies. Early methods of frequency control included the use of a valve-maintained tuning fork, as for GBR, and of special circuits such as the Franklin oscillator used in the short-wave beam stations. However, the desirable characteristics of quartz crystal vibrators, i.e. great stability of natural frequency and very sharp change of reactance with applied frequency, were early appreciated, and the Post Office took an active part in their exploitation.

Quartz vibrators[11] were first used by the Post Office in 1926, in the form of resonators for the calibration of wave-meters, and up to about 1935, X-cut plates were purchased partly finished and were finally adjusted in the laboratories for use in short-wave transmitters. By this time the Post Office had developed quartz-cutting equipment which enabled it not only to produce crystal vibrators to meet all the requirements of Post Office radio stations but also to give assistance to other Government Departments and to act in an advisory capacity generally on quartz crystal matters. The specialcuts announced (around 1934) by Mason and other workers,[12] whereby oscillators could be made with very low frequency/temperature coefficients, were studied and vibrators of high stability were produced. Thus when, for example, the introduction of single-sideband working on high frequencies required the use of high-stability oscillators and band-pass filters with sharp cut-off, the basic techniques involved in satisfying these requirements were available or within reach.

The Post Office has maintained its own frequency standards since 1920, when a valve-maintained steel tuning-fork, vibrating at a frequency of 1,000 c/s and having an accuracy of the order of one part in 10^4, was used for this purpose.[13] This type of standard was improved by substituting an elinvar fork, and later by controlling its ambient temperature and pressure, and an accuracy of better than one part in 10^6 was realized. In 1937, the first crystal-controlled oscillator standard, incorporating a 1-Mc/s AT-cut quartz crystal operating in a Pierce circuit, was installed,[14] and by 1939 a new concept of a frequency standard was emerging, based on a group of three crystal-controlled oscillators.

Application of Radio Practice to the Design of Coaxial Cable Equipment.

Experience in radio design contributed largely to the success of early coaxial cable systems. Operation at frequencies above about 100 kc/s was an entirely new development in line transmission, and the knowledge and practice acquired by the Post Office in the development of radio equipment was drawn upon extensively in the design of coaxial cable repeater and terminal equipment. Thus the repeater and terminal equipment of the first coaxial cable system[15] were designed entirely by the Post Office, and many of the units such as the master oscillators, carrier generators and filters,[16] including all the crystal resonators,[17] were produced in the Post Office laboratories.

Development Since 1939

Services to Ships.

The Burnham station[18] was enlarged between 1946 and 1948. For h.f. reception, it is now equipped with omni-directional aerials for the initial receipt of calls, and a "fan" of ten rhombic and vertical-Vee aerials so oriented that the benefit of high directional gain is available for receipt of messages from all points of the compass. Operation of the long-distance service is in six h.f. bands near 4, 6, 8, 13, 17 and 22 Mc/s, and aerials can be used simultaneously by any number of operators without interaction. There are 28 h.f. receivers (Fig. 8), and a switching system that enables

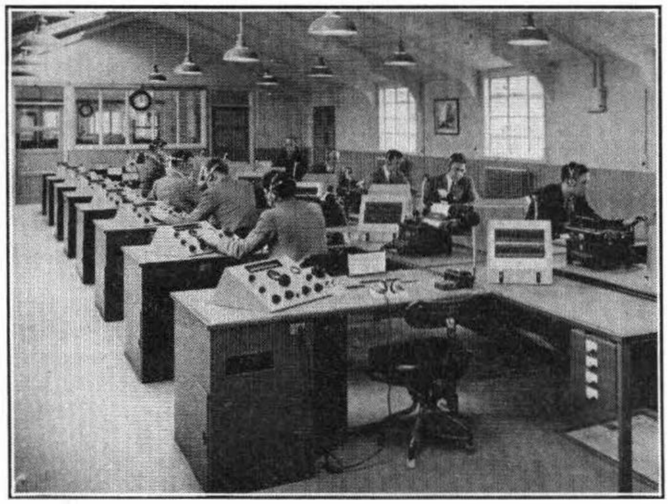

Fig. 8.—Receiving Positions at Burnham Radio Station.

individual aerials and receivers to be inter-connected as desired. The vertical-Vee aerials supplement the performance of the rhombics, particularly at the lower frequencies where the response of the horizontal aerials to signals arriving at very low angles is poor.

The aerial signals, before distribution, are amplified in multi-band amplifiers, which have six narrow pass-bands corresponding to the ships' frequencies, and which serve as terminating impedances for the double-ended rhombic aerials. The design ensures a good compromise between noise, distortion due to overload, and gain.

For low-frequency reception the principal requirement of the aerial system is the ability to provide directional discrimination, against unwanted signals, rather than high gain. Bellini-Tosi crossed-loop aerials, which may be used omnidirectionally or directionally, are therefore provided, and a distribution system enables four operators to use the aerials simultaneously or independently.

Control of the associated h.f. transmitters at Portishead and of the v.l.f. transmitters at Criggion and Rugby is effected over v.f. channels.

The requirements of the coastal service are met by equipment operating in the medium-frequency band, with two quarter-wave vertical aerials, resonant at 1,300 kc/s and 3,000 kc/s, and one non-resonant inverted-L aerial for the 500 kc/s band.

The gap between the inner limits of satisfactory h.f. reception and the outer limits of the coastal m.f. service is covered by the l.f. service on 110-160 kc/s.

Coastal stations are now all equipped to establish conversation between ships and telephone subscribers on land, generally on a normal duplex basis. Direction-finding has become of less consequence than formerly, as comprehensive ship-borne navigational aids have now been developed; but direction-finding is still an important part of the distress service and coastal stations are being equipped with Adcock systems operating in the 500-kc/s and 2-Mc/s bands.

Fixed Services.

In 1942, in view of the importance of the services provided by the Rugby station, a second high-power station was erected at Criggion,[19] near Shrewsbury, to act as a reserve. The design of this station was in general similar to that of Rugby, but was, of course, influenced both by experience gained in the intervening years and by war-time conditions.

More recently the tendency in transmitter practice is for the distinction between circuits provided for telegraphy and those provided for telephony to disappear. The normal "channel" is capable of transmitting speech or a number of telegraph channels, and transmitters are technically similar irrespective of the service.

The New Rugby Station.

The new Post Office transmitting station at Rugby,[20] with its 28 transmitters, each available for multi-channel telephony or telegraphy, is typical of present-day practice.

In four-channel telephony, for example, the outputs from two land-lines, each carrying two speech channels in the band 250-3,000 c/s, are applied to an independent-sideband drive unit and emerge at 3·1 Mc/s $\pm$ 6 kc/s as a four-channel signal of 0·25W peak envelope power. This signal is translated to the final radio frequency, one of six predetermined frequencies in the band 4 to 27·5 Mc/s, with frequency stability better than 15 parts per million. The signal is then amplified to a peak envelope power of 30 kW in an 8-stage amplifier, having grounded-grid valves in the last two stages.

For telegraphy, a telegraph drive unit, keyed from the output of a voice-frequency channel, generates a signal at a frequency of 3·1 Mc/s. This signal is translated and amplified as above in the transmitter-amplifier unit.

The aerials are three-wire rhombics, many of them in pairs one above the other, mounted on light steel-lattice masts. For the New Zealand service, however, four Koomans arrays suspended from 325-ft masts are provided because of the wide variations of azimuthal arrival angle experienced on this route. Transmitters are switched to the required aerials by remotely-controlled motor-driven switches.

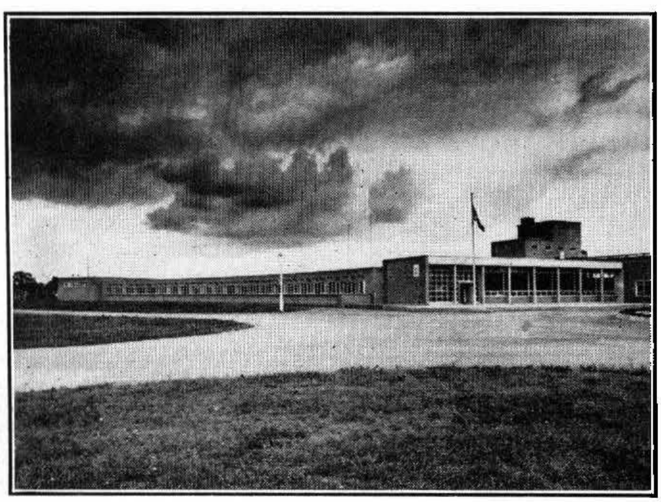

FIG. 9.—THE NEW RUGBY RADIO STATION.

The new station (Fig. **9**) is probably the biggest ever built as a single project. It is certainly in advance of any other in technique and in economical use of man-power, a large measure of automatic control and monitoring being exercised from a central control position. Many safeguards are incorporated: the transmitters (Fig. **10**), for instance, are fully equipped with interlocks which prevent access when dangerous voltages are present, and with devices which shut a transmitter down if the cooling system should fail or if the aerial system should become mismatched.

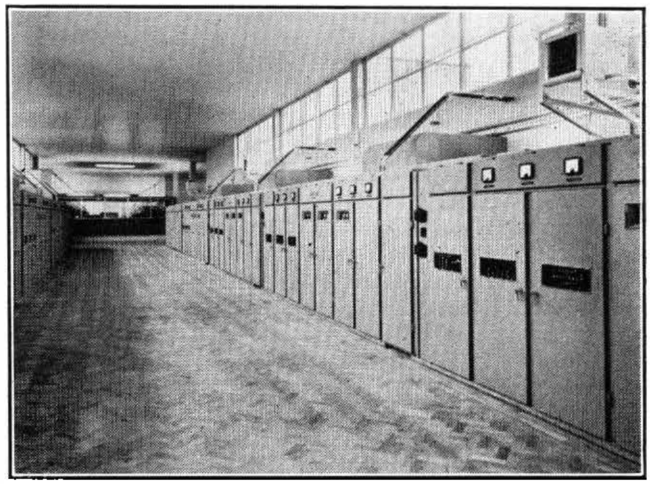

FIG. **10**.—TRANSMITTER WING AT THE NEW RUGBY RADIO STATION.

Bearley Receiving Station.

Recent developments in reception techniques have been embodied in the new radio receiving station at Bearley, near Stratford-on-Avon. This station is equipped for receiving fixed long-distance telephone and telegraph services in the frequency bands 15 to 400 kc/s and 4 to 27·5 Mc/s. The high-frequency aerial system consists of 30 rhombic aerials arranged in an approximately circular pattern having an overall diameter of some 2,500 ft; diametrically opposed pairs are laid out along the same bearing and may be operated in dual diversity if required. Both ends of each aerial are connected by open-wire transmission lines to gantries near the receiving building, where balance-to-unbalance transformers enable coaxial cables to be used for entering the building. Inside the building the coaxial cables are terminated on wide-band amplifiers covering the frequency range 4 to 27·5 Mc/s, each giving up to four 75-ohm outlets to the receivers. This arrangement enables each rhombic aerial to be used for reception in both directions and on several frequencies simultaneously, so that the whole aerial system gives complete azimuthal coverage up to 27 Mc/s, with dual diversity. The complete aerial system, including aerial transformers and amplifiers, was designed by the Post Office.

The telephony receivers (Fig. **11**) are independent-sideband receivers (Receiver No. 22), using intermediate frequencies of 3·1 Mc/s and 100 kc/s, and having both variable and crystal-controlled first beating oscillators (the latter with a choice of nine pre-set frequencies).

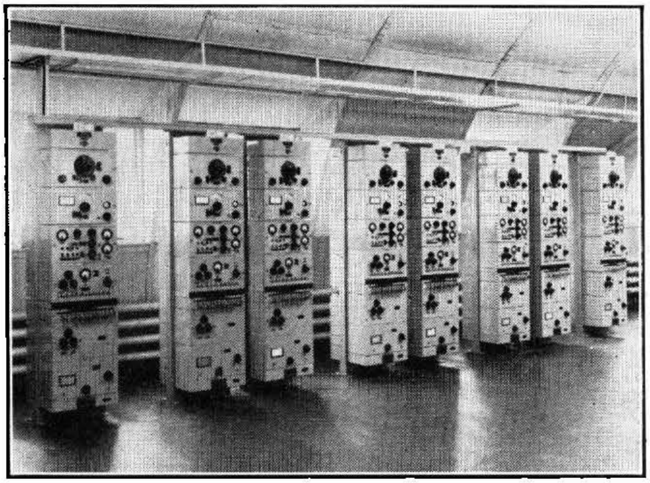

FIG. 11.—INDEPENDENT-SIDEBAND RECEIVERS AT BEARLEY RADIO STATION.

Electro-mechanical automatic frequency-control is applied to the second beating oscillator.

For the telegraphy services commercial dual-diversity receivers are used. As with the telephony receivers, variable and crystal-controlled first beating oscillators are incorporated, with automatic frequency control applied to the second beating oscillator. The main adjacent-channel selectivity is by crystal filters with bandwidths of 0·5, 1 and 2 kc/s.

The receiving system for low frequencies (15 to 400 kc/s) comprises a Bellini-Tosi aerial system feeding six goniometers and associated receivers, the latter being preceded by tuned circuits employing large Litz-wound coils. It is interesting to note that the goniometers and the tuned circuits are the identical units first installed for a low-frequency service at St. Albans in the 'twenties.

Links to Off-shore Islands.

Operation of links to the islands around Great Britain is now at frequencies of about 165 Mc/s; rhombic aerials have superseded the earlier Koomans arrays, and frequency modulation is employed. Valve characteristics have improved and it is now normal practice to transmit two groups of 12 channels assembled as in normal land-line carrier practice. Where necessary, four groups can be transmitted. Radiated powers do not exceed 10 W and the radiated frequency is controlled by reference to a quartz crystal oscillator; any frequency divergence automatically brings into action compensating and correcting circuits. Output levels from the radio system are now stable within 10 per cent of the nominal value for a 1,000 to 1 variation of incoming signal strength.

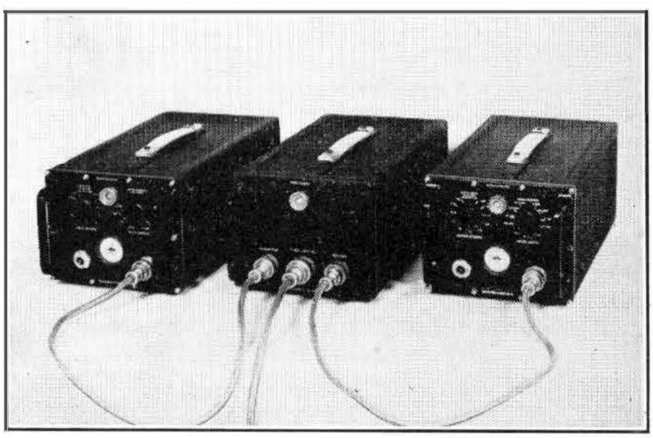

FIG. 12.—ISLAND-LINK RADIO-TELEPHONE EQUIPMENT.

By 1951, the radio-phonogram links, which had been used from about 1934 onwards, had been replaced by radio-telephone equipment (Fig. 12) providing a duplex radio channel with complete signalling facilities and designed for inclusion in a subscriber's line circuit. The equipment uses phase modulation and operates at 70 to 90 Mc/s, using horizontal Yagi aerials. The radio transmitter is switched on only during telephone calls, and the radio receiver for only a few seconds every half-minute between calls to test for the presence of a calling signal. The resulting low power-consumption ensures operation from primary batteries for long periods without attention.

Microwave Radio-Relay Systems.

The coming of radar stimulated developments of microwave frequencies, and after the 1939-45 war, attention turned to the use of these frequencies for radio-relay links for television and multi-channel telephony.[21]

Much work has been done by the Post Office in establishing the operational requirements to be met by microwave links, and the result of this work is now embodied in the television relay links already in operation, and in the specifications to which multi-channel telephone links are at present being installed.

In general the radiated frequencies are about 4,000 Mc/s. The television video signal or multi-channel telephone signal frequency-modulates an intermediate carrier frequency of 60 to 70 Mc/s, and the modulated signal is then translated in frequency to the transmitted microwave frequency, being fed to the aerial (Fig. 13) via a waveguide

FIG. 13.—MICROWAVE AERIAL.

feeder. Frequency modulation is employed because it enables an adequate signal-to-noise ratio to be achieved, and reduces the effects of amplitude non-linearity in valve amplifiers: it does, however, impose stricter requirements on the phase characteristics of the system. The Post Office has successfully developed satisfactory modulators and demodulators and high-quality stable amplifiers for use at the intermediate frequency, and has recently designed units that are suitable for colour television or for operation with 600 telephone channels. Microwave transmitting

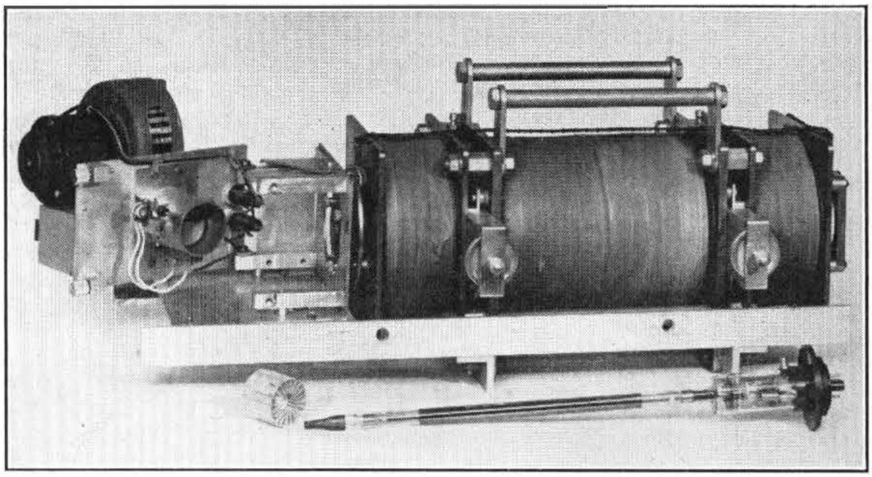

FIG. 14.—TRAVELLING-WAVE AMPLIFIER.

and receiving equipment has also been developed concurrently, and of major importance has been the stimulation of the radio industry to develop the travelling-wave tube (Fig. **14**) as a wide-band microwave amplifier.

Several microwave links, designed to provide one 405-line monochrome television channel for each required direction, are now in operation, and the first microwave link to carry telephony traffic, with a capacity of 240 channels, is due to come into regular operation at the end of 1956.

Frequency Control.

The study of special cuts of quartz crystals, having low frequency/temperature coefficients, has enabled oscillators of very high orders of stability to be produced, and the Post Office has supplied the B.B.C. with crystals which enable two or more broadcasting stations to be operated on the same carrier frequency, broadcasting the same program, each station having its carrier controlled by an independent crystal oscillator. Since 1945, practice has further advanced and new types of vibrator have been made in the audio range (down to 1,000 c/s), and a technique of producing overtone units up to 100 Mc/s has been developed.[22] The special demands on frequency stability made by single-sideband radio systems (at present 15 parts in 10^6) can be met by quartz crystal units without temperature control.

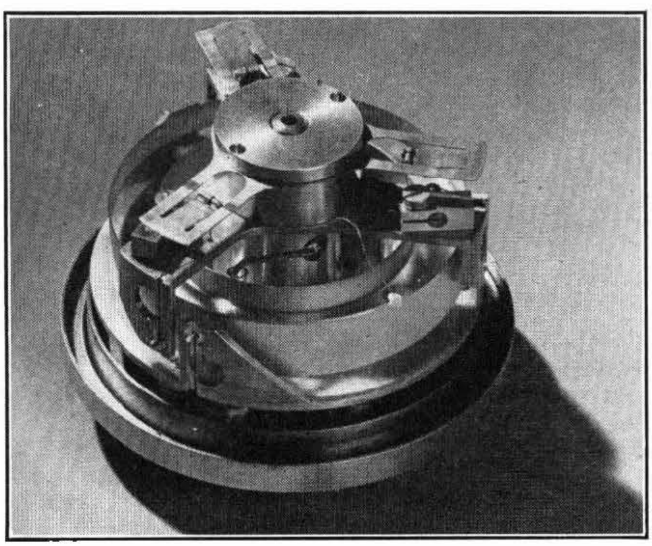

FIG. 15.—100-KC/S QUARTZ RING, MOUNTED ON THREAD SUSPENSION, WITH COVER REMOVED.

Progress in these developments has been accompanied by further improvements in frequency standards. The AT-cut plates used in the first crystal-controlled frequency standards gave performances which surpassed those of the tuning forks previously used, but were in turn superseded by GT-cut plates.[14] Then, in 1945, the Post Office turned its attention to the Z-cut ring-type of crystal (Fig. **15**) described by Dr. Essen of the National Physical Laboratory (N.P.L.) in 1938, and successfully evolved a mounting which combined adequate robustness with minimum damping of the crystal. Rings so mounted, enclosed in ovens with temperature-control to a very small fraction of a degree, and operated in a Meacham bridge circuit, are of extremely high stability, and have replaced all earlier units as Post Office frequency standards. The outstanding performance of these oscillators has attracted requests for similar units from all over the world, and complete oscillators incorporating Essen-rings (all of Post Office manufacture) have been supplied to observatories and laboratories in Canada, the United States, Australia, New Zealand and South Africa.

A ring crystal is used at Rugby to control the carrier frequencies (and also the modulation) of the MSF standard frequency transmitters[23] operated by the Post Office on behalf of the N.P.L., and its constancy may be judged from the fact that, although until recently no adjustment to its frequency had been made for three years, during the whole of that period it had not changed by as much as two parts in 10^8. In 1954, it was arranged that the same crystal should also control the GBR transmitter, instead of the crystal previously used, so that the carrier frequency of the GBR signal now has the same accuracy as that of MSF. From June 1956, at the request of the N.P.L., adjustments will be made as necessary to maintain the frequency of this ring oscillator within five parts in 10^9 of the nominal value in terms of the caesium resonator standard of frequency recently developed at the N.P.L. The present frequency stability of the ring crystal at Rugby is such that this should be necessary only once or twice a year.

The experience gained by the Post Office in the accurate frequency control of transmitters has enabled the U.K. to play an important part at international conferences concerned with establishing internationally agreed frequency tolerances for the various types of radio services, and, furthermore, to give a technical lead by maintaining a very high standard of performance of Post Office transmitters.

Other Developments.

To assist in the constant search for improvements there is to-day a growing demand for specialized, high-quality, and frequently quite complex, measuring equipment. Typical Post Office developments in recent years include:—

A Fading Machine,[24] which enables the noise and fading effects encountered on high-frequency long-distance circuits to be largely simulated, and this forms a useful tool for studying radio-telegraph reception methods in the laboratory.

A Microwave Model Aerial Technique, which enables comprehensive information on the directivity characteristics of high-frequency aerials to be determined readily by measurements on small-scale models, thereby avoiding the inconvenience and expense of tests on full-size aerials, or of lengthy computations. The effect on the performance of an aerial of the presence of, say, a mast or another aerial can be observed and recorded.

A Spectrum Analyzer, whereby the frequency spectrum of any radio signal in the frequency range 3 to 30 Mc/s may be displayed on the screen of a cathode-ray tube, and components spaced by 50 c/s and ranging 60 dB in amplitude may be resolved. This equipment is being produced commercially.

A Scanning Receiver,[25] which enables the occupancy of any desired 1-Mc/s band of the high-frequency spectrum to be monitored. The receiver scans the 1-Mc/s band in a period of 2 minutes (or 4 minutes if required), and the presence of signals is recorded by corresponding marks on "Mufax" electrolytic paper; the receiver then rapidly resets and the operation is repeated indefinitely, the paper moving at a speed of ½ in. (or ¼ in.) per hour.

Future Trends

In the field of high-frequency long-distance radio telephony it is probable that transmitter powers have reached the economic limit, while the sensitivity and selectivity of receivers is near enough to the ideal to make further substantial improvements unlikely. However, interference (by unwanted signals falling within the receiver pass-band) is still quite common, and improvements are desirable in the directivity characteristics of high-frequency aerials with a view to reducing such interference. Present work in the Post Office is directed towards an array of aerials which will allow the system to be "steered" to give maximum response to signals from any desired azimuthal and elevational angle. It is visualized that one such aerial system would meet the requirements of a complete radio station.

Turning to radio telegraphy, recent work in the Post Office has shown that significant improvements in the performance of radio-telegraphy receivers are possible by designing them to make full use of the information contained in a frequency-shift signal, information which in the conventional frequency-shift method of reception is suppressed by the action of the discriminator. A study of the characteristics of radio noise as it affects reception of radio-telegraph signals has also indicated the possibility of improvement in performance with suitable design of receiver.

Future microwave systems will provide broad-band radio channels capable of handling at least 600 telephone channels and 625-line monochrome, or 405-line N.T.S.C.-type colour, television; possible adaptation for 625-line N.T.S.C.-type colour television is also visualized. The transmission of such signals will necessitate increases in bandwidth and improvements in transmission performance. Travelling-wave valves having powers of the order of 20W will be used for transmitting, and those for receiving will be of improved low-noise types. Valves of improved performance will also be required for amplification at the intermediate frequency, and the use of ferrites as isolators to reduce the effects of reflections of waves in waveguides will be of increasing importance. The trend towards higher and higher frequencies will continue, since use is thereby made of hitherto unused parts of the frequency spectrum, and the wide bandwidths mentioned above are more readily available. This will necessitate further advances in the technique of filter design and the development of suitable amplifiers and oscillators (using new types of valves); furthermore, the efficient use of these higher frequencies will also require very high frequency-stabilities.

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Research

The main purpose of the work at the Dollis Hill Research Station is to improve the efficiency of telecommunications services provided by the Post Office, by the study of new phenomena, techniques and materials and by the development of experimental systems and apparatus. Other laboratories of the Engineering Department, housed elsewhere, carry out investigations and development work on systems already approved or in use. The Station is consulted by other Government Departments and Laboratories, and some work is done for them. Close contact is maintained with University, Government and Industrial laboratories doing allied work. The first section of this article is devoted to experimental work in the Post Office up to 1920 (except for work in the radio field, which is described in a separate article); each of the other sections deals with research since 1920 in one of the main fields of line telecommunications.

Research Prior to 1920

THE Post Office entered the field of electrical communication in 1870, when the telegraph companies were transferred to Government ownership. Bell's telephone was still a few years ahead, but commercial telegraph systems were well established, and the first transatlantic submarine telegraph cable had already been laid. Maxwell had published his electromagnetic theory five years earlier, predicting the free-space waves demonstrated by Hertz in 1888.

The small size of the engineering organization in those days is illustrated by the fact that the total technical and non-technical staff of the Engineer-in-Chief, in 1880, was only 18. Yet 1880 is nearer in terms of years to the present than it was to the year 1753, in which the fundamental idea of using the conduction of electricity for communication was first proposed. An interesting account of the developments in the intervening years has recently been published.[1]

In this article it is proposed to deal with research prior to 1920 on a general basis. After that date, the rapid growth in telecommunications techniques, and the extent of specialization in different aspects of research resulting from this, make it more convenient to deal with each of these aspects separately.

In the early days, probably most telegraph engineers were also experimentalists, but in the Post Office, experimental work was particularly the province of the "Electrician." The first Electrician, who later became Sir William Preece, was very interested in the problem of induction between circuits, the importance of which became apparent after the invention of the telephone. Experiments to reduce inductive interference led to the introduction of "metallic" loop circuits, crosses in overhead wires, twisted pairs in cables and so on. By 1896, when the National Telephone Company's trunk telephone network was added to that of the Post Office, many of the problems of induction in the existing overhead network appear to have been solved.[2]

From the earliest days Post Office engineers were continually experimenting to improve telegraph apparatus, and early work was particularly directed to improvements in duplex and quadruplex working, and to multiplex systems generally. The continual effort to establish more and more independent channels of communication in a single conducting medium is one of the outstanding features of research and development in communication in the last hundred years. The experimental and development work carried out by the Post Office on the Delaney multiplex system (Fig. 1) from 1882 onwards is of interest to-day because it was a direct forerunner of the time-division principle used in some modern transmission and experimental electronic-switching systems. Unlike the Baudot system, usually quoted in this connexion, the rate of transmission of the characters was not synchronized with the channel-switching rate.

In the first 20 years of this century the Post Office experimented with many types of multiplex and printing telegraphs submitted by outside parties. This period, before the general establishment of large commercial research laboratories, was noteworthy for the large number of inventions which were submitted to the Post Office by private inventors. The testing of these occupied much of the time of the experimental staff.

When the Post Office acquired the whole trunk telephone network in 1896, very few of the local exchanges were under Post Office control. This fact, together with the need to extend the range of economic telephone communication, naturally led the Post Office to concentrate on research in line transmission. By the end of the last century, congestion of overhead routes and their liability to blizzard damage were already becoming apparent, and the first long-distance paper-insulated underground cable was laid between London and Birmingham during the period 1897 to 1899. Tremain and Martin conducted a classical series of experiments on balancing the effects of induction in this cable. Their techniques were subsequently refined by other members of the research staff and played a very important part in the era of loaded and repeatered lines.[3]

Tremain had also been given the job of following up the theoretical work of Heaviside and others, on loading, and in 1901 he conducted the first experiments on loading in this country, using air-cored coils on the London–Birmingham cable. These experiments were successful, but adequate correlation of theory and practice had to await the better audio-frequency measuring techniques developed in the following years by workers like Duddell, Cohen and Hay. The frequency characteristics of loaded lines also suggested the construction of artificial filters with similar characteristics, and such a filter was already in use in the National Telephone Company's laboratory in 1907.[4] The variable cut-off frequency which could be obtained by varying the spacing of loading coils had also enabled an estimate to be made in 1907 of the maximum frequency (1,600 c/s), then considered necessary for commercial telephony.

Most of the early telephone transmission measurements were made using speech tests to compare the circuit under test with a "standard cable," which could be varied in length until the received sounds were of the same intensity on both the standard and test circuits. When new laboratories were occupied in King Edward Building, in 1912, drums of standard cable were installed in the basement. There was a lot of discussion in the first decade about what

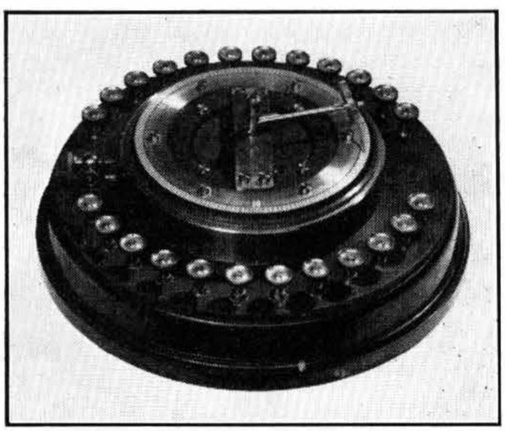


Fig. 1.—Delaney Multiplex Distributor (1882).

value of single frequency should be used for testing to obtain transmission test results similar to those obtained with speech testing.

Speech testing with standard cable, or artificial networks equivalent to standard cable, remained in use for most of the transmission testing before the era of the hard valve. This was probably due partly to the fact that the only laboratory sources of variable audio-frequency testing current available were large dynamo machines (Fig. 2), and these were cumbersome to transport. When a cross-Channel cable was tested in 1909, at a number of frequencies in the audio range, the testing current from the laboratory generator in London was transmitted to Dover by overhead line. This is a good example of the many handicaps to telecommunications research which were removed by the hard valve and which, to-day, are largely forgotten. One of the first applications of hard valves by Post Office research staff before 1920 was to valve oscillators and valve voltmeters for transmission measurements. These later became very important for field maintenance of repeatered lines.

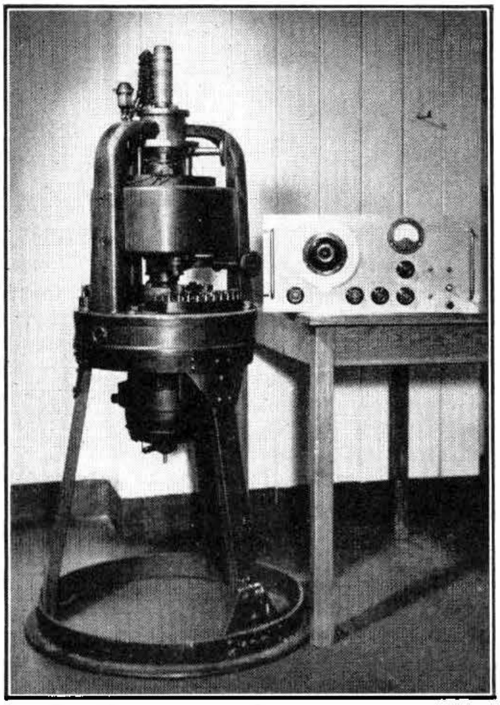


FIG. 2.—THE FRANCKE A.C. GENERATOR AND A MODERN AUDIO-FREQUENCY TEST OSCILLATOR.

When speech testing was used for transmission testing, and most cables had attenuation/frequency characteristics approximating to the "standard cable," the old "mile of standard cable" (m.s.c.) transmission unit had advantages over the β unit (later called the neper) or the decibel. These advantages largely disappeared for long-line testing when the lines were loaded, for the impedance no longer matched the standard cable, and the attenuation/frequency characteristics were no longer similar. With equalized repeatered lines the attenuation/frequency characteristics became nearly flat, and the disadvantages of a frequency-dependent unit like the m.s.c., even greater. It was, of course, possible to make resistance attenuators in units of attenuation equal to the attenuation of the m.s.c. at the mean speech frequency of 800 c/s, but such units were inconvenient for computation. In spite of the fact that the β unit was being discussed as early as 1910, it was not until the early 1930s that the m.s.c. unit was finally abandoned, in this country, in favour of the decibel.

Speech tests to measure the volume, intelligibility and articulation efficiency of subscribers' apparatus were introduced more than 50 years ago and have remained in use in various forms since then. At the same time it was appreciated that it was desirable to know more about the frequency characteristics of such apparatus. Speech waveforms, from the microphones then available, were being examined on the new Duddell oscillograph, and analysed by Fourier analysis, as early as 1905. A crude attempt to measure the frequency response of a microphone from the acoustic input to the electrical output was made by A. Campbell at least as early as 1907.[4] Rapid developments in this field, however, had to await the advent of improved measuring techniques made possible by the hard valve.

There is little evidence that the research staff were much concerned with switching problems prior to 1920, apart from some work on contacts, relay testing, and transmission measurements on exchange apparatus. The reasons for the concentration on transmission research in the first decade of the century have already been mentioned. Had it not been for the 1914-18 war the research staff might, perhaps, have been more closely associated with the field trials of the various types of automatic telephone exchange installed by the Post Office in the period 1912-1920.

In the early days, experiments were often conducted in the field, but a small "experimenting room" was provided at headquarters. In 1904, experimental work was started on an organized basis, and in 1909 a Research Section was formed and work started in a new and larger "experimenting room."[5] In 1912 the experimental staff of the old National Telephone Company joined the Post Office and were transferred from their original laboratories, established in 1905, to new laboratories in King Edward Building.

During the 1914-18 war the research staff were largely engaged on war work, and made important contributions to sound ranging and aircraft communication equipment. They were, however, able to continue with the very important project of the development of line repeaters, the potential advantages of which had been recognized since the invention of the telephone. The microphone-receiver type of repeater had not proved very practicable, and in 1913 experiments were conducted in co-operation with the German Post Office using soft valves.[6] During the war, repeaters, and valves for them, were made by the research staff, and the first commercial repeater stations in Europe (Fig. 3) were operated by research staff on the London–Birmingham–Liverpool cable in time to reduce the effects of the loss of all

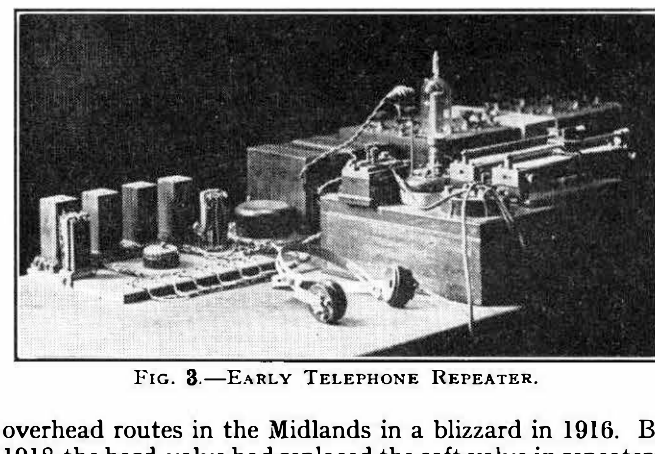


FIG. 3.—EARLY TELEPHONE REPEATER.

overhead routes in the Midlands in a blizzard in 1916. By 1918 the hard valve had replaced the soft valve in repeaters, and the foundations had been firmly laid for the rapid development of loaded and repeatered lines in the 1920s.

By 1919 it was clear that these developments, in which the research staff were playing so important a part, together with the probable impact of valve developments on radio, and the development of automatic telephony, would necessitate a rapid increase in the staff already engaged on research and development in many different places. The urgent need for a central research station was apparent. Prospective financial savings which could accrue from improvements in line practice alone were shown to be sufficient justification for this move.

The Research Station at Dollis Hill

The Research Station was established in 1921 at Dollis Hill,[7] at first in ex-army hutments (Fig. **4**) with a total area of 36,000 sq ft. The first permanent building on the site was completed in 1924, and by 1931 the main permanent buildings[8] were well under way. Up to 1933 work on trunk telephone research continued to be carried out at Marshalsea Road, in the Borough. By 1933, when the Research Station was formally opened by the Prime Minister, the Right Honourable J. Ramsay MacDonald, the transfer to permanent buildings was practically complete.[9] The Research Branch staff has since expanded into further buildings erected during and since the 1939-45 war, and most of the accommodation originally provided for the Training School has been taken over for research work. Fig. **5** is a simplified site plan of the Research Station as it is to-day.

Fig. 4.—Part of the Dollis Hill Research Station in 1922.

Until about 1935 the radio experimental staff, who originally came to Dollis Hill about the same time as the research section staff, occupied only a small part of the available premises. This was mainly used for work on field-strength measuring apparatus, frequency measurement and control, receiver design and other work not requiring extensive site facilities.

In 1935 the accommodation requirements of the radio experimental staff rose steeply with the commencement of work on telephone and television coaxial cable systems, and with developments in short-wave practice. As the permanent buildings for this work could not all be ready in time, accommodation was provided at the old Wembley Exhibition site, and this is still in use. Experimental sites at Castleton and Backwell Hill, chosen for early field trials across the Bristol Channel, became permanent additions to the radio experimental laboratories.

The Post Office undertakes a considerable amount of general development work—construction and testing of modified or prototype equipment, improvements in standard methods, circuit design and new applications of established principles—which does not demand the full resources of a research organization, but much of which was once done by research staff. Work of this kind is now carried out in laboratories attached to individual Branches of the Engineer-in-Chief's Office.[10] Acceptance-testing of contractors' deliveries, which may involve routine physical, chemical or electrical tests, is the responsibility of the Test and Inspection Branch.

Assessment of Telephone Transmission Performance

Some method of assessing quantitatively the performance of telephone transmitters and receivers is necessary, and measurements of performance have been made since the early days of telephony. Such measurements are essentially subjective, and it may not be generally appreciated how difficult it is, even to-day, to rate accurately the performance of subscribers' sets, particularly the transmitters. The carbon-granule transmitter is an efficient and cheap means of converting sound energy to electrical energy, but it remains the most variable element in commercial telephony. In the early days it was natural that subscribers' sets should be rated on a "loudness" or volume basis, by comparison with a standard or "reference" circuit. As telephone sets with improved frequency-response, lower non-linear distortion and reduced side-tone became available, a more comprehensive method of comparison became necessary. Articulation testing, which goes back at least as far as 1905 in the Post Office, was therefore developed as a means of assessment that would take account of these improvements. In the method used by the Post Office, the percentage of syllables correctly received by a trained crew, under carefully controlled conditions, is plotted against added attenuation in the circuits of the test and standard sets.[11] The number of decibels difference between the points on the two curves at which 80 per cent of the syllables are correctly received, is used as a "performance rating" of the test instrument and circuit in terms of the standard.

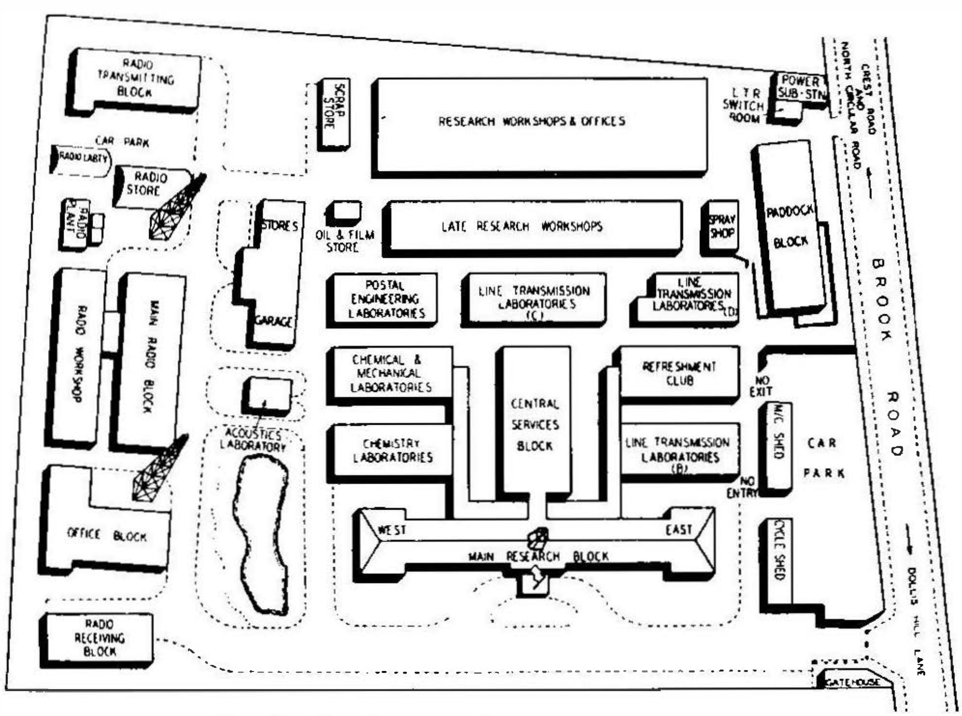


Fig. 5.—The Research Station as it is To-day.

Both in volume and articulation testing, closely controlled conditions with trained crews are essential to obtain repeatable measurements (Fig. 6). Articulation measurements have been found to give reliable results for relatively small changes of test instrument or circuit, but due, it is believed, to the artificial conditions in which these tests are necessarily made, the tests have shortcomings which are shown up when comparing telephone sets having widely different characteristics.

NOTE: The list of speech sounds is spoken into the microphone under test; one of the two high-quality microphones and the level meter are used for controlling the loudness of speaking.

FIG. 6.—ARTICULATION TESTING.

Performance ratings based on articulation tests by trained crews are therefore likely to hold the field for determining the effect of changes in the local line, feeding bridge, etc., while the transmitter inset, receiver inset and the handle of the telephone remain unchanged.

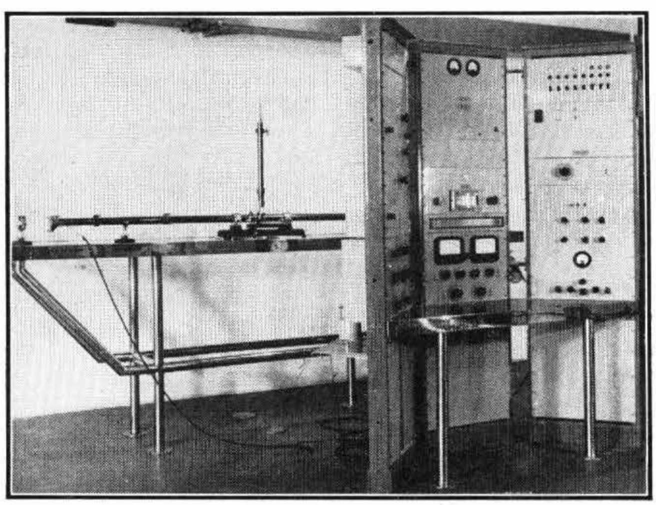
When important decisions are involved in the development of telephone sets having a new design of handset or transmitter inset, it is advisable to make use of other methods of assessment in addition to the formal volume and articulation tests. The Post Office has developed one such method, known as "free conversation testing," in which the participants in the test are drawn from the Post Office Research Station as a whole, but are not practised in testing by voice-ear methods.[12] In this type of test Fisher's methods of designing experiments are used.[13] The experiments are designed specifically with a view to affording maximum information when the data are analysed according to the mathematics of probability. By the use of tape recordings, the time required of volunteers is reduced to a minimum, but the subsequent computation is heavy. A most interesting feature of Fisher's experimental method is that several parameters are changed simultaneously during the experiment, yet it is possible to assign separately the effect of each of the changes with acceptable degrees of accuracy and probability.

Various standard sets for telephone transmission are maintained by the Post Office, and comparisons of performance of telephone apparatus with these sets are made by subjective tests as required. A "basic" standard set is the high-quality system, the performance of which is specified and maintained by absolute physical measurements. A "working" standard set is made up from components, selected as average, of telephone apparatus currently in service. At the present time the working standard which represents the poorest "local" transmission that is normally allowed in the Post Office network (i.e. the poorest transmission between a telephone and the exchange to which it is connected) consists of a Telephone No. 162 with Bell-set No. 25, fed from a 50-V non-ballast transmission bridge through 450 ohms of 10-lb cable. As improvements in circuits or components are introduced into the service their transmission performance can be assessed, by comparison with the working standard, to determine new limits for local lines, which can be used for telephone stations where the improved apparatus is installed, without allowing the transmission to become worse than standard. For the more important tests it is usual to use a testing procedure in which comparison is made of both the item under test and the working standard with the high-quality system.

For day-to-day use in the field, it is necessary to know the performance ratings of a considerable number of combinations of telephone, line and transmission bridge. It is also necessary to know the transmission loss incurred by the insertion of components associated with P.B.X. switchboard and extension circuits. A major review of basic transmission data was made shortly after the war of 1939-45, when "volume efficiency" gave place to "transmission performance" assessments, and transmission data and line limits are revised from time to time as circumstances require. Short-cut methods are available for many purposes, requiring a minimum recourse to subjective testing.

Generally, the most used and most useful criterion of transmission performance is the difference of non-reactive attenuation between the circuit under test and the standard circuit. In special cases, however, other criteria may be needed. For example, for comparing circuits which have adjustable gain, but sometimes severe non-linear distortion, a circuit with variable and specifiable distortion is used as the standard of comparison, and the criterion used is the amount of distortion in the standard to give equivalent performance to the apparatus under test. Again, a useful criterion for speech-compression systems (proposed for economizing in bandwidth) is the equivalent bandwidth of uncompressed speech.

The British Post Office, as a member of the C.C.I.F., co-operates in the work of correlating national standards of telephone transmission performance, and of specifying limits to be observed for international telephony. In this connexion it is of interest to record that the high-quality telephone system now in use as a standard at the C.C.I.F. laboratory in Geneva (Fig. 7) was designed and supplied by the British Post Office,[14] which has also contributed substantially to the statistical methods of designing and controlling experiments used by that laboratory.



NOTE: The measurement is by a Rayleigh Disk at the centre of the horizontal tube, and observations are made at the table in front of the three racks.

FIG. 7.—APPARATUS FOR MEASURING SOUND PRESSURES.

Telegraphy

Telegraphy in the classical sense had passed its zenith by the time the Post Office Research Branch was formed. Interest was therefore mainly centred on the problems that arose from the introduction of teleprinters, and from the integration of the inland telegraph and telephone networks, using multi-channel voice-frequency operation on the main links. These developments gave a degree of line exploitation never before achieved by traditional multiplexing methods. Problems of frequency generation and filtration, of spectrum utilization and of line-transmission characteristics called for study.

The examples that follow illustrate the range of the contributions made by Post Office research to the telegraph service.

Telegraph Repeaters.

In 1942 duplex transmission was required on the Wick–Lerwick and Lerwick–Thorshavn submarine sections of an Iceland telegraph circuit. Conventional duplex repeaters using Gulstad relays could have been provided, but such repeaters had almost disappeared from the Post Office network. The repeaters were to be installed in multi-channel voice-frequency telegraph terminals, which at the places concerned were also telephone repeater stations. The existing type of submarine cable repeater, which required a large amount of table space and specialized maintenance, would have been out of place in such stations. A rack-mounted repeater was therefore developed,[15] comprising balanced equalizer, artificial line balance, input transformer and push-pull valve amplifier having a long time-constant and d.c.-restoration circuit. Similar equipment was later provided for a Norwegian cable.

Telegraph Distortion Measuring Set.

Accurate measurement of telegraph distortion (particularly of start-stop distortion) has been important in the development of telegraph transmission and terminal equipment, and in the design of telegraph switching circuit networks. The development of an electronic start-stop telegraph distortion measuring set was initiated in 1939 but was delayed by the war. Work was resumed in 1947, and a set was designed for measuring the start-stop distortion of teleprinter signals within a range of ± 40 per cent and with an accuracy of 1 per cent. The distortion readings are displayed as spots on a graduated cathode-ray-tube screen, the spots for successive signal transitions occurring on vertically-displaced rectilinear beam-sweeps. Subsequently, the set was redesigned to provide 2 per cent accuracy on a smaller (6 in.) tube, and the redesigned sets[16] have been provided at teleprinter automatic-switching centres. Distortion measurements can be made while normal traffic is proceeding, and the set can also be used to measure the speed of teleprinters.

Telegraph Distortion Analyser.

Between 1951 and 1953 a telegraph distortion analyser[17] was developed which has enabled some important statistical studies of telegraph distortion to be made, notably on tandem-connected channels in switching systems. The analyser examines every instant of change-over in a start-stop telegraph signal for time distortion and counts and records the number of instants falling within each of 20 selected ranges of distortion. Curves showing the frequency distribution of occurrence of various values of telegraph distortion can be very quickly obtained by this means.

Error-Correcting Equipment.

Falsification of telegraph signal elements during radio transmission causes errors in reception which, in general, are undetectable if a non-redundant code is used. By the use of codes having redundancy, in conjunction with special equipment, the probability of occurrence of undetectable errors in reception can be made negligible, and detected errors can be automatically corrected.

Thus, for example, a five-unit two-condition code can provide only 32 distinct character combinations, all of which may be needed. Hence a falsified element is bound to produce a wrong character or function, which may not be evident. A seven-unit code will, however, provide 128 combinations, many of which will be unused. If a falsified element turns one of the used character combinations into one of the unused combinations, it is possible to detect the error.

An early method of providing redundancy in Baudot transmission, developed by C. Verdan, depended upon transmitting each signal element three times at intervals. Early examples of special equal-length error-detecting codes were those of Moore and Mathes (U.S.A.) and van Duuren (Netherlands).

In 1951 the Post Office began research into the properties of the many types of error-detecting and error-correcting codes. Theoretical studies showed that seven-unit codes (associated with automatic request for repetition after the manner of van Duuren) were likely to be most generally useful. Radio trials of three different seven-unit codes indicated that transmission conditions associated with long-distance h.f. circuits most frequently favoured the constant-ratio 3-mark/4-space type of code. A two-channel electronic error-correcting multiplex equipment has been developed along these lines.

Line Transmission at Audio Frequencies

The earliest line amplifiers were mechanically coupled, telephone receiver and transmitter units, with which the names of S. G. Brown (Great Britain) and Shreeve (U.S.A.) were associated. They were tried but with little success during the period 1910-14. In May, 1916, four valve-repeaters were installed at Birmingham on 200-lb unloaded phantoms in the London–Birmingham–Liverpool cable, and by the end of the First World War the experience already gained left no doubt that the thermionic amplifier would make a major contribution to the improvement and expansion of the trunk service.

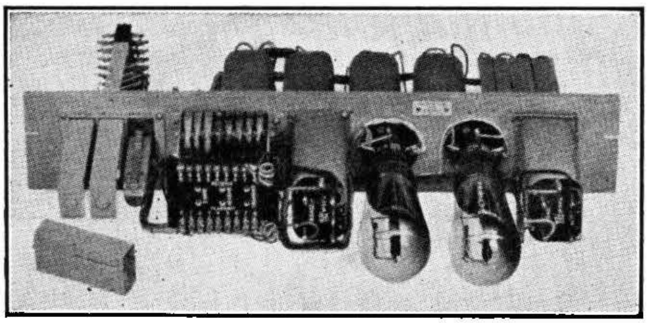
Repeaters to laboratory designs were constructed and subjected to systematic field trials, first on 2-wire and later also on 4-wire circuits, to determine the practical limitations to their use. Standards of performance were evolved which provided a basis for commercial designs and for the planning of the trunk network. By the later 1920s repeaters were coming into fairly extensive use, and cable conductor gauges were reduced, generally to 40-lb/mile and 20-lb/mile for 2-wire and 4-wire circuits, respectively. Loadings heavier than 176 mH at 2,000-yd intervals (cut-off 2,800 c/s) were abandoned, and on important routes pairs with extra-light loading (44 mH at 2,000-yd spacing—cut-off 5,500 c/s) were provided.[18]

Further refinements were called for in making, laying and balancing cables. Tolerances on loading-coil spacings were investigated and specified, chiefly to ensure efficient operation of the 2-wire circuits then used in considerable numbers. Manufacturing methods were improved so as to reduce capacitance unbalances, and balancing practice was reviewed. Following experience with the London–Derby–Manchester cable of 1922, efforts had been made to secure some degree of mutual capacitance matching. Methods already in use for reducing unbalances were found to give adequate freedom from crosstalk for 2-wire repeatered circuits, but the rather high gains then used in 4-wire circuits called for further reduction in crosstalk between "go" and "return" channels. This was achieved by "group-working," wherein "go" and "return" groups of pairs were shielded from each other by intervening pairs allocated for 2-wire circuits.

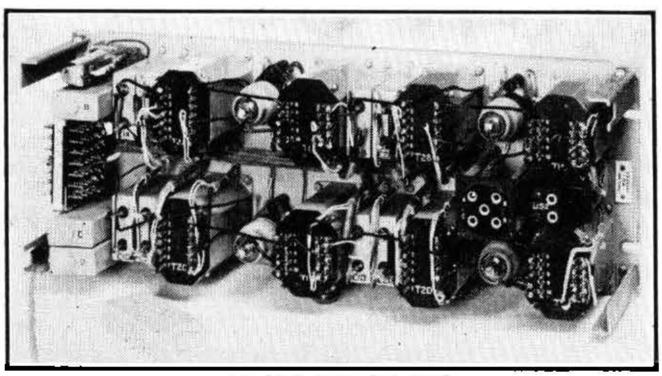
In 1922 trials were already being made to determine the effects of phase distortion and the extent to which echo effects could be tolerated in conversation.

Echo suppressors in which the presence of speech in the "go" direction reduced the gain of an amplifier in the "return" direction had been developed by 1924; thermionic valves were used for rectification of speech currents to control the amplifier gain. About 1934, equipment using a simple network of series and shunt copper-oxide rectifier elements was introduced, wherein the attenuations in the "go" and "return" directions were controlled by biasing currents derived from the anode circuits of the two halves of the 4-wire repeater.

A series of simple and inexpensive amplifying units used in large numbers in the audio network began with the development by the Post Office, in 1932-33, of "Unit, Amplifying, No. 1." This was a single-stage unit with a gain of 30 dB. Equalization was provided separately. The last of the series—"Unit, Amplifying, No. 20"—was current until 1940 when it was superseded by the "Amplifier No. 32" (Fig. 8), also developed in its basic form by the Post Office. This amplifier covers the functions of all existing types other than music amplifiers and is still



(a) "Toll" Repeater (about 1933).



(b) Panel, Amplifying, No. 32.

FIG. 8.—AUDIO-FREQUENCY AMPLIFIERS.

standard in the audio network. It is a single-stage amplifier, with a stable uniform gain of 27 dB over the whole working range up to 6 kc/s, and incorporates negative feedback. The design achieved its main objects of simplicity and reliability and the amplifier is still used in large numbers.

Present-day experiments with audio amplifiers include the so-called "negative impedance" devices[19,20] (Fig. 9). In the simple shunt or series form these promise to provide a very cheap and reliable means of giving a few decibels of gain in short-distance circuits. In the combined form they appear suitable for inclusion in a long-distance network.

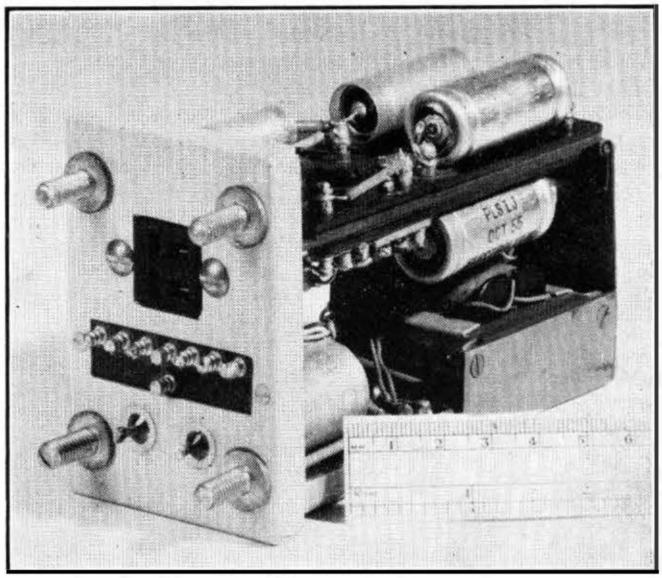


FIG. 9.—NEGATIVE IMPEDANCE AUDIO AMPLIFIER.

LINE TRANSMISSION BY CARRIER FREQUENCIES

Radio telephony based on the thermionic valve developed during the First World War, and the principles of carrier generation, modulation and rectification became well established. It was an obvious step to substitute a metallic link for a free ether path.

Single Carrier Channel on Overhead Lines.

Experiments by the Post Office led to the establishment in 1921 of the first carrier telephone system in this country. This provided one carrier circuit, in addition to the audio circuit, on a pair of open wires, using different carrier frequencies, 16 kc/s and 23 kc/s, for the two directions of transmission. The carrier was generated and modulated by means of a valve oscillator circuit, and valves were used for detection and amplification at the receiving end. Both sidebands were transmitted and simple tuned circuits were used as filters. At about the same time, a carrier telephone circuit was successfully tried on a submarine telegraph cable.

It proved by no means easy to develop carrier operation to the standards of stability required to justify its exploitation in a public telephone network, and during the next ten years experimental work continued,[21,22] interest lying mainly in the use of carrier operation to obtain additional circuits on submarine cables. The carrier frequency was reduced to about 6 kc/s, and high-pass and low-pass filters were introduced to separate the audio and carrier channels. Valve-maintained tuning forks were used to generate carriers of stable frequency.

By 1933 a successful single-channel system for overhead lines had been developed; single-sideband transmission was employed, and modulation was effected by applying audio signal and carrier together to a metal rectifier.

Single Carrier Channel on Underground Lines.

The first British experiments in the application of carrier operation to land cables were carried out in 1932 on music circuits in the London–Derby cable, lightly loaded with 22-mH coils spaced at 2,000-yd intervals. These tests led to the design of Carrier System No. 2, which provided one audio and one carrier circuit on cable pairs on a 4-wire basis. The amplification of audio channel and carrier channel together in a common repeater focused attention on the problem of intermodulation due to non-linearity.

Introduction of Negative Feedback.

In January, 1934, H. S. Black, of the Bell Telephone Laboratories, had formulated clearly the principle of negative feedback applied to amplifiers. It is perhaps difficult to appreciate to-day the tremendous impact of the negative-feedback amplifier, which offered much improved gain stability and seemed at the time to promise almost literally the elimination of amplifier distortion. Without it, modern systems of long-distance line communication would have been impossible. The way was now clear for a rapid rise in the frequencies used.

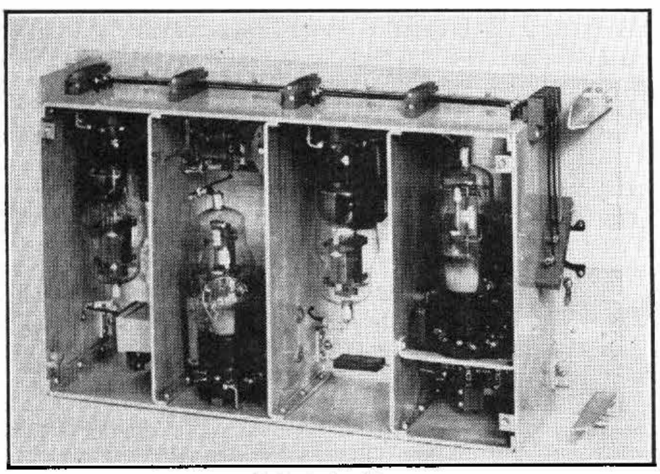
Four Carrier Channels on Underground Lines.

By 1936 Carrier System No. 4 had been developed to provide four carrier channels, in addition to the audio channel, on existing land cables. The two-stage negative-feedback amplifiers covered the frequency range 250 c/s to 16 kc/s, with a gain of 43 dB and harmonics 76 dB below fundamental at an output of 1 mW.

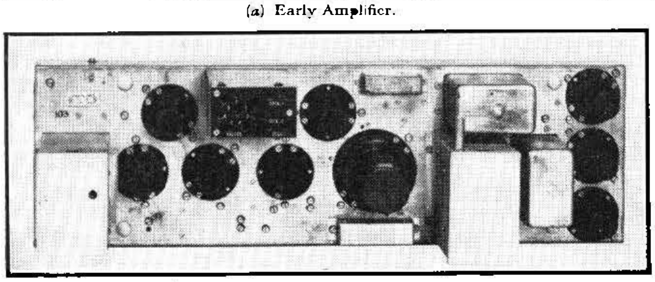
Twelve-Channel Carrier, and Coaxial Cable Systems.

Carrier operation was no longer regarded as a means of obtaining a little more transmission capacity on lines intended initially for audio working; multi-channel systems were now designed as a whole with line plant suited to carrier working. Development of the 12-circuit carrier system using separate "go" and "return" cables with 40-lb low-capacitance pairs was quickly followed by plans for the first coaxial system in this country, between London and Birmingham.

The development and construction of terminal and line repeater equipment for this coaxial system and its successor involved research in many fields—for example, the design of the cables themselves; the development of high-performance valves, and their use in negative-feedback amplifiers, two examples of which are shown in Fig. **10**; the production of quartz-crystal resonators and their application to filters[23, 24]; mathematical work on the transmission properties of coaxial cables[25] and on the effects of non-linearity[26]; and the development of measuring equipment for the wide frequency range involved.[27]



(*a*) Early Amplifier.



(*b*) Modern Amplifier.

FIG. **10**.—COAXIAL LINE AMPLIFIERS.

The majority of the coaxial line amplifiers in use at the present time are based on Post Office designs. In their standard form they transmit the frequency band 60 kc/s to 2,852 kc/s with a flat gain of 48 dB. Change from main to standby amplifier is automatic on failure of a 300-kc/s line pilot. Temperature equalizers are switched in along the line to compensate for fluctuations in cable loss with seasonal changes in temperature.

Transmission of Television Signals by Coaxial Cable.

For the first long-distance television cable link, between London and the Sutton Coldfield station of the B.B.C., a system was developed using 0·975-in. diameter coaxial tubes; two such tubes were provided in the London–Birmingham No. 4 cable, and the link was brought into service in October, 1950. This system was notable for the achievement of a high degree of uniformity in the coaxial pairs, the development of a method of translating the video signals to a suitable frequency range (3 to 7 Mc/s) on an asymmetric sideband basis, and the accurate equalization of delay as well as of attenuation.

Later television links provided in the cable network have made use of the normal $\frac{3}{8}$-in. coaxial tube. The distinction between coaxial tubes and line equipment provided for telephony, and those provided for television, now tends to disappear; the line equipment is capable of transmitting 960 telephone channels as an alternative to a 3-Mc/s video signal. Features of the equipment are line amplifiers with a rising gain/frequency characteristic designed to match the loss of six miles of cable (the normal repeater spacing) very closely over the range 60 kc/s to 4,400 kc/s, and television frequency-translating equipment that employs a double-modulation process to give an asymmetric-sideband signal with the carrier at 1 Mc/s.

Although the first high-definition television broadcasting service in the world was inaugurated in this country in 1936, it is only in the last decade that serious attention has had to be paid to the many difficult problems attending the point-to-point transmission of television signals over cable and radio links. One such problem, which deserves special mention, was that of specifying the maximum permissible amount of linear transmission distortion for each link so as to ensure that television pictures could be transmitted satisfactorily over a chain of links connecting a studio with a broadcasting transmitter. It now seems obvious that a rational specification of this distortion is one of the basic essentials for the economical design of links. However, it was not until 1954 that the first comprehensive but practical waveform method of specification was evolved by the Post Office with the co-operation of the B.B.C.[28]

There were several reasons for the apparently slow progress. In the early days, the link designer used the best available techniques and hoped that the overall performance would be adequate. The steady-state attenuation and phase characteristics were measured but the final judgment of the link was based on a test-picture appraisal. Later, as test-signal generators and oscilloscopes were gradually improved, greater reliance was placed on what were little more than qualitative waveform tests. It is only in the last few years that further improvements of technique have enabled waveform testing to be put on a quantitative basis.[29] At the same time, on the theoretical side, the difficulty of handling the computational problems of tandem-connected links has been reduced by the development of the time-series method of expressing waveform responses.[30,31]

Another reason for the slow progress was the lack of adequate means of synthesizing networks to have specified waveform-transmitting properties. It is still necessary for parts of certain types of television link to be designed and maintained on a steady-state basis. However, this difficulty is to some extent being overcome by the development of waveform correctors of the "echo"[32] and other types. For example, video cable links are now being designed and maintained entirely on a waveform basis, the conventional attenuation and phase equalizers having been supplanted by waveform correctors, which give better results at much less cost.

Many different problems, such as the specification and measurements of non-linearity distortion and noise, remain to be dealt with before monochrome television transmission can be said to be on a sound footing. Such problems are, however, already being overshadowed by the more stringent requirements of colour television systems.

SUBMERGED REPEATERS

Submerged Repeaters for Telephone Cables.

The insertion of repeaters in submarine telephone cables, as a means of increasing circuit capacity, did not receive serious consideration until the late 'thirties because of the very evident unreliability and short mean life of available thermionic valves. Tests then carried out by Post Office staff on specially selected commercial valves engendered sufficient confidence to inspire the design and construction of the first submerged repeater (Fig. **11**), which was duly laid in the Irish Sea in 1943.[33] To ensure a reasonable life, three alternative valves for each amplifier stage could be switched into circuit, as desired, from the land terminal. Later repeaters employed only one valve per stage; but more recently, for example on the transatlantic telephone cable, parallel amplifying paths have been introduced with a common feedback path.[34] Failure of one path does not cause an appreciable degradation of the amplifier.

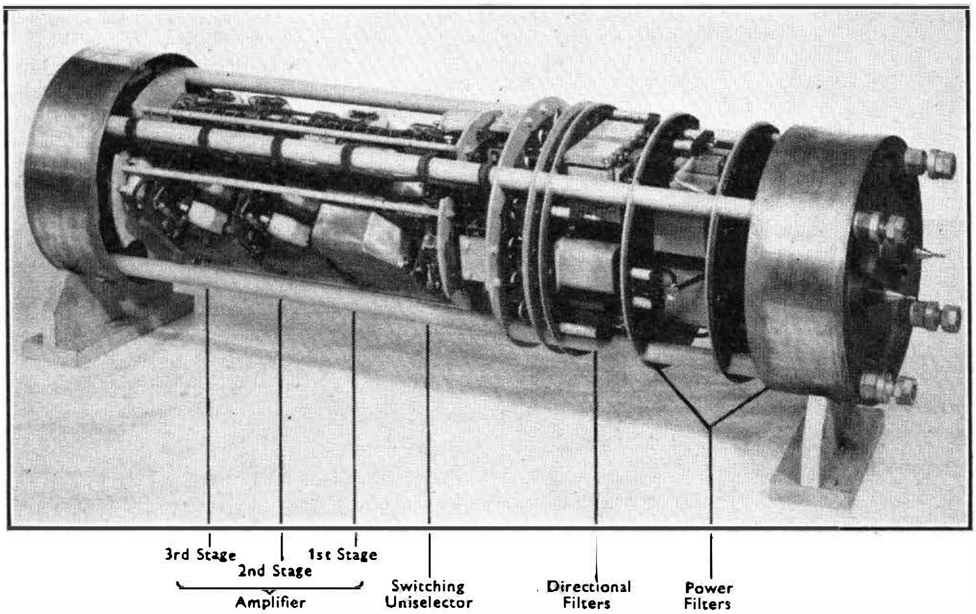


FIG. **11**.—EARLY SUBMERGED TELEPHONE REPEATER.

British submerged repeater experience has been gained on the many comparatively short shallow-water cables round the British Isles[35,36], a number of which are now equipped, generally for one supergroup of 60 circuits. These are single-cable systems using different frequency bands for the two directions of transmission. In the two earliest installations, amplification is in one direction only—that using the higher frequency band. In the remaining installations, amplification is in both directions. The two frequency bands are combined and separated by means of directional filters on each side of a common amplifier. The sea pressure housing has always been of the rigid type, but both the size of the housing and the type of cable-entry gland were unsuitable for use at depths greater than about 250 fathoms.

A smaller-diameter cigar-shaped housing with redesigned glands, developed in 1952, is however satisfactory up to the highest ocean pressures likely to be encountered. In 1953 it was fitted with a new type of gland, developed by the Post Office, which has from its inception proved to be completely reliable. Seven such repeaters have been in service in a cable between the United Kingdom and Norway since 1954.

Fault locating on multi-repeater systems is of first importance and presents a serious problem, but the single-cable technique is found to lend itself well to differentiation between repeaters on a frequency or time basis, as signals in one direction of transmission can readily be made to return monitoring indications in the other band, that are unique to each repeater.

In the matter of equalization, submarine cable schemes differ radically from land systems in that the attenuation/frequency characteristic after laying must be accurately predicted. All attenuation changes due to temperature variations are in practice compensated at the ends of the cable. This has an important influence on system design, but fortunately long cables are almost invariably laid at depths where the temperature is virtually constant.

The successful laying and recovery of conventional single-wire-armoured cables with repeaters in the deepest oceans is not yet fully assured because such cables rotate under tension and can, under certain conditions, form twists which damage the cable.[34] To overcome this trouble, original work has been proceeding to develop a cable which will have no tendency to rotate and yet be cheaper than the present type. Tests on experimental cables appear to indicate that a practical solution will be realized.

The most up-to-date submarine system yet designed and laid by the Post Office is the recent 14-repeater link between Newfoundland and Nova Scotia, which forms part of the transatlantic telephone cable. Under the guidance of Post Office staff, greater care than ever before was taken to ensure the highest possible degree of reliability, and to this end the most meticulous attention was directed to the design, manufacture and testing of these repeaters (Fig. **12**). It is hoped that there will be very few failures in the first 20 years of their working life.

Valves for Use in Submerged Repeaters.

In 1946 an intensive study of the factors leading to thermionic valve failure was initiated. As a result of this work, valves made at Dollis Hill and incorporated in submerged repeaters are regarded as possessing a degree of reliability at least as great as the best of other components, such as resistors and capacitors.

From studies made at Dollis Hill[37-40] and elsewhere it has become apparent that the valves in a submerged repeater are liable to the following forms of electrical failure: decay of mutual conductance; growth of spurious noise; growth of certain stray capacitances and leakances;

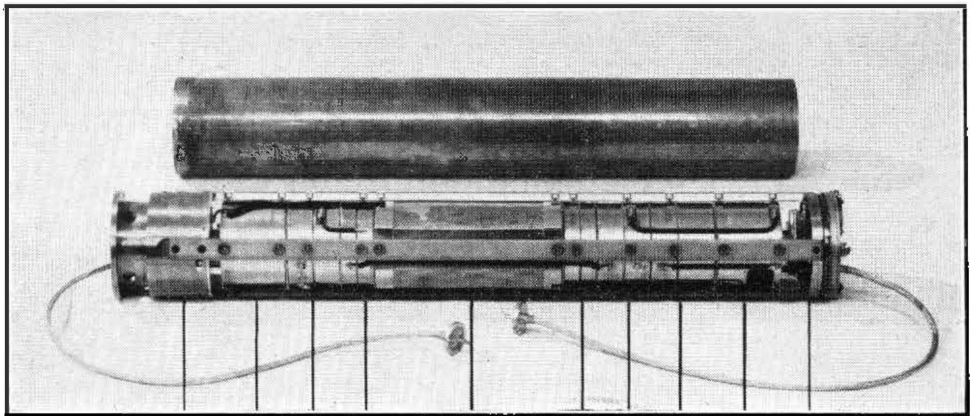


FIG. 12.—THE BRITISH REPEATER USED FOR THE NEWFOUNDLAND–NOVA SCOTIA SECTION OF THE TRANSATLANTIC TELEPHONE CABLE.

growth of grid emission; and failure of heater-cathode insulation.

Experience in experimental valve production at Dollis Hill has shown that the last four types of failure can be eliminated by careful design. In the new G.P.O./10P1 high-slope pentode for submarine work, such design features have been incorporated and the only forms of failure now envisaged are those due to mechanical causes, or to decay of mutual conductance.

Much can be done to guard against mechanical failure by the use of robust structures and suitable combinations of mechanical and welded joints, and of course by meticulous inspection. For wide-band use in cables, however, it is necessary to employ high-slope valves of limited cathode power and this necessarily involves close spacings between electrodes. There remains, therefore, an inherent element of mechanical risk, now mitigated in British repeaters by the use of parallel amplifiers already noted.

Decay of mutual conductance is the basic electrical form of failure and is usually due to growth of a resistive interface between cathode core and oxide matrix, and to destruction of emission by the action of residual gases. The interface-resistance element of failure has been eliminated in Post Office valves by the use of platinum-cored cathodes but the residual-gas hazard remains as the fundamental problem of valve life. The only safeguard lies in rigorous pre-processing of piece parts before assembly and in the employment of adequate pumping techniques.

Submerged Telegraph Repeaters.

In 1947 the Post Office investigated the problem of inserting submerged repeaters into existing single-core telegraph cables in the Cable and Wireless network. The aim was a working frequency band of a few hundred cycles per second. The project was abandoned in 1948, because it was thought that the power supply voltage required to feed several repeaters would break down the cable insulation. This later appeared to have been a pessimistic view.

In 1951 work was begun on a single repeater for use in such cables, in the manner pioneered by the Western Union Telegraph Company.[41] The cables are operated in one direction only, the repeater being inserted on the edge of the shallow-water shelf near the receiving end. At this point the unamplified signal is still fairly noise-free because little of the total noise is induced in the long deep-water section of the cable. The repeater may be up to 200 miles from the receiving terminal, from which power feeding and control are carried out. In 1955 the first two telegraph repeaters designed and constructed at Dollis Hill were incorporated in the Porthcurno–Gibraltar No. 3 and No. 4 cables.

AUTOMATIC SWITCHING AND SIGNALLING

For the automatic exchanges installed up to about 1930, the manufacturers supplied their own particular versions of the basically standard system—the Strowger system, with director working in very large cities. The work falling on the Post Office was largely circuit and durability testing, and was carried out in the newly established Engineer-in-Chief's circuit laboratory in King Edward Building. Research was turned mainly toward magnetic, spring and contact materials and to the analysis and testing of apparatus supplied by the various companies. Out of this work came the very important step of standardizing the relay to be used by all manufacturers.

Relays and Selector Mechanisms.

By 1930 research had demonstrated that a magnetic circuit using an armature pivoted on a knife edge, and with the core head under the armature enlarged, was to be preferred to other designs. It had also been established that for single contacts the fault rate decreased as the contact pressure was increased, that the fault rate was very high for pressures less than about 10 gm and was still appreciable for any pressure which could be reasonably developed in a telephone relay. Twin contacts were much more reliable than single contacts under the same pressure. It was ascertained that rubbing action, as the contacts came together, increased rather than diminished the number of dust faults; and that dust faults were more numerous for springs mounted horizontally than for those mounted vertically, and for relays unprotected from dust than for relays well protected. The desirable features were, therefore, twin contacts on vertically mounted springs, buffered springs to produce a quick build-up of contact pressure, with very little rub between contacts, and a final pressure of 12 to 20 gm, the contacts being operated by a magnetic assembly of the kind described, and enclosed in a well-fitting cover. The result was the 3,000-type relay, which has now endured practically unchanged for over 20 years.

Durability testing was transferred to the Research Branch in 1933 in time to make some contributions to the detailed design of the 2,000-type switch, still the Post Office standard, to the Siemens high-speed motor switch and high-speed relay, and to the trigger-type dial.

Metallic Contacts.

In later research more fundamental work was done on the mechanisms of conduction between metallic surfaces and the behaviour of the molten bridges which are formed.[42]

The need for "wetting" base-metal contacts was early established, but wetting may, under certain conditions, produce microphonic noise. Recent research[43] on the effects of mechanical pressure, wiping action and environment on base-metal contacts has elucidated the optimum conditions for metallic contact, but these conditions necessarily involve high wear. Good contact can be achieved and wear reduced by lubricating rubbing contacts by poly-tetra-fluor-ethylene which, combined with cheaper plating techniques, may eventually make the use of noble metals economical on bank contacts.

V.F. Signalling—Internal and International Systems.

Although voice-frequency signalling was invented in England during the First World War, it had to wait for better valves and more widespread use of automatic switching before it could become commercially attractive, except for the relatively simple 500/20 c/s generator signalling on the early repeatered circuits. Interest revived about 1930, and some work was done by Siemens Brothers and Standard Telephones & Cables in this country. The Post Office became interested in the design of long-distance v.f. signalling and dialling equipment in 1932. High-emission indirectly-heated valves had recently become available and with them notable advances were made in the design of v.f. receivers. In particular, the use of pentodes enabled receivers to be run directly off the 50-V exchange battery. Matters investigated included variations in received-signal levels, imitation of signals by speech, interference by speech and switching transients, effects of including echo suppressors, and the spill-over of signals from one v.f. circuit to another when operated in tandem. After field trials between London and Bristol, what is now known as A.C. Signalling System No. 1[44] became the subject of a Post Office specification and was produced by manufacturers. Operational service commenced in 1939 and was of great value during the war because an appreciable number of long-distance calls could be completed without the services of a second operator. One of the conditions specified for the system was that it should work on 2-wire circuits or between the 2-wire ends of 4-wire circuits. It was realized at the time that a system for use only on the uni-directional channels of a 4-wire circuit would be much simpler, but there were many 2-wire trunk circuits in existence and many of the 4-wire circuits had long 2-wire extensions at the ends.

With the reconstruction of the European network after the war, the need arose for a standardized international v.f. signalling system. The first problem was to obtain agreement on the frequencies to be used. The Post Office constructed an apparatus which, without interfering with service, could be connected to a number of trunk circuits so that the speech on the circuits could be sampled and processed to explore the probability of signal imitation with different signal frequencies, receiver bandwidths, guard coefficients and receiver sensitivities. This apparatus was initially installed in London Trunk Exchange. With the co-operation of the Swiss Administration, the apparatus was later installed and used in Zurich Trunk Exchange for observations to be made on circuits carrying conversations mainly in French, German, and Italian, and many European administrations provided high-quality records of speech in their own languages for analysis by the apparatus. The present recommended international v.f. signalling frequencies are based on this work,[45] and on some similar but less extensive observations in other countries. The C.C.I.F. proceeded to develop and test two semi-automatic v.f. signalling systems, one using two frequencies and the other a single frequency, and these have now been adopted for international working. These are 4-wire signalling systems, the use of which can be expected to increase steadily from now on.

Electronic Switching.

The use of electronic devices in switching circuits had begun some time before the 1939-45 war. Gas-discharge tubes were employed in timing circuits and the laboratories used vacuum-valve circuits for counting pulses. A relay and electronic director was under development, in which the translator was common to a number of register-senders. The possibilities offered by what is now described as "electronics" were appreciated from wartime work which brought Post Office engineers into contact with engineers and scientists in other fields. Artillery predictors, digital computers, code converters and numerous other applications clearly established the versatility of electronic devices. Perhaps more important still, mathematicians had their attention directed to problems then being solved by electronics, and they made notable contributions to the basic concepts underlying the design of automatic machines. The post-war research program included the construction of a large digital computer, subsequently christened "Mosaic," and also an investigation into the possibilities of electronic switching in the telephone system. The Mosaic computer[46] uses ultrasonic pulses in mercury as the memory organ and vacuum valves as switching elements. The basic switching operations are timed at intervals of about 1μs, which is about 1,000 times faster than can be achieved with relays. The large memory capacities and high switching speeds suggested new kinds of register-translators (or directors). A universal director[47] translating any number of codes of mixed lengths was shown to be possible using mercury delay lines, hot-cathode vacuum valves and cold-cathode gas-discharge tubes. The advantages of such a system are most pronounced in a fully electronic exchange. For the first practical trials, experimental directors giving the facilities of their mechanical equivalent were installed at Richmond exchange, in the London director area; these directors,[48] operating at a lower speed and with less memory capacity, have proved a valuable pioneering effort.

Analysis of the electronic exchange problem showed that there were three classes[49] of electronic switches capable of interconnecting speech circuits. It further indicated that the higher speed of switching would make possible new kinds of telephone switching systems; for example, a system in which only one call is being set up at a time. The three kinds of electronic switch were called space-, time- and frequency-division. The space type uses an array of, for example, cold-cathode diodes in horizontal rows and vertical columns, to produce switches very similar in capacity to cross-bar switches, and trunked in much the same way as cross-bar exchanges. Time-division switches use switched pulse-trains, and frequency-division switches use switched sine-wave carriers to effect connexion between circuits, and both generally result in larger switches with fewer stages of selection than the space-division type. In co-operation with our manufacturers, a joint study of the requirements of an all-electronic exchange is being made with the object of producing a working exchange as early as possible.

Components and Materials

One of the most important contributions of research to the development of the telecommunications service is the study of new materials which promise useful applications, and of components and fundamental circuit elements required to enable development engineers to provide new features in the design of systems and equipment. In such a short history as this, it is not possible to do more than mention a few typical examples of work on components and materials.

Filters.

Filters with recurrent sections were first needed in 2-wire repeaters to limit transmission to the band of frequencies for which satisfactory balances could be constructed.

D•

Thereafter, with the coming of multi-channel carrier systems, the use of filters of increasingly sharp cut-off characteristics grew apace. The electrical similarity between simple low-pass and high-pass filters and loaded lines[50] was well known, and provided a starting point for design. During the 'twenties and 'thirties the principles of filter design were developed by Zobel[51] and others[52,53] initially by allowing the tandem-connected impedance-matched networks to have separately controllable loss characteristics. Subsequently these ideas were developed to give greater choice of networks.

The last major development came around 1940 when Darlington[54] described design methods which start directly from the required insertion loss. Such designs are theoretically complete, giving the filter of optimum numbers of components for any normal requirement, but the methods can only be handled by specialists, and involve very heavy computation.

Equalization problems are fundamentally of a more difficult nature and practical equalizer-design methods are still fairly primitive. The Post Office, like other organizations, has given the matter much study; but little improvement has been found on the constant-impedance networks described by Zobel,[55] and designs still proceed largely by graphical cut-and-try methods.

Magnetic Materials.

In some fields of research it is more rewarding to set teams of specialists to study aspects of the same problem than to set them individually to solve unrelated problems. Since the end of the war the Research Branch has included a few teams working in this way. One such team has worked on soft magnetic materials; one result has been a better understanding of these materials as used in telecommunications, and another has been an improvement in manufacturing processes, yielding material of more consistent properties.

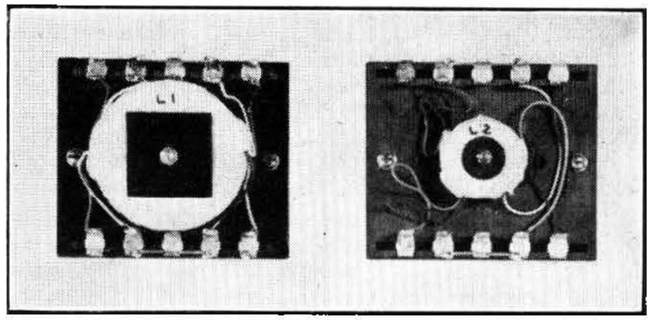
The development of soft magnetic materials really started in the closing years of the last century, when the silicon-irons were discovered. These were the highest class substances available, and they held the field for all purposes until the introduction of the nickel-iron alloys in the years following 1920. The use of nickel-iron alloys in telephone engineering followed the work begun by Elmen in 1913, but it was more than 10 years before they began to be applied. Since then, not only have there been many modifications to the nickel-iron alloys, but also the silicon-iron used for power applications has been improved by the introduction of cold rolling. Using initial permeability as a yardstick the changes over the years are:—

Iron	150
Hot rolled silicon-iron	500
Cold rolled silicon-iron	1,500
Mumetal	20,000
Supermalloy	100,000

In addition to these developments the last ten years have seen the introduction of a whole new series of ceramic magnetic materials, the ferrites, which can be made either magnetically "soft" or "hard" or to have rectangular hysteresis loops.

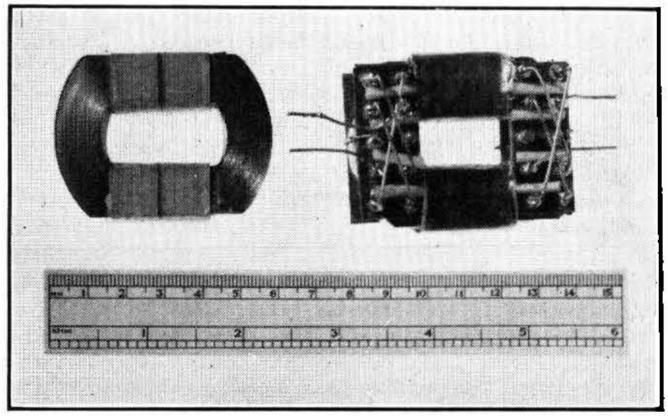
The improvement in initial permeabilities has led to some reduction in transformer sizes (Fig. **13**), and also to the realization of certain transformer designs (Fig. **14**) which would otherwise have been impossible.

Permanent magnets have also changed; before about 1910 they were glass-hard martensitic carbon steels and the years have seen the introduction of tungsten, chromium and cobalt steels, followed by the dispersion-hardening types, which are basically iron-aluminium-nickel-cobalt, some of which can be further improved by cooling in a



(*a*) Core Permeability 5,500. (*b*) Core Permeability 30,000.

FIG. **13**.—REDUCTION IN SIZE OF WIDE-BAND TRANSFORMERS BY THE USE OF HIGH-PERMEABILITY CORE MATERIALS.



NOTE: The response of the transformer is 1dB down at 40 c/s and 2·5 Mc/s.

FIG. **14**.—WIDE-BAND TRANSFORMER WITH HIGH-PERMEABILITY CORE.

magnetic field and by the development of a columnar structure.

The efficiency of a permanent-magnet material is judged by the maximum product of flux and field, $(BH)_{max}$, in the demagnetization part of the hysteresis loop. This quantity has increased from $0{\cdot}18 \times 10^6$ ergs/cm^3 for carbon steel to about 8×10^6 ergs/cm^3 for the most modern alloys, which allows smaller magnets to do the same work. The improvement has been in coercivity rather than in flux density, and this has led to the use of shorter, fatter magnets than those made from the older alloys.

Transistors.

The Bell Telephone Laboratories announced the discovery of transistor action in 1948; they had realized the aims of earlier experimenters, who had attempted to convert dry-plate rectifiers into triodes, by providing a solid-state amplifying device. The discovery was made using germanium, an element which had already made possible a new range of point-contact (cat's whisker) rectifiers. Transistor action can be demonstrated with other semiconductors, but not with selenium or copper oxide, the important constituents of most large-area rectifiers. The structure used in the discovery, two whiskers pressing on the surface of a piece of germanium with their tips very close together, is now called a point-contact transistor and has been in small-scale production. It has been used in some experimental computers, but does not seem likely to become an important component in telecommunications.

Soon after the discovery, Shockley proposed and realized the junction transistor, in which the two metal-semiconductor contacts are replaced by two transitions (p-n junctions) within one piece of monocrystalline germanium. The new structure proved superior in performance as an amplifier and easier to make in a stable and reproducible form.

Audio amplifiers designed by the Post Office are on field trial. One type uses a single push-pull stage and provides a gain of about 25 dB between 600-ohm terminations, with some mixed feedback, and acceptable return losses. A more promising design for use in large numbers uses two stages in cascade with overall feedback; it awaits production of a medium-power transistor, which is at present under development in this country. Other designs of amplifier have aimed at wider bandwidths, e.g. 50-20,000 c/s and 60-108 kc/s; some success has been achieved in the laboratory. Oscillators of good stability have been designed.

What are the advantages of transistors, real or potential? There is no heater and therefore a saving of power consumption; the reduction in heat to be dissipated allows more compact assembly of equipments. Transistors require, in general, low-voltage supplies; electric stresses in accompanying components are less than in valve circuits. Full advantage has yet to be taken of this reduction. Transistors are small and very robust. Insufficient is known of their reliability but confidence is growing that the defects in technology that caused rapid failure in some early units can be eliminated without difficulty and that the residual changes, diffusion of atoms and drift of ions, take place very slowly indeed. When it has been established that transistor lives are adequate, then consideration can be given to their use in equipment not easily accessible for maintenance, such as submerged telegraph repeaters.

The equivalent circuits for the transistor are more complex than those for valves. Circuit analysis is therefore more involved, but the difference is not such as need deter those wishing to take advantage of the small size and low power consumption.

Progress has been made towards the production of practical specifications for transistors as engineering components.

The most recent developments in the junction transistor take it well into the radio-frequency field (reception but not yet transmission); other properties, not much exploited so far, make it a versatile switch.

Electronic engineers seem assured of a new component whose advantages over a wide field of use far outweigh any disadvantages.

Water-Soluble Piezo-electric Crystals.

Other piezo-electric materials besides quartz have been studied with a view to their use in communications. Such materials might either serve as substitutes for quartz (which might become necessary in the future because the continued supply of high-grade quartz crystal is not assured), or give electrical characteristics unobtainable with quartz. Rochelle salt has been used since about 1930 in electromechanical devices (such as loudspeakers and gramophone pick-ups), but its properties are not suitable for its use in oscillator or filter circuits.

The Post Office has produced large crystals of several other water-soluble materials, and examined their elastic and piezo-electric properties in great detail. Generally, their properties change with temperature more than those of quartz, but their greater piezo-electric activity gives a wider choice of equivalent electrical circuits. None of them is as generally useful as quartz, but enough is known about two of them to allow them to be brought into use if necessary.

The Future

The transatlantic telephone cable is likely to be followed by a period of expansion in transoceanic communication by submarine cable, in which, for some years, the techniques of the present transatlantic telephone cable or of the Newfoundland–Nova Scotia cable will be followed. The cost per circuit will be reduced by closer spacing of repeaters (thus increasing the bandwidth transmitted) and by new designs of cable, but the cost of a transoceanic call will remain high. Attention is even now being directed to methods of increasing the number of calls which can be passed during the busy hours. Two lines of attack may be mentioned here which may be used to reduce the cost per call.

That which is perhaps likely ultimately to be most profitable is the transmission of commercial-quality speech within a restricted band of frequencies. The best-known device of this kind is the vocoder, but this requires the use of high-quality microphones and is therefore not immediately applicable to commercial service. Work is in hand on a system in which a substantial part of the speech band is transmitted directly, but is supplemented by vocoder channels derived from the upper part of the band. This shows some advantage over obtaining more channels by restricting the bandwidth, with the consequent loss of speech quality (without supplementary vocoder channels), and might be a short-term expedient. In recent years the analysis of speech in terms of the movements of formants (due to resonances in the vocal tract) has been studied in a number of countries. Work on bandwidth-compression systems based on formant movements has made a promising start in this country, including work at Dollis Hill, but it is as yet too early to predict a successful outcome.

Another possibility of increasing traffic-carrying capacity is to combine the channels of the system into (unidirectional) go and return "pools"; channels being switched as required for the period needed for transmission of speech or supervisory signals. Switching would be controlled by a subscriber commencing and ceasing to speak and by the beginning and end of supervisory signals. Margins must be allowed to ensure that when a channel is required the chance of finding all channels engaged is acceptably small. The traffic capacity of a group of 36 circuits (as in the transatlantic telephone cable) would perhaps be doubled, but with such expensive circuits, speech interpolation equipment might well be justified. This is an example of a problem which, as a result of advances in electronics, is now capable of practical solution.

The high degree of freedom from faults in the repeaters of the transatlantic telephone cable (not approached in normal equipment) has been attained by ruthless testing and selection of every component used and extreme care in assembly. One of the tasks for the future is to achieve a significant increase in the reliability of normal equipment at a cost which will be more than balanced by reductions in maintenance costs and other charges and an increase in revenue due to more efficient service. Chemists and physicists have contributed greatly to the reliability of submerged repeaters and will have an indispensable part to play in improving the reliability of components for the telecommunications system in general. Advances have already been made in designing accelerated life tests of components and in their interpretation. Continued progress and close liaison with manufacturers will be necessary to make possible the design and manufacture of equipment which will have a negligible fault rate over a long term of years.

A number of patents relating to waveguide transmission were published more than 20 years ago, and rectangular waveguides were used in radar equipment during the war. They have since been extensively used as feeders in microwave radio equipment. Comparatively recently significant progress has been made towards the solution of some of the problems associated with the use of circular waveguides, which have the possibility of a particularly favourable attenuation/frequency characteristic. With one of the several possible modes of transmission, above the cut-off frequency attenuation falls as frequency rises. Until recently it seemed that to transmit this mode the accuracy needed in the construction and placing of the waveguides would make their use in commercial service impracticable for long-distance communication. Amplification at frequent intervals will be necessary, perhaps every mile or even more frequently. There are many problems to be solved, but maybe in 10 years' time waveguides will be in competition with coaxial cables and microwave radio links on routes where very large blocks of telephone circuits and many television channels are needed.

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N.B.—A number of the references in "Transmission and the Trunk Network," p. 226, are relevant also to this article.

Buildings for Telephone Exchanges and Repeater Stations

A review of the growth of the Post Office telecommunications services would be incomplete without reference to the main changes that have taken place in buildings used for housing telecommunications equipment. Although equipment is of paramount importance, suitable buildings play an important part in its efficient operation and maintenance.

IT was the general practice of the National Telephone Company to buy or lease existing premises for use as telephone exchanges and adapt them to the needs of the day. Buildings in use ranged from private dwelling-houses to disused factories, and presented many problems to engineers responsible for the layout of equipment, who had perforce to adapt their plans to the assortment of accommodation available. The Post Office, however, even at that time, had some of their buildings designed specifically for use as telephone exchanges by the Office of Works, now the Ministry of Works, though many were combined with Post Offices.

The problem of making the best use of buildings acquired from the National Telephone Company in 1912, and the planning of the first automatic telephone exchange, directed much thought to building requirements. It was appreciated that many of the buildings acquired from the National Telephone Company would have to be replaced if the program for the extension of automatic working was to proceed, as they were either unsuitable structurally or were held on a short-term lease; but the outbreak of the First World War interrupted progress.

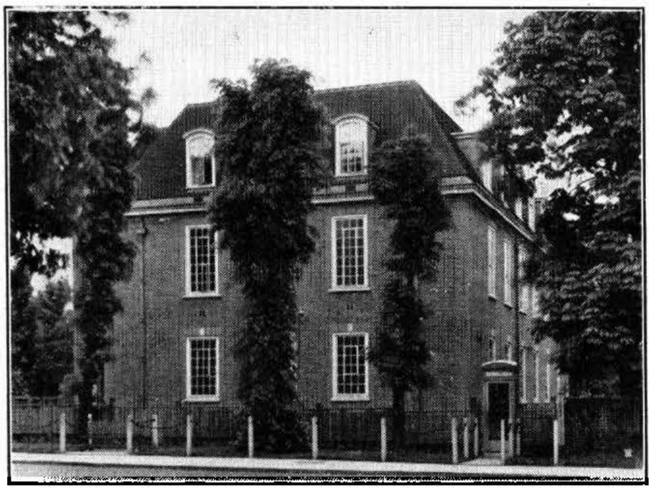


FIG. 1.—LIVINGSTONE TELEPHONE EXCHANGE, NORWOOD, LONDON.

FIG. 2.—RURAL AUTOMATIC EXCHANGE.

After the war, planning was resumed and in 1927 a very large building program was begun in London. The Ministry of Works was responsible for structural design and architecture whilst the Post Office specified the floor areas required and the functional needs to be met. The Ministry of Works architect normally has to produce an exterior aesthetically suited to the character of the neighbourhood and satisfactory to the Planning Authorities. An early building which shows the effect of these considerations is Livingstone Telephone Exchange (Fig. 1), which had to be designed to suit the style of adjacent residences.

Most of the buildings erected under the London program were designed to accommodate equipment for a multiple of 10,000 lines, but some were designed for several units; e.g. Mayfair Building, which housed four exchanges—Mayfair, Grosvenor, Langham and Regent.

During the middle 1920s the demand for telephone service for small communities increased and the need arose for small buildings, first known as Rural Automatic Exchanges (Fig. 2). The Post Office undertook responsibility not only for the internal equipment but for the design and erection of the building itself, and the Architect's

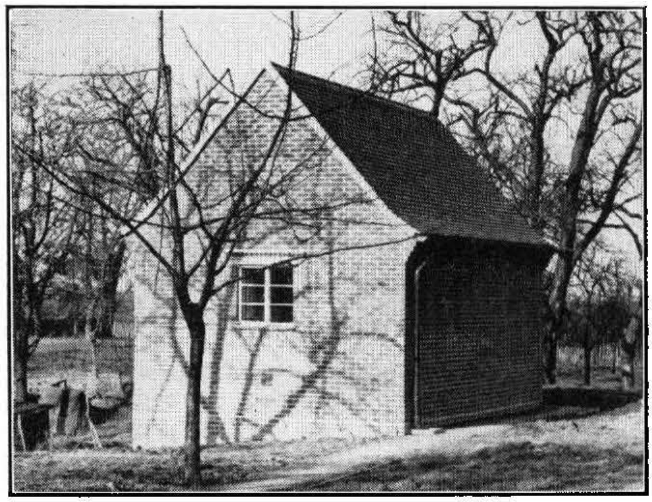


FIG. 3.—BRICK-BUILT B1 BUILDING.

FIG. 4.—F BUILDING.

Section at Post Office Headquarters co-operated with the Engineering Department in the development of a series of small buildings.

The term "rural" became inappropriate, and the title was changed to Unit Automatic Exchange. Three sizes were standardized: 100-line, 200-line and 800-line. The buildings for the 800-line exchange, being much larger than the other two, were dealt with by the Ministry of Works.

Three types of standard building were developed for the 100-line and 200-line exchanges, designated A, B and B1. In addition, each type had three different constructions: brick, for erection generally; stone, for erection in particular rural areas; and a special construction, either brick or stone, for erection on sites liable to flooding. Special features, designed to make these buildings weather-proof, were a steeply pitched roof and double windows. As the equipment was installed in sealed cabinets, these weather-proofing qualities made the provision of heating unnecessary. The space available in type A was approximately 110 sq ft; in type B, 200 sq ft; and in type B1, 300 sq ft. Usable heights were 8 ft, 9 ft and 9 ft, respectively. Fig. **2** is typical of the stone type A building and Fig. **3** shows a brick-built B1 building.

For the 800-line exchange three types of standard building were designed, the D, E and F buildings. The D building is not extendible. The E building and the F building (Fig. **4**), however, can be extended, the former being arranged for vertical extension and the latter for horizontal extension.

The Second World War interrupted development to a lesser extent than had the first. New developments in transmission and radio, accelerated as part of the war effort, required building design to keep in step.

The first standard repeater station building, the R1, had been designed by the Ministry of Works in 1937 and was followed in 1940 by the R2, slightly larger than the R1. During the war a number of temporary huts, smaller than both the R1 and R2 buildings, were used for housing telephone repeater equipment and had been found very useful, and after the war a new standard building, half the size of the R2, was produced. It consisted of a central apparatus room with two small wings, one for use as a battery room and the other as a staff room. This building was designated R3. Fig. **5** shows one of the R3 buildings, which is a very good example of a design that blends with its neighbourhood. Growth of the main trunk network could not be met by the existing range of buildings, however, so two additional buildings, the R4 and R5, were designed in 1951. The R4 is similar in design to the R3 but has a larger apparatus room; the R5 is almost double the size and includes a cable chamber.

The development of coaxial cable systems made further demands on the building program. The repeater spacing for these systems was much less than that required for existing carrier systems, and type R buildings were larger than was necessary to contain the amount of equipment required. A new series of buildings, termed CR buildings, was therefore introduced. There are four types in general

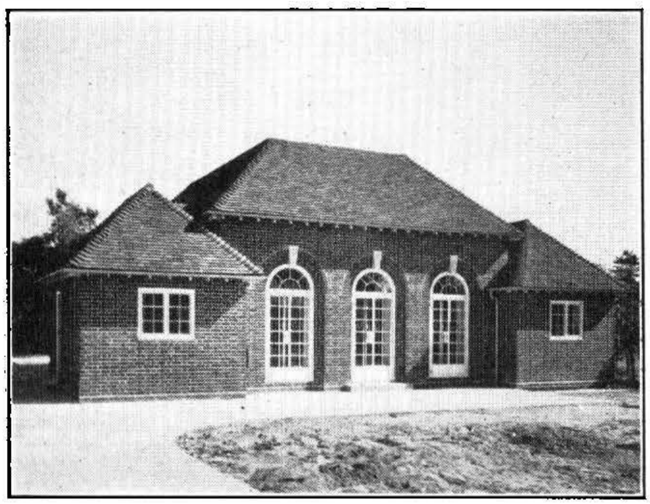


FIG. **5**.—R3 BUILDING.

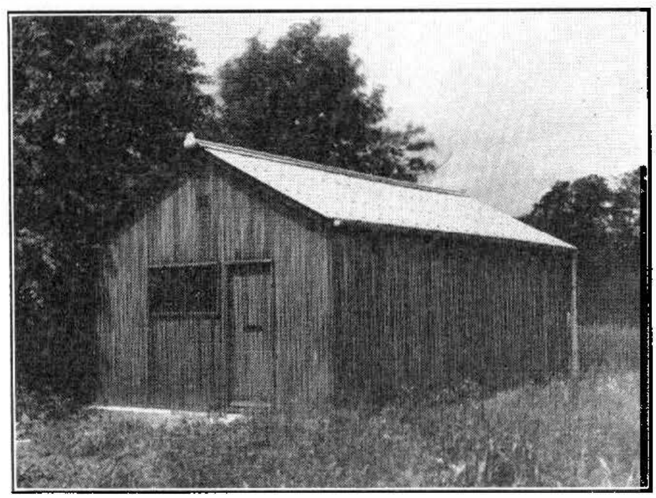


FIG. **7**.—B1 TIMBER BUILDING.

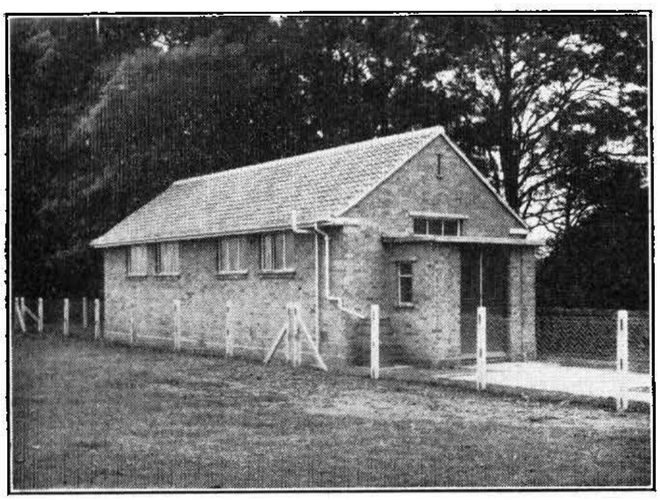


FIG. **6**.—CR6 BUILDING.

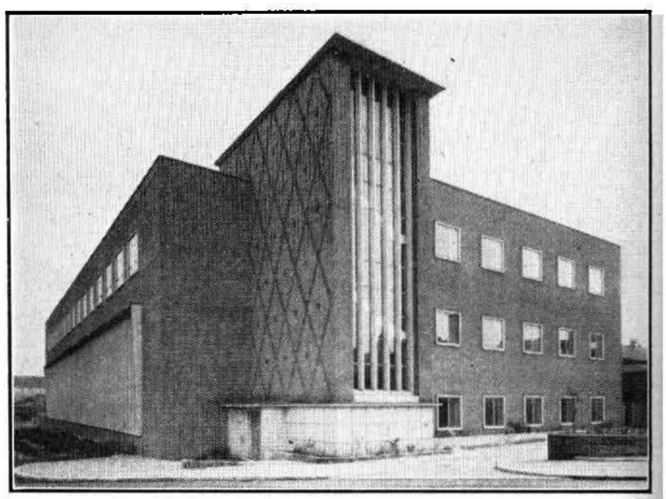


FIG. **8**.—YORK TELEPHONE EXCHANGE.

use, designated CRA, CR4, CR5 and CR6. They differ mainly in the amount of floor space provided. Two different constructions are available for each type, normal brick for general use and a special brick type for flooded areas. Fig. 6 shows the standard CR6 building.

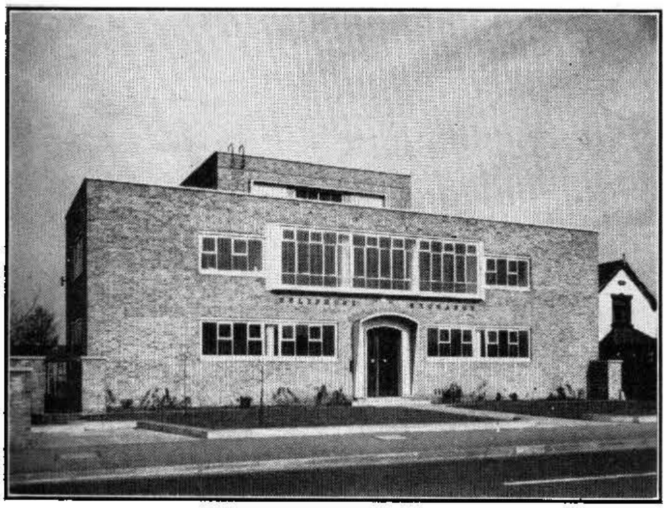


FIG. 9.—FAIRLANDS TELEPHONE EXCHANGE, SURREY.

The steep rise in building costs after the war led to consideration of cheaper forms of construction, especially for the smaller buildings. As timber had been used very successfully during the war, a series of good-class timber buildings was introduced to house the smaller unit automatic exchanges. They are constructed with an oiled hardwood exterior and a corrugated asbestos roof, and are of quite pleasing appearance. The buildings replaced were the brick and stone A, B and B1 types, and the timber buildings are now used in all situations except where severe weather or flooding make them unsuitable, or where the Planning Authority insists on a brick or stone structure. Fig. 7 shows a B1 timber building.

The post-war period has seen the introduction of changes in architectural style, and telecommunications buildings have been no exception. Planning Authorities now, more than ever, insist that buildings must harmonize with their surroundings. Notable among the changes has been the inclusion of large windows arranged as a decorative feature of the exterior, as can be seen in the buildings erected for York Telephone Exchange (Fig. 8) and Fairlands Telephone Exchange (Fig. 9). Fairlands is made additionally attractive by a garden frontage. Architectural extremes may sometimes conflict with engineering requirements, and thus an excess of window area, while attractive, is disadvantageous for apparatus rooms due to loss of heat in winter and intensity of sunlight in summer.

FIG. 10.—CORBY'S CRAG, INTERMEDIATE STATION ON MANCHESTER-KIRK O'SHOTTS RADIO-RELAY LINK.

With the continued expansion of the telephone system and the increasing part radio links are playing in long-distance inland communications, the Post Office is now building a number of radio-relay stations. Since the war a number of stations similar to that shown in Fig. 10 have been erected on routes for single-broadband systems. Future systems will be multi-broadband and will require a greater number of aerials than can reasonably be fitted to a lattice steel mast. Plans are progressing to provide buildings to cater for these requirements, and in co-operation with the Post Office, the Ministry of Works has reached an advanced stage in planning the type of building shown in Fig. 11. The striking and attractive appearance of this design is evidence that aesthetic considerations are by no means incompatible with functional requirements. Tower structures of this type will probably become a feature of main telecommunications centres in many large cities.

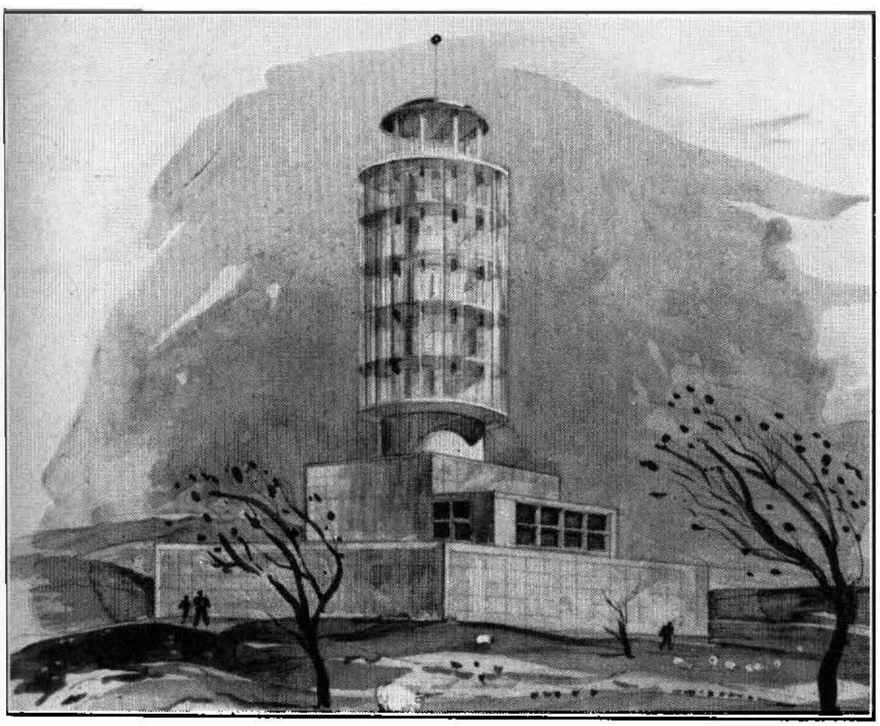


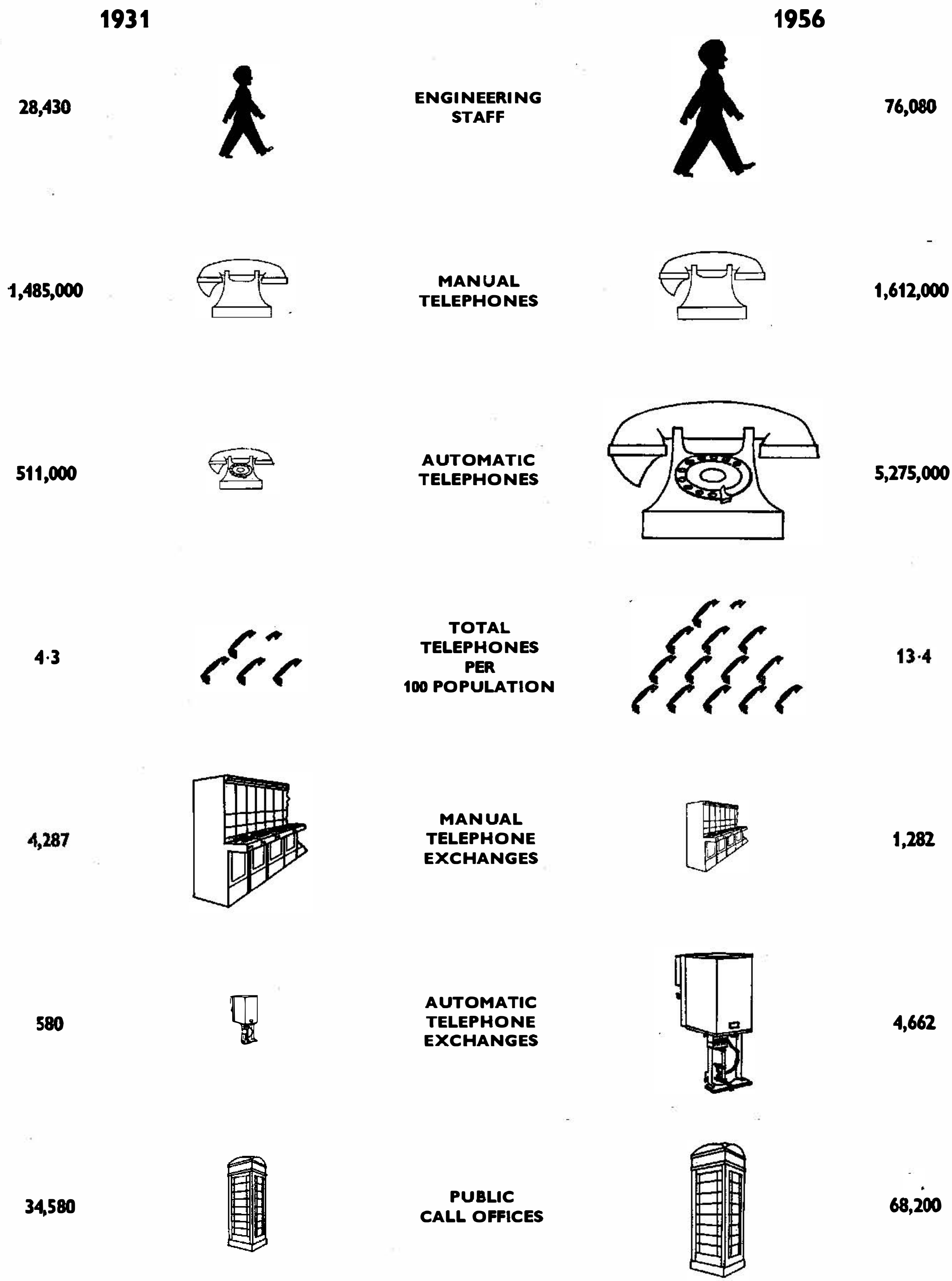
FIG. 11.—SKETCH OF PROPOSED BUILDING FOR MULTI-BROADBAND RADIO-RELAY STATION.

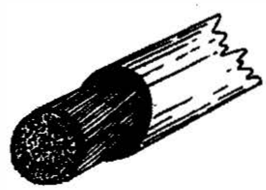
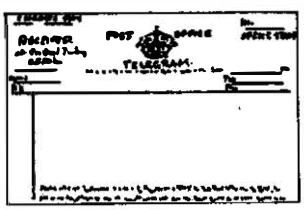
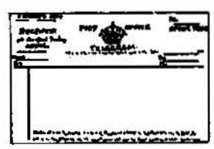
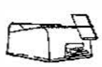
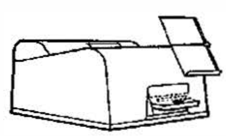
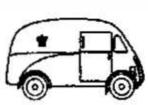
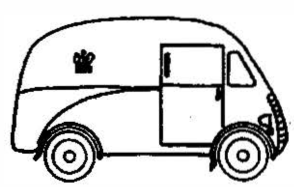
ACKNOWLEDGMENT

Fig. 1, 4, 5, 8, 9 and 11 are reproduced by kind permission of the Ministry of Works.

Change and Development—March 1931 to March 1956

The last 25 years have been chosen because some services were not operating in 1906, and for others suitably related statistics, either Post Office or National Telephone Company, were not available.



1931				1956
3,900		PUBLIC TRUNK CIRCUITS		21,550
B Million		LOCAL TELEPHONE CALLS		3,865 Million
. Million		TRUNK TELEPHONE CALLS		333 Million
541,000		CONTINENTAL TELEPHONE CALLS		1,954,000
4,460		INTERNATIONAL RADIO-TELEPHONE CALLS		107,300
),849,000		INLAND TELEGRAMS		20,547,000
1,500		TELEPRINTERS IN USE ON PUBLIC, PRIVATE AND TELEX SERVICES		8,700
2,560		ENGINEERING MOTOR VEHICLES		18,590

Mechanization of the Postal Services

Over the years, the Post Office has built up a system for the handling and processing of mail which is simple, efficient and adaptable but is based on traditional manual techniques. The increased volume of mail handled in recent years—9,500 million letters and nearly 250 million parcels, against 4,500 million and 100 million 50 years ago—has focused attention on the need for mechanical aids to assist at all stages of the work, but manual methods which have been proved and improved during a very long period are not readily superseded and some still defy the best efforts of the machine designer

Introduction

THE first postal process to be performed by machinery was stamp cancelling. The use of hand-operated machines dates from 1857, but by the beginning of this century the early "Bickerdike" and "Boston" machines, having stamping rates of 130 and 100 letters per minute, respectively, were giving way to the prototypes of the present-day machines.

During the year 1902 an electric dog-cart was employed to carry mails in London; the Post Office was thus one of the earliest users of electric transport on a commercial scale in this country. The first conveyor belt was installed in the Post Office Savings Bank in 1902; this conveyor, which is still in use, though in a different location, is illustrated in Fig. 1.

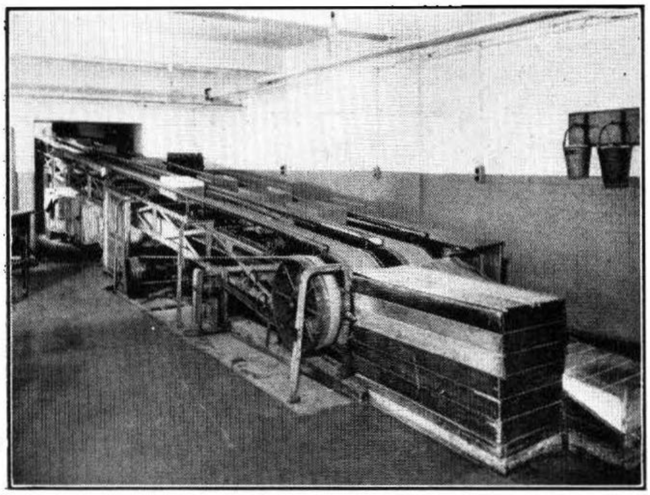


Fig. 1.—The First Conveyor Belt in the British Post Office (with Guards Removed).

In 1910 further consideration was given to the potential uses of postal conveyors, and the year marked the completion of King Edward Building, which now accommodates the London Chief Office Public Counter, the headquarters of the London Postal Region and large sorting offices occupying several floors. This building was equipped with the most extensive mechanical-handling plant installed by the Post Office up to that time: three letter-bag conveyors, one letter-tray conveyor, a double-track rope-way with carriers for trays of letters, and six facing-table conveyors.

During the ensuing 15 years several offices were provided with internal conveyors and with facing and bag-opening table bands, but the next office to be systematically mechanized was the Manchester Parcel Office, in 1925. Two rising conveyors brought the parcels from the loading platform to the first floor and discharged them into trolley baskets from which they were sorted into a nest of 12 chutes, giving access, via conveyors, to the secondary sorting positions (known as "roads") on the floor below.

In 1927-28 the Inland Parcel Office at Mount Pleasant,[1] London, was mechanized. Parcels, brought by two conveyors from the loading platform, were diverted from the belts to a long sloping storage bank (known as a glacis) on which they awaited primary sorting. The parcels were sorted via multiple hoppers on to seven distributing conveyors serving the busiest of the secondary roads. The middle 'thirties saw the completion of the letter office at Mount Pleasant which, with bag conveyors, selective tray conveyors for letters and a packet conveyor system was, at that time, undoubtedly the largest and best equipped mail-handling office in the world. Unfortunately, the parcel installation was destroyed by enemy action in 1944, and has been only partially replaced.

Birmingham Parcel Office, London South Eastern Parcel Office,[2] Liverpool,[3] Newcastle,[4] Bristol[5] and Nottingham Sorting Offices were all mechanized in the 1930s, and the first twin-band riser was installed in 1933 at Crewe; all these installations are still in use after 20 years.

The Processing of Mail.

It may be helpful to recount the stages in the progress of mail from posting to delivery. Slightly different treatment is accorded to certain special categories of mail; e.g. prepaid postings and registered items, but the principal stages in the treatment of ordinary mails are:—

- (i) Collection.
- (ii) Segregation of short letters, long letters and packets.
- (iii) Facing (letters only), i.e. stacking with the stamps in position for cancellation.
- (iv) Stamp cancelling, by machine (letters only) or by hand.
- (v) Sorting.
- (vi) Collection from the sorting frames and (for letters) tying bundles.
- (vii) Bagging, followed by tying, labelling and sealing.
- (viii) Movement of bags by road or rail transport.
- (ix) Bag opening and further sorting at forwarding or delivery offices.
- (x) Delivery to addressee.

Packets, after segregation at stage (ii), are re-associated with letters at stage (vii).

Parcels are treated independently (sometimes in a different room or building) but follow the same essential processes of stamp cancelling (by hand), sorting and bagging.

Scope for Mechanization

The greatest scope for mechanization is in the carrying of mail as it passes through successive processes within a sorting office. Conveyors are used for the movement of letters, packets and parcels, loose or in bags. Their function may be to transport mail to and from a loading bank, to distribute mail within a sorting-office (often between floors), or to serve the processes of segregation, facing and stamping. Where justified by the volume of business, conveyors may also be provided for clearing posting-boxes at large post offices and for transport to and from a nearby railway station. Conveyors of one form or another therefore constitute the most extensively-used major items of mechanical equipment.[6]

Stamp-cancelling machines for letters are used in all but the smallest offices. A few are also employed for bulk postings of books and similar objects. In recent years large firms have made increasing use of meter franking machines, over 25,000 of which are now in use in this country. Nearly 20 per cent of the letters posted to-day are machine-franked: these items do not require stamp cancellation. No mechanical method has yet been devised to obliterate postage stamps on packets or parcels of varying size, weight and shape.

Considerable research effort has been concentrated, in this country and abroad, on the task of designing letter-sorting machinery. Whilst it may ultimately be possible, under favourable circumstances, to design a machine which will sort letters by scanning a printed address, it seems certain that in the foreseeable future operators will be necessary to read and translate addresses into suitable codes. With this limitation in mind, the ideal should obviously be for each letter to be looked at once only (at the office of first sorting) and to be code marked in such a way that all subsequent sorting, including that in forwarding offices and at the office from which it is delivered, can be performed mechanically.

Mechanical aids have been tried for some of the subsidiary processes. Several proprietary bundle-tying and bag-sealing machines are available, but unless they are provided on such a scale that every user has one close at hand, the time spent in walking to the machine may exceed that saved by its use. A possible addition to a letter-sorting machine would be a device to tie and eject the bundle of letters from each sorting hopper as it became full.

A number of bag-opening aids are in use. Experimental machines for segregating letters and packets and for facing letters have been constructed, but whilst a measure of success has been achieved no machine yet satisfies all requirements.

The essential processes which at present cannot be mechanized, particularly the major operations of collection and delivery, absorb a large proportion of the total postal force and the field in which manpower can be saved is limited accordingly.

A Mechanical Aids Committee, presided over by the Director-General, keeps under review the various types of postal engineering apparatus available in this country and abroad, authorizes research and development work in this field, and determines the extent to which machinery shall be employed in sorting offices.

Investment in mechanization is influenced by the fact that postal traffic is timed to a tight schedule to meet the public demand for early deliveries and late collections, and the exigencies of road and rail transport. There are two short-duration traffic peaks in the late afternoon and early morning. The machinery must cater for these peak loads, and can, therefore, be used to maximum economic advantage only for a few hours each day. Some special considerations apply to the design of postal aids. The very varied assortment of articles presents unusual difficulties and has greatly retarded mechanization. Furthermore, postal apparatus must not lose, injure or destroy any item whatever and in this respect is different from industrial plant, in which a small amount of wastage and damage can usually be tolerated.

Machinery Used in Postal Processes

Conveyors.

From the wide variety of commercial conveyors only a few are found by experience to be suitable for postal work. In sorting offices, flat-belt conveyors are chiefly used, from the 10-in. wide facing-table conveyor to the 48-in. wide parcel-bag conveyor. Solid-woven cotton or soft cotton-duck belts are preferred unless exposure to weather necessitates the use of rubber. Where ploughs or diverters are used to discharge mail sideways off a belt, the low coefficient of friction of nylon or steel belts is advantageous. Cotton belts are from $\frac{1}{8}$ in. to $\frac{3}{8}$ in. in thickness and are commonly jointed by toothed metal fasteners, though sewn or adhesive joints are used in some applications. Load-carrying belts are supported on steel bedplates or on idler rollers; the return half of the belt is usually carried on idlers. Rollers are of the enclosed ball-bearing type, and on recent installations oil-filled "sealed for life" types have been used to reduce the need for routine maintenance. Electric motors are coupled to the driving rollers by "Vee" rope or chain reduction gearing, or by integrally-mounted worm gears.

Cotton belting can be used at inclinations up to 17 degrees. When a conveyor is steeper than this the surface of the belting is treated to ensure adequate frictional grip on the load, and for this purpose pile-faced, latex-coated or grip-face ("knobbly" rubber) surfaces are used. The last-mentioned is suitable for angles up to 30 degrees; an illustration of its use is given in Fig. 2, which is a photograph

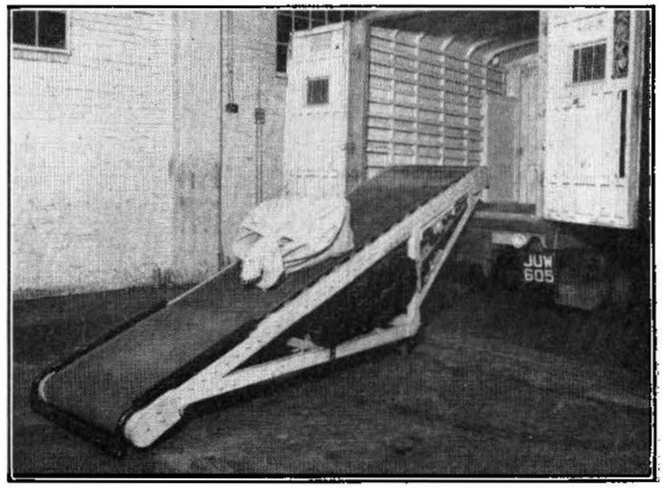


FIG. 2.—VEHICLE-LOADING CONVEYOR.

of a transportable self-contained conveyor designed to assist the loading of vehicles. About a score of these conveyors are in use, many at provincial sorting offices where there is no loading platform.

When the angle of rise exceeds 30 degrees, twin-band conveyors are employed. These can carry loose or bagged mail at inclinations up to 60 degrees and have the advantage of occupying less floor space than slow risers. The load is prevented from slipping back on the steep band by a second belt which presses down upon it. This upper belt is weighted by transverse iron bars enclosed in pockets; it is loose enough to hang in folds and thus enwrap the load, and is driven at the same speed as the load carrying band. Attempts are still being made to perfect a vertical twin-band conveyor, but up to the present time no continuous vertical conveyor has been adopted operationally.

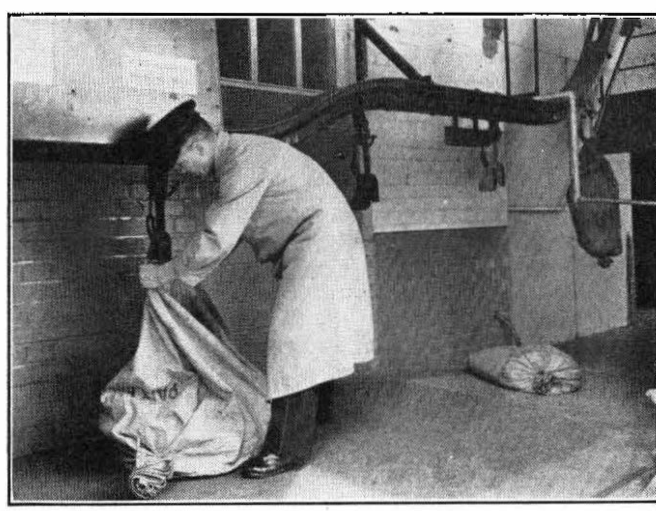


FIG. 3.—CHAIN CONVEYOR AT LEAMINGTON SPA SORTING OFFICE.

The first operational chain conveyor in the British postal service was installed in December, 1955, at Leamington Spa sorting office. Part of the conveyor is illustrated in Fig. 3. Attached to the traction chain are self-gripping carriers to hold the mail bags. The system incorporates selective discharge arrangements so that letter and parcel bags put on a single conveyor at the loading platform may be discharged in different parts of the building. Whilst it is a little more difficult to load a chain conveyor than a flat belt, the former can more readily deviate from a straight line route to suit the configuration of the building; furthermore, it can rise vertically, is almost impossible to overload, and, once the bag is on the chain, bag opening (see Fig. 4) and other ancillary operations are facilitated.

Fig. 4.—Bag Opening from a Chain Conveyor.

The use of roller conveyors is seldom practicable for loose mail or bags, since small or awkardly-shaped items may be trapped. Rollers are suitable for carrying trays or other rigid objects; they may be power-driven or gravity-operated at a descending angle of a few degrees.

Lifts, Elevators and Gravity Chutes.

Bucket elevators, skip hoists and tray elevators[7] have been tried, but each of these devices has shortcomings for postal duty and few have been installed. The most commonly used vertical transporters are, of course, electric lifts, which are provided in sorting offices for carrying passengers and for the movement of registered mail and high-value packets under escort.[8] In some of the smaller offices lifts constitute the only means of taking mail to an upper floor; in others they serve as a standby for use in the event of breakdown of a belt system. The larger lift cars are designed to accommodate two or more mail-carrying trolleys.

Gravity chutes afford controlled descent for material despatched from the upper floors of a building. They are constructed of steel plate or hardwood in straight, curved or spiral form. A chute or spreader is also placed beneath the end roller of a conveyor to control the descent of the discharged mail which must, however, fall clear of the roller as quickly as possible to prevent damage by chafing on the moving belt. To minimize obstruction, a chute may be retracted upwards or sideways about a suitable pivot when not in use.

Stamp-cancelling Machines.

The high-speed stamp-cancelling machines of to-day can stamp 700 letters in a minute. Their design has changed little during the period under review, but it is now being critically examined with a view to incorporating automatic feeding and stacking. An important subsidiary function of the stamp-cancelling machine is to count the letters, and a machine that gives sampling facilities for statistical purposes is now on trial.

Photo-electric or mechanically-operated recorders are also available to count packets, and a continuous-weighing machine,[9] to weigh mail bags moving on a conveyor belt, was tried shortly before the Second World War.

Letter-facing Machines.

The complete process performed at a manual facing table, on mail collected from posting boxes, consists of the removal of packets and outsize letters, separation of the remainder into "long" and "short" letters, and arrangement of these with the stamps in the bottom left-hand corner ready for cancellation. Printed matter has sometimes to be extracted. The whole task is simple but tedious, yet its complete automatization presents formidable difficulties, not all of which have yet been satisfactorily solved.

The basic design of the manual facing table has varied little for half a century. In 1910 tables with double conveyors for carrying letters and packets to opposite ends were installed in King Edward Building, and although trials were made at Birmingham (1910) and Liverpool (1913) with alternative designs, and again in 1916 on an American (Cummins) pick-up table, it was decided that the King Edward Building type was most suited to British requirements. Quite recently, a twin-conveyor facing-table of tubular steel construction has been designed (see Fig. 5).

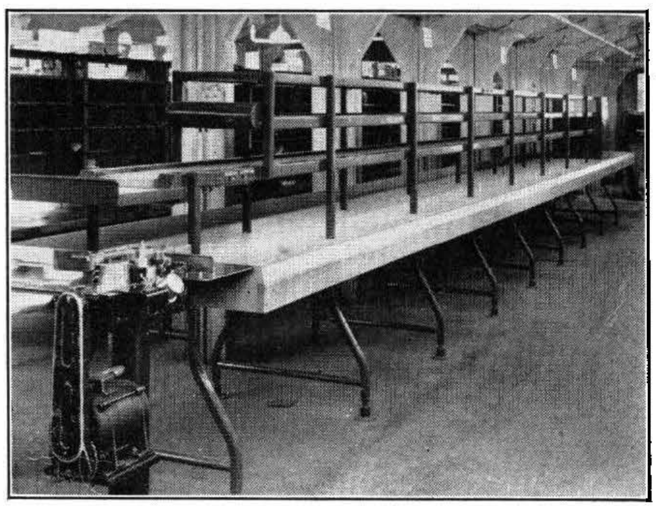


Fig. 5.—Tubular Steel Facing-Table.

This has a better and more modern appearance and its driving mechanism is totally enclosed and clear of the floor.

Research by the Post Office into automatic facing began in 1934 on the basis of stamp detection by photo-electric means. A little later, in collaboration with Sovex, Ltd., research into the segregation of packets, etc., and the presentation of the letters to photo-electric scanners was commenced. After the war the facing machine was completed and tested, but the scanners, which employed simple photo-cells and reacted to unevenness in the light reflected from a surface partly covered by a stamp, were also affected by crinkles and warps in the envelope and by certain textures of paper. The signal-to-noise ratio was also inadequate. Mechanically, the machine was no better as the manipulation necessary in two twisting sections and a reversing section caused letters to bounce and lose position.

A second facing machine was constructed during 1949-50, employing photo-multiplier cells which made absolute measurements of reflectivities. With yellow-green illumination of a narrow wave-band, all the lowest-value stamps gave approximately equal reflectivities, lower than that of a buff envelope. The letter-reversing mechanism was avoided and only a single twisting section employed. This machine gave an encouraging performance at speeds up to 480 letters per minute.

The study of printed-paper segregation was resumed in 1952, and trichromatic (blue, red, green) and dichromatic (blue, red) scanners were developed which could segregate letters bearing only a green three-halfpenny stamp with fair accuracy.

Consideration has also been given to alternatives to photo-electric stamp detection.

A packet segregator was completed before the 1939-45 war but it proved unsuccessful. More recent research on packet segregation, and on other operations which precede facing, shows encouraging progress, however, and work is now being directed to the provision of a complete equipment for live traffic trials.

The Development of Sorting Machines.

Letter sorting.—The wooden sorting fitting with its 48 pigeon-holes is familiar to all who have been in a sorting office. This device is simple, effective and adaptable, but its use demands not inconsiderable physical effort and the number of selections cannot be increased without causing disproportionate fatigue to the sorter when reaching to the outer compartments. Early attempts to design letter-sorting machines were not successful. The first machines to be tried in a British office were two Dutch "Transorma" machines[10] installed at Brighton in 1937. These incorporate carriers moving on an endless track, which distribute the letters in accordance with a pre-set code, via chutes, into 250 box receptacles. The code is set by an operator who, having read the address, inserts the letter into the carrier and with his left hand impresses two figures on a keyboard. Whilst the machine has worked satisfactorily certain of its technical and operational characteristics are open to criticism, and experiments to find a better system have continued.

In 1938, and again in 1946, studies were conducted at the instance of the Mechanical Aids Committee into the problem of mechanical letter sorting and as a result it was decided to begin research upon a multi-position letter-sorting machine, and also on the code marking of letters by fluorescent or phosphorescent means. It eventually became apparent that a single-operator machine suitable for many smaller offices gave promise of quicker development, and effort was accordingly concentrated on this machine. Construction of an experimental model using drag-belts was abandoned in favour of the use of roller conveyors which gave more-positive drive with less risk of slip. Many difficulties had to be overcome before a model was ready for live traffic trials, which began at Bath sorting office in October, 1955. The machine (see Fig. 6) has 133 boxes on five levels, the heavier selections filling two or more boxes in automatic succession. The operator sits facing one end of the machine and a long horizontal input stack is accommodated between two of the selection-box levels. The letters are presented to the operator by a spiral device which makes one revolution whenever a code is keyed. The operator is not tied to the machine rhythm, but can key at any time subject to a maximum rate of 80 letters per minute. If he makes a mistake he can recover the letter by pressing a "cancel" key. Simple gravity stacking is used in the selection boxes. Although it was originally intended to exclude electronic devices, the control system eventually adopted was a combination of simple electronic elements and electromagnetically-set pin-wheels, the level and box diverters being actuated by the pins. The machine, which is 16 ft long, $2\frac{1}{2}$ ft wide, approximately 6 ft high and weighs $2\frac{1}{2}$ tons, can be transported as a complete unit and brought into service very quickly. In use at Bath, the machine has handled up to 26,000 letters per day, with negligible mis-sorting.

In 1947 the Post Office set up a laboratory unit at Mount Pleasant, which undertook, concurrently with the above, the development of a 6-position letter-sorting machine giving 120 selections. Little knowledge existed on which to base the design, and the new unit had to establish its own techniques. To-day there is a well-equipped workshop with adequate records and a film library of experimental work done in connexion with letter sorting. During the progress of this work research was also being carried out at Dollis Hill, on electronic memory techniques, and it was decided to incorporate such a memory in the multi-position machine. During the period 1953-55 the machine completed a series of operational tests. Whilst these showed the ease with which letters may be sorted by an operator when divorced from machine rhythm, further development work was shown to be necessary to perfect the mechanical performance.

To assist in the training of operators for sorting machines a training machine has been built. This incorporates replicas of the keying and viewing units of the sorting machine and uses a large number of addressed cards, each bearing a coded indication of the correct way to sort it. These cards are presented singly in the aperture, and if the operator depresses the correct sorting keys the card is released and replaced by another. If he keys incorrectly, a buzzer is heard; the correct sorting code can then be made to appear on a display panel if required.

Packet stamping and sorting.—Despite a number of proposals for the mechanical

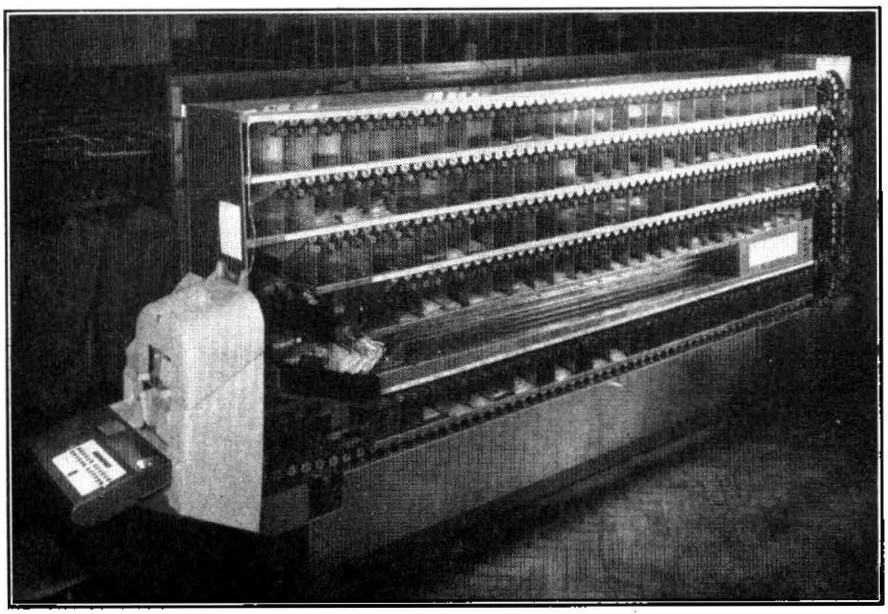


FIG. 6.—SINGLE-POSITION LETTER-SORTING MACHINE.

clearance of packets from stamping tables, e.g., the Cromo sorter (1900) and the Spencer apparatus (1917), the basic design for the manual stamping table has remained unchanged for many years. Normally, the packet-stamping table is located at the end of the facing-table remote from the stamp-cancelling machine, and receives the packets deposited by the facers on the upper conveyor belt. In a number of offices under-floor conveyors, fed via retractable chutes in the sides of the stamping tables, have been provided to link the latter with the primary sorting position. Counting devices (photo-electric and flap types) have been developed for use in conjunction with these installations.

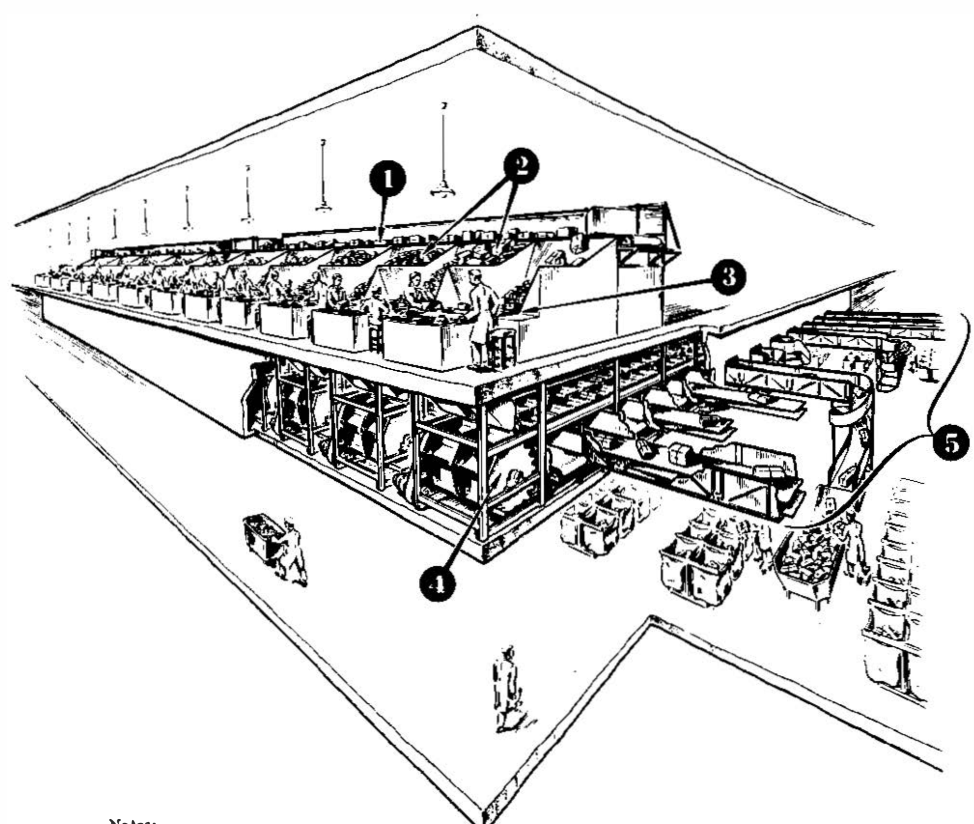
Three automatically-cleared packet-sorting machines manufactured by Messrs. Sovex, Ltd., were installed at Mount Pleasant in 1934.[1] The packets, received in baskets from two stamping tables positioned in the spaces between the three sorting machines, are sorted into 24 boxes arranged in four rows of six. Each box is about 12 in. × 12 in. × 12 in. Every box is emptied, at a predetermined time in a 3-minute cycle, by the opening of a hinged flap in its base and its contents then discharge on to a conveyor running beneath the row of boxes. By synchronizing the operation of diverters on these conveyors with the times of opening of various sorting boxes the packets are routed to the appropriate secondary roads. Each sorting machine incorporates nine groups of 24 boxes and the three machines (27 groups of boxes) can accommodate 108 sorters.

Parcel sorting.—Mention has already been made of the method of sorting parcels at Manchester. At Birmingham, a similar sorting and disposal system is used, but parcels are sorted into a nest of hoppers located between two glacis. A single long glacis was built at the London S.E. Parcel Office, but here there are multiple nests of hoppers parallel with and adjacent to the glacis. These three offices mark stages in the evolution of a technique for partial mechanization; i.e., the conveyance of parcels to and from manual sorters.

To eliminate the physical effort entailed in placing the parcels in one of a number of sorting receptacles the Post Office made experiments at Paddington office in 1937 with a Sovex parcel-sorting machine. The operator of this machine works beside a pair of trap-doors upon which, after reading the address, he places the parcel. He then presses a button corresponding to the secondary road for which the parcel is destined; this opens the trap-door and allows the parcel to discharge into one of a continuously-moving chain of hoppers. Electromechanical control mechanism ensures that at the appropriate point the hinged bottom of the hopper is opened and the parcel drops on to a cross conveyor which carries it to the secondary sorting position.

Development work on this machine was resumed in 1948 at Mount Pleasant, and it is now suitable for operational use. As will be seen in the perspective sketch (Fig. 7), the system lends itself to a three-floor arrangement. The capital cost and space occupied are, however, such that it can be justified only in the largest sorting offices. Research on the development of a smaller machine is in progress.

Parcels occupy a great deal of space in a sorting office. They can be stored in trolley baskets in which they can be parked or wheeled to the next point of treatment, but there is always a limit to the number of baskets that can be accommodated. In such circumstances it is usually more economical to install a storage glacis. As the name implies, this is a large sloping bank, inclined at about 30 degrees, and having a horizontal conveyor along the top from which the parcels can be pushed on to the slope by means of hinged diverters or a power-driven plough.[11] At the lower end there is a reverse slope and a stop-board. On such a glacis, 9 ft high and 100 ft long, about 4,000 parcels can be stored. Considerable experimental work has been done to determine the most suitable design from the point of view of storage capacity and method of presenting the parcels to the sorter.



Notes:
1. Incoming parcels for sorting.
2. Parcel storage spaces.
3. Feeder belt (operator-controlled).
4. Selective bucket conveyor (one per sorting position).
5. Belt conveyors to secondary or sorting or bagging (each collecting from all bucket conveyors).

FIG. 7.—SOVEX PUSH-BUTTON PARCEL-SORTING SYSTEM.

Bagging of Mail.

The final processes are bagging, tying, labelling and sealing. No machine has yet been developed that will discharge mail, especially parcels, into bags. From an engineering viewpoint, bags are a brake on mechanization; it would be preferable to use rigid containers of standard dimensions suitable as storage and sorting receptacles in the office, and for movement on railway or road vehicles and fork lift trucks. Apart from the capital cost, however, there would be numerous operational difficulties to overcome if bags were abandoned in favour of containers.

Bag-cleaning machines are installed in a number of large sorting offices, and a random selection of the bags passing through these offices each day are cleaned. The earlier Eureka suction cleaner[12] has been superseded by the drum-type machine illustrated in Fig. 8. Dirty bags, in a wooden container,

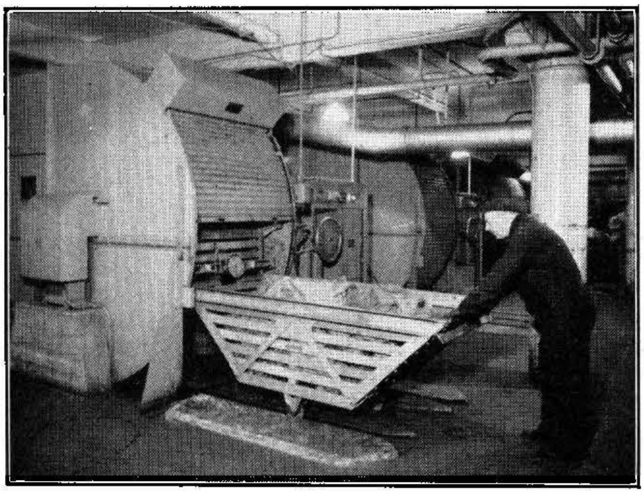


FIG. 8.—BAG-CLEANING MACHINE.

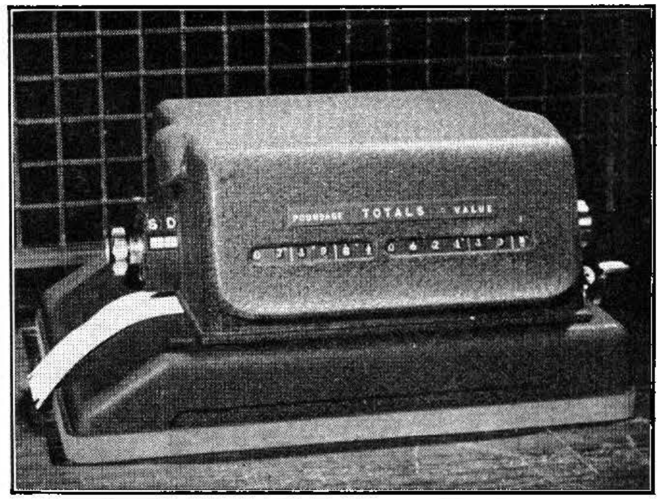


FIG. 10.—POSTAL-ORDER ISSUING MACHINE.

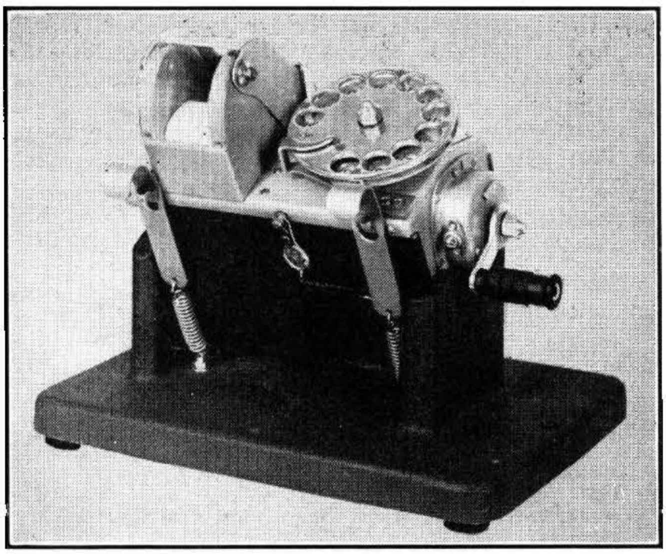


FIG. 9.—PARCEL-LABEL ISSUING MACHINE.

are placed in a large drum which is then rotated. Dust released by the tumbling of the bags is extracted by suction. The cleaned bags and their container are then removed.

Counter Mechanization.

Factors such as noise, counter design and layout, security and accounting records have all to be considered when designing counter aids. The speed of reaction of the public, for example, in picking up change or in making way for others, may limit the effectiveness of these devices. The several types of stamp-selling machines (operated by the customers) are well known, but there are also machines for the use of counter clerks.

Single-denomination and six-denomination stamp emitters accommodate rolls of stamps from which a small number can be issued by flicking the milled edge of a small wheel.

Parcel-label issuing machines[13] (Fig. 9) are designed to issue, at the turn of a handle, an adhesive label for any value up to 19s. 11d. in one penny steps. The label, instead of an ordinary stamp, is fixed to a parcel. A general view of a postal-order issuing machine[14] is shown in Fig. 10. It is designed to issue postal orders of any value from 6d. to 21s. 11d., in one penny steps, and prints the selected value and the appropriate poundage on paper strip, on which all standard information has previously been printed during manufacture. The advantages of both machines lie in eliminating the need for multi-denominational stocks, and their totalizing meters simplify accounting.

Experiments with change-giving machines have indicated that these offer little advantage over the ordinary cash till, but some 300 coin-counting machines are used to assist the staff in the laborious task of counting cash takings, particularly the large volume of copper coin recovered from stamp-selling machines and telephone call-offices.

TRANSPORT OF MAIL BETWEEN SORTING OFFICES

Although air transport is playing an increasing role in the movement of mails to overseas destinations, by far the greater part of the inland conveyance of letters and parcels is undertaken, under contract with the Postmaster-General, by British Railways.

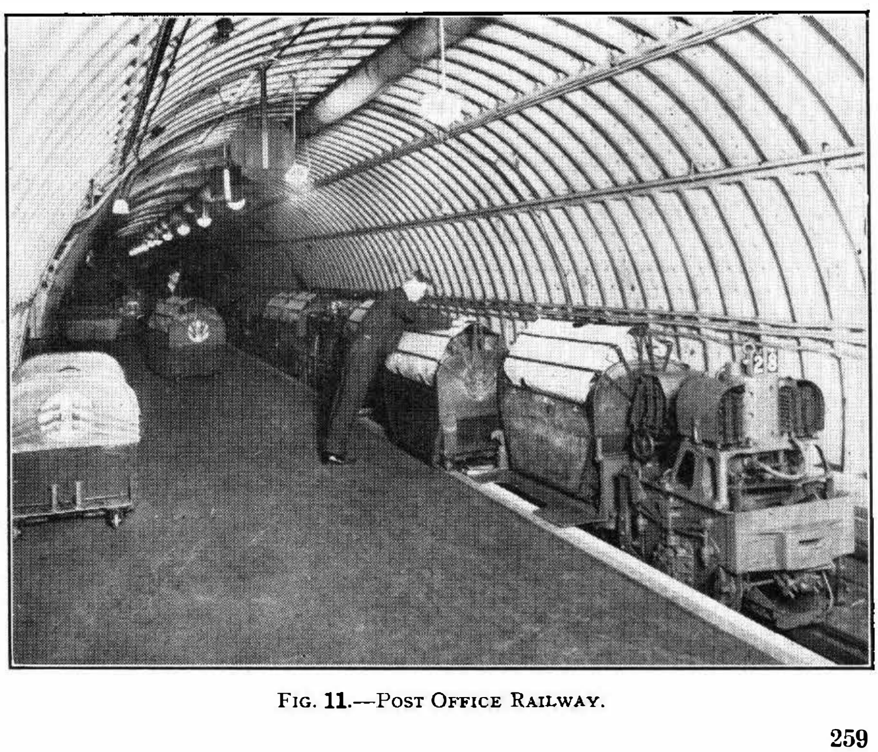


FIG. 11.—POST OFFICE RAILWAY.

Post Office sorting offices are in a few instances, notably that at Bristol,[5] linked to adjacent railway stations by means of conveyors. Elsewhere, petrol-driven or battery-driven trucks[15] are used to carry mailbags to and from the station. These, together with the pedestrian-controlled electric trucks recently introduced, have more than proved their worth for short-distance work. For the bulk of the station services, however, together with inter-office distribution in the large cities and in rural areas inadequately served by rail, Post Office or contractors' motor vans are used.

Some 70 ft beneath the streets of London the Post Office operates a 2-ft gauge electric railway[16], linking seven principal offices and two main-line railway termini on a 6½-mile route through East, Central and West London. The design of the Post Office railway was initiated in 1909, but the First World War and its aftermath delayed the completion and opening of the system until 1927. Apart from the saving of time by comparison with road journeys, the railway can be relied upon when weather or other conditions disrupt surface transport. Minor modifications and improvements have been adopted from time to time but its basic design is still satisfactory. A two-car train (see Fig. **11**) can carry 40 parcel bags or 110 letter bags at a maximum speed of 35 m.p.h. in the 9-ft twin-track tunnels. The d.c. traction supply is derived from three independent mains sources. The normal operating voltage is 440V, but this is reduced to 150V in low-speed sections such as station approaches. There is a central conductor-rail and one of the running rails serves as the return path for traction current, whilst the other is employed for signalling and control purposes. The track circuits are so arranged that a failure of the apparatus or of the supply of current stops the trains. Switch-men, located in cabins at the main stations, control the movement of the driverless trains by means of levers which are so interlocked and guarded that current can be connected only when the track has been tested and found clear, points proved correctly set, and all other safeguards are in operation.

The annual traffic is now over 12 million bags and the cars travel nearly two million miles in a year, equivalent to over 750,000 motor-van miles. The railway thus makes a not inconsiderable contribution to the relief of street congestion.

The Trend of Sorting-Office Design

The siting of a sorting office is invariably a compromise between conflicting requirements, but easy access to the railway is clearly one of the essentials. The ideal is, of course, for bags to be moved by trucks or conveyors directly between the train and the first and last handling points in the sorting office. The use of air transport, including helicopters, is now beginning to influence the location and design of sorting offices. The type and number of mechanical aids to be used in an office, either at its inception or in the foreseeable future, is considered jointly by postal, engineering and building specialists at a very early stage in its design and the building is planned to accommodate these aids to best advantage.

At very large offices the positioning of a parcel-sorting machine, occupying a floor area of perhaps 20,000 sq ft, may be a dominant factor in deciding the layout and design of the office as a whole. Where there is no parcel-sorting machine the layout of mechanical aids centres around the loading platform.

Two sites are seldom alike and office requirements differ so much that every job has to be tackled individually. The layout is arranged so that conveyors are as short as possible, or better still are eliminated by siting successive processes close together. Where possible, mail movement is arranged to be from the top of the office downwards to take advantage of gravity-operated transport devices.

Increasing traffic, shortage of labour, and cost considerations make it essential for the postal services to keep abreast of the times, and the search for new materials and methods, and for new applications of established techniques, proceeds continuously.

Postal administrations throughout the world are showing interest in mechanization. The United Kingdom takes an active part in the work of the Universal Postal Union, an international organization with headquarters at Berne, the object of which is to promote collaboration between the postal administrations of all countries. In 1951, in concert with the Netherlands and Switzerland, Great Britain produced a technical brochure,[6] later published by the Union, covering most aspects of mechanized mail handling. Through the Universal Postal Union and by direct contact with Commonwealth and other overseas Administrations, the Post Office participates in a steady interchange of information about this work.

Acknowledgment

Acknowledgment is made to Messrs. Sovex, Ltd., for permission to publish the drawing shown in Fig. **7**.

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1906—1956 : A Regional Review

It is fitting that tribute should be paid to the manner in which Post Office engineers have adapted themselves to the growing complexity of their work. In 1906 they were primarily concerned with the construction and maintenance of heavy overhead lines and of telegraph services. To-day they are called upon to exercise a wide range of technical and managerial skills, and the organization within which they function has become more and more complex. The Department conducts, at its Central Training School, courses of instruction in the more advanced aspects of the work. The simpler classes of work are taught at schools in each Region. The Post Office tries to avoid over-centralization, especially in staff relations, and the Whitley system of staff consultation operates in the Regions as well as at Headquarters. Joint Production Committees operate in each Telephone Manager's Area. Staff Associations have been recognized by the Post Office since 1906 and they are now an essential feature of the machinery for consultation.

FIFTY years ago, the everyday work of Post Office electrical engineers consisted mainly in the provision and maintenance of the telegraph service, for which the Post Office had for many years been solely responsible, and of the main trunk telephone service, which had been taken over completely by the Post Office in 1896. The local telephone service, however, was in its infancy and in only a few towns and cities was it provided by the Post Office.

The engineering organization of the telegraph and telephone services provided by the Post Office involved the division of the country into suitably-sized areas, termed Sections, each under a Sectional Engineer who was responsible for the construction and maintenance of plant for the two services in his Section. His staff consisted generally of an Assistant Engineer, one or two Chief Inspectors, perhaps seven or eight Inspectors and about 200 skilled workmen and labourers.

A number of adjoining Sections were suitably grouped together to form an Engineering District under the control of a Superintending Engineer, who had a small staff of specialist engineers, termed a Technical Section, and a small clerical force to deal with records of staff and equipment, estimates, Works Orders, and correspondence generally. The Superintending Engineer was directly responsible to the Engineer-in-Chief for the efficient performance of the plant in the District under his control. His financial authority, however, was comparatively limited and all large engineering works required authorization by Post Office Headquarters. In building matters, the Post Office Surveyor, who controlled an area comparable in size although not always coincident with an Engineering District, held the financial authority for all but the most minor changes in accommodation. Similarly, the District Manager was responsible for the traffic and commercial aspects of the telephone service, and his territory was often the same as that of an Engineering Section.

The era of 1906 may appear, in retrospect, a time of relatively unhurried existence, free from the complexities and frustrations of the present day. Yet for the working staff hours were long, travelling conditions primitive, and mechanical assistance almost non-existent. The foreman, with his unsurpassed knowledge of heavy line construction, wielded considerable power and was perhaps the key man of the day. The Inspector appeared on Fridays to review progress of work and to pay his men—an occasion of some ceremony, for pay-packets and paper money had not yet displaced sovereigns and silver. The upper ranks of the engineering staff were remote and rather awe-inspiring figures, seldom seen on the job, who concerned themselves with matters beyond the ken of the humbler ganghand.

Travelling, when it could not be by train or tram, was leisurely. By horse and cart, trap and gig, and official bicycle, the engineers went about their business over the countryside; the Sectional Engineer, Gloucester, was the proud possessor of the only motor vehicle in the Engineering Department, a motor-car (Fig. 1) which he himself drove on his business journeys. By contrast, six-horse teams of Shires hauling a low-loader could be an inspiring sight. Less inspiring, though, was the sight of a gang of seven or eight men pulling a handcart laden with tools and equipment, not forgetting the brazier and coke which were essential for heating soldering irons as well as for making tea, as they trudged along the dusty country roads moving from one job to another. The covered handcart of that time was adapted for horse haulage.

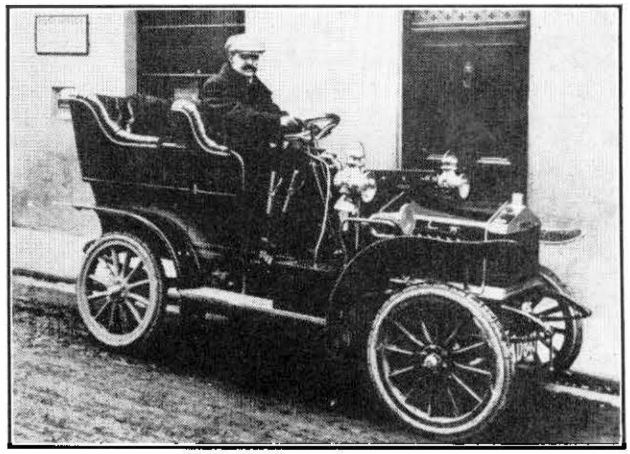

FIG. 1.—THE FIRST MOTOR-CAR IN THE ENGINEERING DEPARTMENT (1906).

The year 1906 was notable in the history of staff relations in the Post Office. On 1st February in that year, the Awards Suggestion Scheme was inaugurated and has since become a model for similar schemes in public and private undertakings in all parts of the world. Also, the Post Office Circular of 13th February, 1906, contained the momentous announcement by the then Postmaster-General, the Rt. Hon. Sydney Buxton, M.P., that he would grant recognition to all Post Office Staff Associations. So began an evolution in staff relations that was to achieve far-reaching results, undreamed of in those days, for both management and men. At that time the engineering rank-and-file grades of the Post Office were represented by the Post Office Engineering and Stores Association; those of the National Telephone Co., by the Associated Society of Telephone Employees (A.S.T.E.).

Training in those days was largely done on the job but the desirability of regularizing training was much discussed among telephone engineers. A growing need was felt for better facilities for recording and circulating information about new developments, and for discussion between engineers of matters of common interest. In these early years, the shape of things to come was beginning to emerge as a result of recent discoveries and theories. Pupin and Campbell had already developed practical forms of line loading. Marconi had demonstrated his method of wireless telegraphy, and during 1907 engineers had been excited by the fact that the U.S. Pacific Fleet was to be equipped with wireless telephony. Fleming had discovered the thermionic valve. A disgruntled undertaker named Strowger living in a small American town had demonstrated that connexion between two subscribers on the same exchange could be made without the intervention of an operator; automation in the telephone service was on its way. Post Office electrical engineers of 50 years ago had much to stimulate their technical interest, and so it was that the Institution of Post Office Electrical Engineers came into being, serving at first a small though enthusiastic membership.

It had been known for some time that the Post Office was to take over the National Telephone Co., and in 1911 Post Office and N.T.C. engineers were busily engaged in the Inventory, an assessment of the value of the plant that was to be taken over. On 1st January, 1912, the take-over was completed and field engineers were immediately engaged in assimilating their erstwhile rivals into their own ranks. It was not to be expected that two staffs who had been brought up to different methods of organization and procedure should, on the instant, work as one, but it did not take long for old rivalries to be forgotten and for the interests of the telephone service as a whole to become paramount.

In that year, too, the first automatic telephone exchange in Great Britain was opened at Epsom; automation had arrived.

The impact on Sectional Engineers and their staffs of the outbreak of war in 1914 was immediate. With additional work to do for the Armed Forces, they found their staffs rapidly diminishing as reservists were recalled to the Colours. Soon it was essential to introduce female labour into the work of the Engineering Department in the field, and girls were employed to assist with test-desk and test-room records, with jumpering, with cord repairs, with the periodic primary-battery inspections and the refreshment of the wet cells then in common use in subscribers' premises, and later to assist with the clearance of faults on subscribers' equipment. By improvisation and hard work field engineers managed to cope with the additional load of providing the circuits required for the defence of the country. Even during war conditions, the hazards of nature were still to be reckoned with, particularly during the winter months, and the severe snow storm that occurred in March, 1916, causing extensive damage in an area over a hundred miles wide from the Bristol Channel to the Yorkshire coast, threw an added strain on the resources of the Post Office. Almost every able-bodied man, whether normally engaged on overhead work or not, was needed to assist with the temporary repairs to the overhead lines. As was inevitable when a skilled staff was heavily diluted, maintenance of plant suffered, and when the Armistice was signed in November, 1918, the Post Office emerged from the war with the condition of its plant sadly run down and with a backlog of applications for telephone service.

With the return of men from the Forces the work of reconstruction and expansion gradually increased and it became possible, from the disposal of surplus war material, to obtain motor transport for use by engineering staff. The formation of the nucleus of the Engineering Department fleet of motor transport vehicles occurred in 1919 with the purchase of some 600 miscellaneous surplus army vehicles ranging from three-ton lorries to motor-cycle combinations. So began an expansion in the use of motor transport for the conveyance of gangs and their handcarts to the site of their work but, at that time, the number of vehicles was insufficient to make journeys by train exceptional and none of the vehicles had been designed originally for the purpose for which they were now used.

At the end of 1908, a rudimentary form of Unit Maintenance Costs (U.M.C.) was in existence, and in April, 1911, an experimental form of Unit Construction Costs (U.C.C.) was tried, but it cannot have been very successful because it was suspended in 1913; in any event, it related only to six main classifications of work. In August, 1920, the U.C.C. system was re-introduced on a simplified unit-manhour basis under which the results were available during the month following the execution of the work instead of after the closing of the Works Orders, as under the former system, and the Engineer-in-Chief's annual report for the year ending 31st March, 1922, notes that the U.C.C. system had been extended in July, 1921, to cover internal work. Similarly in July, 1921, the units under which the Analysis of Maintenance were furnished were revised and the number of units increased from 9 to 22, by the sub-division of some of the old units.

In the meantime, the two Staff Associations of the National Telephone Co., and the Post Office had amalgamated in 1915, and in 1919 the present title of the Post Office Engineering Union was adopted. In the following year the Whitley system of consultation was introduced in the Post Office and committees consisting of representatives of management and staff under the chairmanship of the Superintending Engineer met to consider all matters affecting staff. With his limited financial authority, however, the Superintending Engineer could do little to implement Whitley agreements on accommodation matters.

With the end of the First World War, the way was clear for a rapid increase in the application of the latest techniques to the provision of a nation-wide telephone service. Methods of cable balancing and the application of loading to audio cable circuits had been developed by 1922. The telephone repeater was so far advanced that it could be applied to such cables, and about this time the Post Office embarked on a large-scale program for the expansion of the trunk service by the provision of loaded audio trunk cables with repeater stations every 50 miles or so. About this time, too, the decision was taken to adopt as standard the Strowger step-by-step system of automatic switching, and this paved the way for a rapid increase in the rate of replacement of the earlier manual exchanges by automatic exchanges.

It became obvious that the vocational training of the staff required to provide and maintain these new equipments could no longer be undertaken on the job. Specialist courses were therefore started under the auspices of the Engineer-in-Chief, and in 1924 the Training School in King Edward Building, London (Fig. 2), was established to cope with the heavy demands for training.

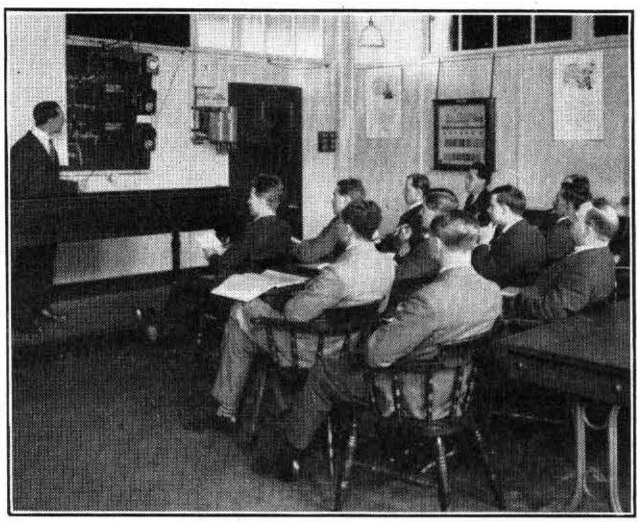

FIG. 2.—LECTURE ROOM AT THE CENTRAL TRAINING SCHOOL, KING EDWARD BUILDING, LONDON (1924).

The City and Guilds of London Institute had, throughout the period under review, been the examining body for the technical subjects associated with Post Office engineering work, and the advent of automatic telephony led to an increase in the range of subjects and a revision of the earlier syllabuses. Thus, means were now available for both the

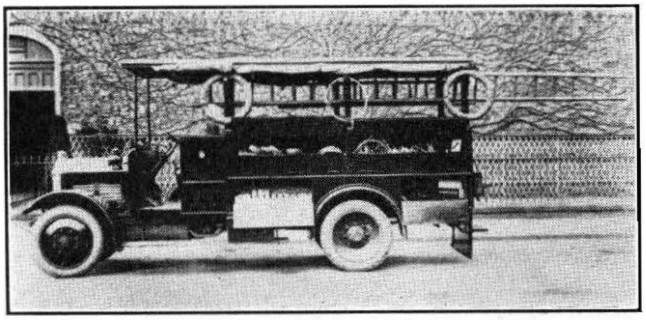

FIG. 3.—THE FIRST UTILITY VEHICLE (1925).

theoretical and vocational training of Post Office engineering employees.

The use of motor transport continued to increase, and in 1925 the first utility vehicle (Fig. 3) specifically designed for use by engineering staff was brought into service. This event marked the beginning of an evolutionary process that led to the now familiar green vehicles of many types, from the Morris Minor to the heavy utility and stores-carrying vehicles. By 1939, the engineering motor transport fleet had grown to a total of some 8,000 vehicles.

The Wall Street crash that took place late in 1929 had severe repercussions in Great Britain and by 1930 a period of retrenchment had set in and the depression was on its way. The number of unemployed rose to unprecedented heights and for Post Office engineers in the field this was a harrowing period in which they found themselves forced to downgrade and even to dismiss workmen known and personally respected by them. Such was the inevitable result of the severe retrenchment in capital investment that occurred, and this bitter experience left an aftermath of mistrust that took many long years to eradicate. As the nation gradually recovered its economic health the growth in the telephone system, slowed down by the depression, nevertheless passed the two-million-station mark in 1931, but it was not until 1934 that the rate of expansion was materially accelerated.

On the 1st October, 1934, during the Kingsley Wood era of advertising and popularizing the telephone service, the cheap evening rate for trunk telephone calls was introduced. It was immediately an overwhelming success and engineers all over the country were hard pressed to find the additional trunk lines required to carry the evening trunk traffic, which expanded so quickly that it very soon exceeded that of the day busy hour. With a rapidity fostered by the sudden spurt in the growth of the telephone trunk traffic, the newly-developed voice-frequency method of telegraph line transmission was introduced throughout the telegraph network to enable the old telegraph cables to be made spare for reconditioning for telephone use. So it came about that Alexander Graham Bell's dream of a multi-channel system of "harmonic telegraphy," that had led him to the almost accidental discovery of the telephone, was at last realized, although in circumstances that Bell could hardly have envisaged.

In one year, between 1933-34 and 1934-35, the rate of increase in the telephone service was almost doubled. The increase in work led to expansion of the staff, and field engineers now found themselves in a position to re-employ men who, in many cases, had been out of work for several years.

The London–Bristol–Plymouth 12-channel carrier system was brought into service in 1935, and this system of line transmission gradually spread throughout the country, involving the training of staff in the new maintenance techniques required.

In 1929 a system of Unit Maintenance Costs based upon the work-unit system had been introduced experimentally for automatic exchange equipment. It had proved very successful and in November, 1932, a committee under the chairmanship of the late Mr. B. O. Anson, a former Vice-Chairman of Council of the Institution, recommended that this system should be adopted as standard procedure for exchange equipment, subscribers' apparatus, line plant, telephone repeaters, telegraph apparatus, and testing and records. This recommendation was adopted and in 1934 the first set of national statistics in pillar-graph form was published, showing the manhours per work unit for every Section and District in the country.

Early in the 1930s, a Unit Construction Cost system was devised and introduced, in which the work of construction staffs was divided up into small units of work, to each of which was given an average time required for its performance. The actual time taken to do a particular job was assessed in relation to the total of the average times required by the various units of work comprising it, and the result expressed as a percentage of this average time, which was then given the title of "Performance Rating." Considerable effort was made by Sectional Engineers during these years to improve the organization of both maintenance and construction so that the overall costs of the work could be reduced. Major Works Controls were introduced with the object of relieving field Inspectors of much clerical labour, so leaving them free to supervise the construction work in progress, and at the same time enabling the controlling engineer to program the works to be done for a period of several months ahead. This enabled men and equipment to be allocated to works to the best advantage and achieved considerable economy in the cost of doing construction work.

Between 1936 and 1938 an experiment was made in the Bristol Section on construction and maintenance methods and it was shown that by introducing new methods major improvements could be made in the standard of telephone service, and the manpower required could be reduced. Maintenance controls had long been in existence but some improvement in their general organization resulted and the general standard of maintenance of plant improved.

The introduction of broadcasting in 1922 had its impact on the communication networks and special circuits were provided in all main audio trunk cables for the purpose of connecting broadcasting studios with one another and with the transmitters. The repeaters associated with these circuits were of a special type capable of dealing with the wider frequency range necessary. This was the first impact of radio on the field engineer, but he was very soon concerned with problems of interference with broadcast reception by electrical plant in the vicinity of a receiver, and the radio interference service was set up to deal with the technical problems arising. Then, in the middle 1930s, radio links were introduced in normal trunk circuits to bridge the gap between the Scottish mainland and certain islands. The technical interests of field staff were now considerably wider than 30 years previously.

Although, in 1938, the Prime Minister returned from Munich promising "......peace for our time," it was soon apparent that this was not to be and it was not long before Post Office engineers throughout the country became concerned in urgent and vital matters associated with the defence of the country. The technique of radar had been sufficiently developed to justify its employment for early warning of possible attack by enemy aircraft, and a chain of radar stations was erected along the East Coast. These had to be connected to the main trunk cable network, involving considerable construction work, and this, with many other requirements of the armed services and Civil Defence, made heavy demands on the Post Office.

The growth in the telephone service, and in the construction and maintenance work required by its development, had made it clear that the authority for accommodation and engineering works was too remote and that it ought to be placed at a point in the organization closer to the work being done. Accordingly, the Bridgeman Committee was set up and recommended the establishment of Telephone Areas, each under the control of a Telephone Manager, who would have the authority previously vested in the Superintending Engineer and the Surveyor. He would also take over the functions performed by the District Manager on the commercial and sales side of the business. In addition, the Committee recommended that the country outside London be divided into seven Regions, each under the control of a Regional Director who would take responsibility not only for telephone matters but also for the postal service in his Region. In London, two separate Regions were suggested, one taking telecommunications matters and the other postal matters. It was also recommended that the organization proposed should be tried experimentally in two provincial Regions, and so in March, 1936, the experimental Regions covering Scotland and North Eastern England were set up with headquarters at Edinburgh and Leeds, respectively. The authority previously held by the Surveyor and Superintending Engineer in buildings and accommodation matters was vested in the Regional Director, and certain work previously done in the Engineer-in-Chief's office was devolved to Regional Headquarters, notably the equipment design of automatic exchanges.

The Superintending Engineer's Whitley Committee became a Regional Engineering Whitley Committee under the chairmanship of the Regional Director, and this had an immediate effect on the relations between the two sides because the chairman was now able to implement decisions on accommodation matters, as well as others that had been reached through the process of joint consultation.

The Telephone Manager, as the man on the spot, had sufficient authority to enable him to cope with the day-to-day requirements of the organization and it soon became apparent that considerable advantages accrued from this arrangement.

Meanwhile the threat of war intensified until, on 3rd September, 1939, Great Britain was again at war with Germany.

The remaining Regions and Telephone Areas in the country were somewhat hurriedly set up, so enabling both authority and staff to be dispersed from London. The violent air attacks that had been confidently expected did not mature immediately, and engineers in the field had some breathing space in which to expand, improve and safeguard the communications required for defence.

The period of the "phoney war" came to an end with the Battle of Britain in the summer of **1940**, and all the resources of the engineering staff in London and the South East were hard pressed to maintain communications. The winter of **1940** saw the blitz descend upon London, and extensive repair work to underground cable networks had to be carried out at high speed under difficult and arduous conditions (Fig. **4**). It was not long before towns and cities in other parts of the country suffered similar experiences. In the raid on Southampton, for example, the telephone exchange was totally destroyed; yet here, as elsewhere, the engineering staff restored essential services within a commendably short space of time.

The first years of the Second World War saw a sharp reduction in the rate of increase of the telephone system and, indeed, in **1941** there was actually a loss of nearly **28,000** stations. The work involved in the sharp increase in cessations of telephones and provision of new services, necessitated by the dispersal of industry, threw an added strain on an engineering staff already hard pressed to meet defence requirements.

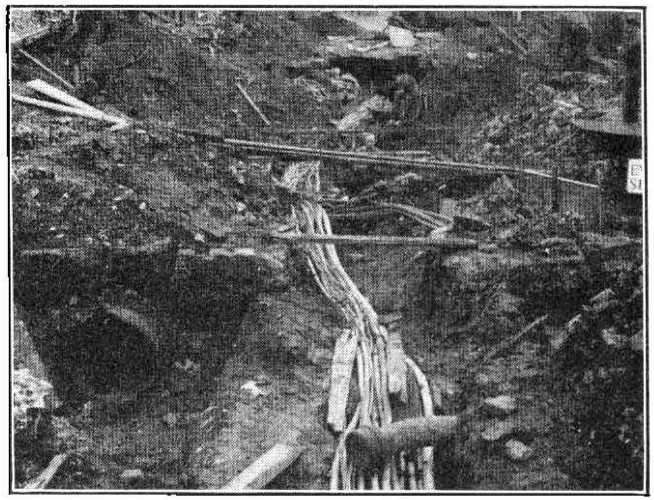

Fig. 4.—Blitz Cable Repairs.

As in the First World War, it was necessary to introduce female engineering assistants to help with the maintenance of communications, and many of them proved very successful even in the more complicated work such as the maintenance of automatic exchanges and repeater stations. This necessitated setting up special training courses of a hurriedly improvised nature to give training to these new recruits in the essentials of the job they would be called upon to do. Here, the newly constituted Regional Training Schools were able to play an important part in providing the vocational training required.

Towards the end of **1943** it became apparent that Britain was not only going to survive but was going to attack in force. Operation "Overlord," the invasion of the European continent, made heavy demands on the communications of the country and many hundreds of circuits were provided at comparatively short notice and under conditions of the utmost secrecy to provide for D-day. It was not long after this that first Germany and then Japan capitulated; by then the Post Office telecommunications network was battered but very far from broken.

The efforts of all were now diverted to the work involved in meeting the heavy demand for telephone service consequent on the movement of business and population back to the cities and on the interruption of normal expansion inevitable in conditions of war. At the end of the war the Services' network of long-distance circuits exceeded in number those of the public trunk network and, as the demands of the Services rapidly declined, circuits were diverted for use in the public trunk system.

In **1946**, the minor grade engineering staff was reorganized and that part of the work requiring higher skills separated in grade from the remainder. At the same time, a **44**-hour 5-day week was introduced and Engineering Joint Production Committees were set up. These developments in staff relations as well as developments in communication techniques made the field of interest of Area Engineers and their staffs ever wider and wider.

Although television broadcasting had been in operation before the Second World War it was comparatively short-lived because it had to be withdrawn on the outbreak of war to avoid giving navigational aid to enemy aircraft. With its re-introduction when the war was over, it was not long before Post Office engineers found themselves heavily engaged in the planning and provision of permanent links for connecting the London studios to transmitting stations, and of temporary circuits for transmitting video signals from outside broadcast sites. In **1948** the outside broadcast of the Oxford and Cambridge Boat Race[1] included pictures of the start and finish, both of which were transmitted via ordinary telephone land line to the nearest coaxial or balanced pair cable, involving the use of video repeaters installed temporarily in Putney and Fulham exchanges.

By the following year the technique of transmitting video signals over ordinary telephone cable pairs had developed considerably, and in 1949 it was possible to provide video circuits to cover a total of seven cameras so positioned along the course of the Boat Race[2] as to provide continuous cover. On this occasion, for the first time, a mobile repeater was brought into use between Chiswick exchange and the Polytechnic Boathouse. It was set up in a quiet suburban street, the local distribution cable being opened for the interception of the cable pairs that were used temporarily for video transmission.

On the 2nd June, 1953, occurred the longest and most comprehensive outside broadcast ever arranged; it covered the television broadcast of the coronation of Her Majesty Queen Elizabeth II,[3] whereby viewers were able to see "The Solemnity of Her Majesty's Coronation."

With the spread of television broadcasting to other parts of the country, outside broadcast teams were trained and available for employment outside London. The advent of the Independent Television Authority in 1955 increased very considerably the amount of work, not only in the provision and maintenance of permanent cable circuits and radio links for the transmission of video signals but also in the amount of outside broadcast work, which involved the expansion of the special staffs engaged upon it.

After the Second World War the engineering motor transport fleet was once again the recipient of a miscellaneous collection of war surplus vehicles, and it was some years before it was possible to introduce any new type of vehicle specially designed to meet requirements. In 1949, the first of the 2-ton utility vehicles[4] (Fig. 5), providing much-improved working conditions for the users, was introduced and is now fast replacing the older types of vehicle in this class.

FIG. 5.—TWO-TON UTILITY VEHICLE.

FIG. 6.—MODERN CABLE-TEST VAN.

The new 10-cwt utility vehicle[5] superseded the old 8-cwt van in 1953. This was quickly followed by the introduction of a new type of cable-test van[6] (Fig. 6) incorporating a specially designed heater for the purpose of creating a dry atmosphere inside the van to ensure the maintenance of the high standard of electrical insulation required for the apparatus used in testing operations. In 1955 the planning and development staff had available a vehicle designed for their specific requirements.[7]

The last few years have also seen the introduction of vehicles for special purposes, such as the television detector vans[8] (Fig. 7) and the television outside broadcast vehicles,[9]

FIG. 7.—TELEVISION DETECTOR VAN.

as well as an improved Minor van providing greater flexibility in the arrangement of the stores-carrying units fitted inside the body.

In the wide range of Accommodation and Postal Services, the provision and maintenance of the lighting installation in Post Office buildings of all kinds, the provision and maintenance of lifts, stamp-selling machines and stamp-cancelling machines, as well as various types of conveyors and chutes used by the Postal Service to facilitate the transmission of mail, are all the concern of the field staff. Indeed, in London, the only driverless electrically-driven underground railway in the world has been in constant use over many years for the purpose of moving mail from point to point. The future will undoubtedly show rapid

FIG. 8.—A CLASS AT WORK AT THE CENTRAL TRAINING SCHOOL, STONE.

developments in the mechanical devices designed to assist in the handling of mail and, indeed, a movement to this end has already begun.

It became evident immediately after the war that the training facilities for engineering staff would require to be expanded because of the rapid developments that were occurring in transmission and switching techniques. Accordingly, in 1946, the Central Training School[10] (Fig. 8) was set up at Stone, Staffordshire, on a residential basis to provide facilities for higher grade vocational training covering the large number of specialized duties required by modern telecommunications. The Regional Engineering

Fig. 9.—Practical Work at one of the Regional Training Schools.

Training Schools[11] (Fig. 9) were also expanded to cover the increased demands for training courses for youths and for elementary vocational courses required by the many different types of work carried out in a Region.

The year 1922 saw the completion of the first million telephone stations in the country, with a ratio of stations to exchange lines of 1·63. At that time an engineering staff totalling some 20,000 was engaged in the provision and maintenance of the telephone system. In 1953 the number of stations passed the six million mark, with a ratio of stations to exchange lines of 1·8 and, although the system had expanded six-fold, the total engineering force required to provide and maintain the system had grown only to about 60,000. Thus, in the intervening 30 years, an improvement in productivity of 100 per cent had been achieved, a trend that still continues.

This improvement is the combined result of a number of different factors. Improvement in design of equipment, the reduction in its fault liability, improvements in methods, both maintenance and construction, all played their part. In external work and plant maintenance, the expansion of the motor transport fleet was an important factor. The introduction of trailer toolcarts in place of handcarts, the more efficient organization of the work, and improvements in tools and mechanical aids illustrate a few of the developments that have assisted in this progress.

In the early years of telephony, one of the most arduous tasks was drawing cable into a duct by means of a hand winch, and it is not surprising that one of the first developments was the introduction of a power-driven winch (Fig. 10 and 11) for this purpose. As vehicles became more widely used, a lighter type of capstan was fitted to vehicles used by cabling gangs, and was driven from the power take-off of the vehicle itself. The use of sheer-legs for erecting poles was tried but never found favour and a mobile crane was introduced for this work. The use of

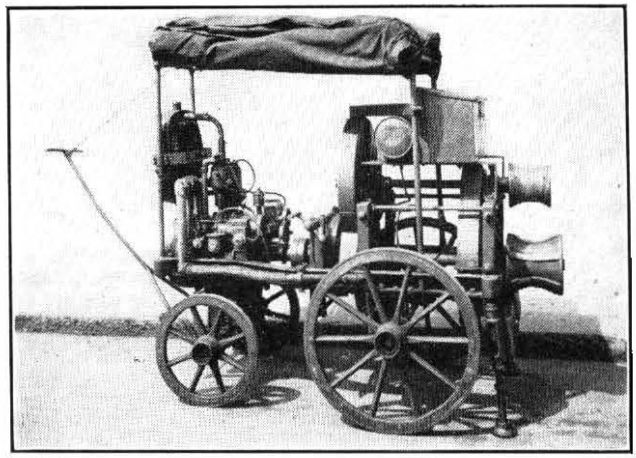

Fig. 10.—Early Power-Driven Winch.

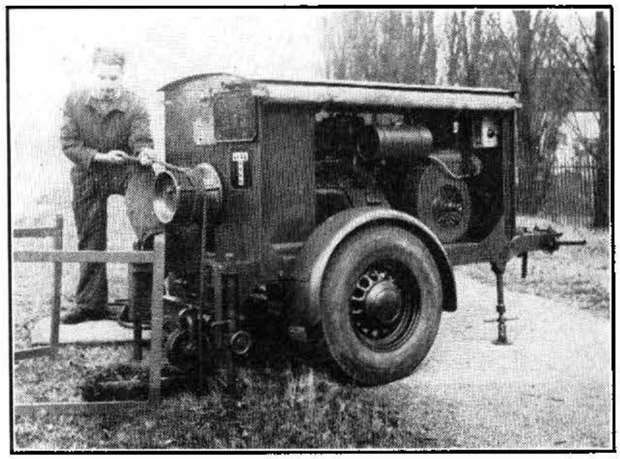

Fig. 11.—Modern Power-Driven Winch.

Fig. 12.—Power-Driven Auger.

power-driven augers (Fig. 12) and of explosive charges[12] for making pole holes are both current practice. In aerial cable construction, suspension rings have been eliminated by using wire spinners to attach the cable to the suspension strand after erection.

In underground work, trench excavators (Fig. 13) are in use that are capable of digging trenches up to 3 ft 6 in. deep and 16 in. wide, with a heavier type for digging trenches

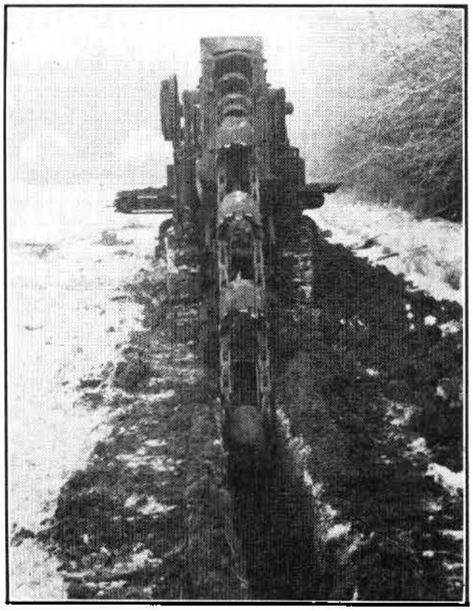

FIG. 13.—TRENCH EXCAVATOR.

to a depth of 6 ft and up to 22 in. wide. In 1932, experiments were made using a mole-drainer for laying underground cable directly in the ground, and in 1940 the tool was modified so that the cable was fed down a tube at the back of the mole plough and was laid in the ground as the tool moved forward. Self-contained petrol-driven pneumatic road-breakers have replaced teams of men with sledge-hammers and spikes for breaking up hard concrete roads. For providing short lengths of cable or asbestos cement duct at road crossings, hydraulic thrust borers are in use. For providing light in manholes and underground jointing chambers, small portable engine-driven generating sets (Fig. 14) were introduced in 1946 and are now commonplace.[13] Similarly, for removing water from manholes, a small engine-driven pump is widely used, replacing the old hand-operated flood-gate pump.

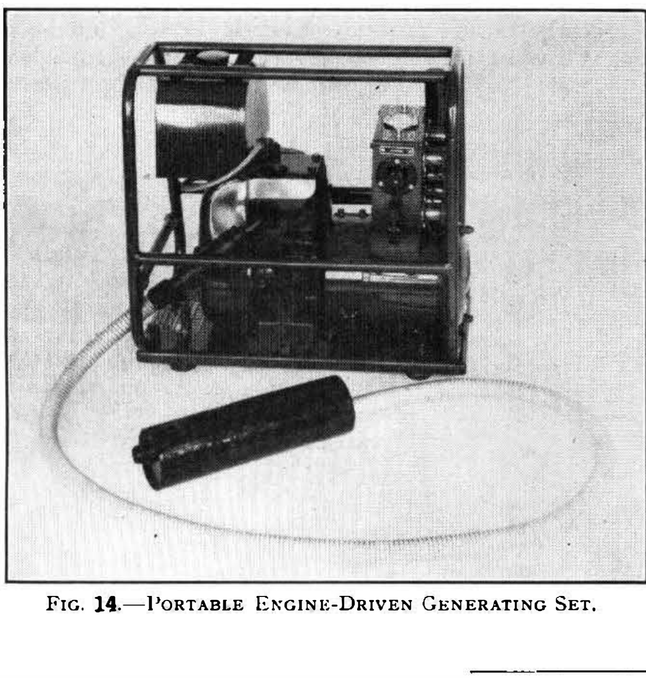

FIG. 14.—PORTABLE ENGINE-DRIVEN GENERATING SET.

Over the past 50 years, the man in the field has become more and more specialized. His training and technical education have been directed specifically to his particular requirements, whether he be engaged in jointing coaxial cable or in maintaining the equipment at a carrier terminal. He has been provided with the latest and best mechanical aids and tools to help him to do his job more effectively, and this continuing process is an essential in the provision of an efficient telecommunications service at an economic cost to its customers.

In addition to the use of electronic switching methods in future telephone exchanges, many office processes associated with the management and control of Post Office business could quite readily be turned over to electronic computer operation, and the field engineer of the future may well find himself concerned in computer maintenance as well as depending upon computers for the information he requires for overall control and management.

Discoveries yet to be made will have an effect in the telecommunications service, which will continue its growth for many years yet. Whatever the future may hold, the man on the job will be found ready to adapt himself to new techniques and methods, conscious always of the vital part he plays in providing a speedy, efficient, and up-to-date service for the British public.

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The Post Office and the Telecommunications Industry

This article has been prepared by the Telecommunication Engineering and Manufacturing Association on behalf of the manufacturers of telephone and telegraph plant, equipment and apparatus. It covers the manufacture, installation and supply of cable, exchange, repeater station and radio equipment, subscribers' and telegraph apparatus during the 50 years of the life of the Institution of Post Office Electrical Engineers. It will be realized, of course, that the manufacturers of these items also cover many other fields of activity which are not dealt with here. We would like to congratulate the Council of the Institution on attaining their Jubilee and on the magnificent way in which they have contributed to the growth of telegraphs and telephones in this country during that period. We regard the Institution's Journal particularly as one of our best ambassadors, not only in the Dominions and Colonies but also in foreign countries throughout the world. The British Post Office Engineers occupy a very high place in the esteem of other telephone and telegraph engineers of all nationalities and the Journal is one of the means by which their prestige has been, and still is being, upheld. The manufacturers place a very high value on the close collaboration with the Post Office which is, and has been enjoyed, in most part, throughout this period and are proud of the part which it has been possible to play in assisting in the developments which have taken place. The Telecommunications Industry is, therefore, very pleased to endeavour to set out within the limited space that is available some of the highlights of its contribution to the story of progress.

The Position in 1906

At the time when the Institution of Post Office Electrical Engineers was founded, in 1906, the telephone system of the country was operated by several organizations. Local telephones were largely in the hands of the National Telephone Company, although the Post Office was operating in a part of London and in some provincial districts. Municipal systems were in operation at Hull and Portsmouth, and the Post Office operated the entire trunk telephone system and also the telegraph system.

It had been agreed in 1901 that the Post Office should purchase the National Telephone Company plant at the termination of its licence in 1911, and Parliamentary ratification for this course had followed in 1905.

Great Britain had been very early in the field with submarine telegraph cables, the first Anglo-French cable having been laid as early as 1851. The conductors were insulated with gutta-percha and heavily protected with tarred hemp and galvanized iron wire. This was followed by many more cables of this type, including the first Atlantic cable, which was completed in 1866, and by 1906 there was a world-wide network of submarine telegraph cables which had been manufactured in this country.

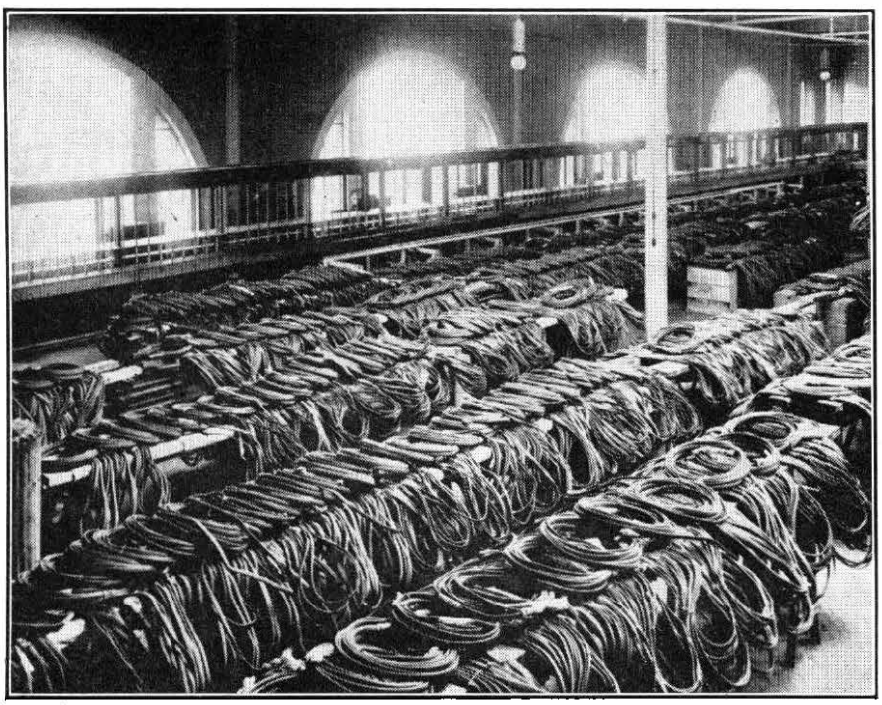
Both France and Belgium were linked to this country by a number of British-made submarine telephone cables, and lead-covered cables for use in the inland network had been manufactured here since 1897.

The manufacture of wireless-telegraph apparatus on a commercial scale in this country had commenced in 1897, and wireless-telegraph apparatus had been provided by the manufacturers to work to ships at sea from a number of coast stations in the British Isles, which were taken over by the Post Office in 1909. Various point-to-point telegraph services were in operation, working on medium and long waves, but although the three electrode electronic valve had been invented by 1906, it had not yet made its great impact on radio and line communications.

The bulk of the telephone equipment and apparatus was, however, at this time imported from abroad, but a number of manufacturers were beginning to set up their plants to manufacture telecommunications equipment in this country, and when our story opens the infant telecommunications manufacturing industry, which can now claim to be one of the major industries of the country, had learnt to toddle, though perhaps not quite to walk.

The Period up to the First World War

This period from a manufacturing point of view is important as marking the beginning of what was to become a very rapid growth, and open up a vast export field. Several firms started manufacturing on a much bigger scale than heretofore. There were difficulties up to 1912, however, owing to the state of uncertainty due to the impending transfer of local telephone services, but nevertheless it was a time of consolidation in the manufacturing field as will be seen from the following paragraphs.



Glasgow Manual Telephone Exchange in Course of Installation, 1910.

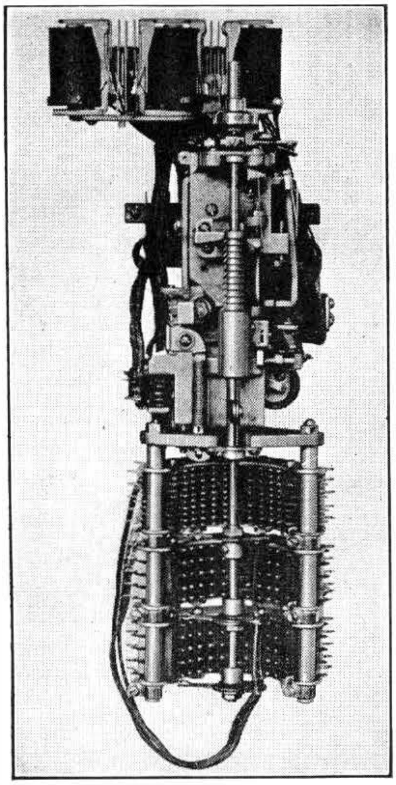
Manual Exchanges.

Progress was made in these years in the manufacture and installation of manual exchanges, and by the time the transfer was effected there were in being about 700,000 telephone stations. About one-third of the larger exchanges were worked on the common-battery (C.B.) system and the remainder were magneto.

The first 10,000-line C.B. exchange to be designed and manufactured in this country was opened, in 1910, at Glasgow, and a number of others of this type followed and a valuable export business to India and Australia was started.

Early Automatic Exchanges.

It was in 1908 that the first model of a Strowger exchange was demonstrated by the manufacturers at the National Exhibition at the White City. By 1912, step-by-step automatic telephone exchanges were installed by the manufacturers at Epsom and at the Post Office



TWO-MOTION SELECTOR AS USED IN THE AUTOMATIC EXCHANGE AT THE NATIONAL EXHIBITION, 1908.

Headquarters. In 1914, two further automatic exchanges were provided, one on the "Lorimer" system at Hereford, and one working on the "Rotary" system at Darlington, but by that time the First World War was upon us.

THE 1914-1918 WAR PERIOD

The intervention of the First World War put an effective brake on telephone progress, since the telephone had not at that time come into its own as a necessary feature in the conduct of the war in these islands, neither was it regarded as of such vital necessity for the armies in the field as it was when the Second World War came. However, its importance grew considerably as the war proceeded, and we, as manufacturers, made our contribution in that sphere. War-time developments, moreover, stimulated considerably the development of the valve, both as an amplifier and as a generator of high-frequency oscillations. It was perhaps hardly realized at that time that these developments were to have such a revolutionary effect on the future of both line- and radio-telephony, and indeed on many other spheres of activity.

Telephone Equipment.

But though the brake was firmly applied, this period was not entirely one of inactivity and Newport, Portsmouth, Paisley, Blackburn, Dudley and Grimsby were all equipped with automatic telephone exchanges, the different manufacturers installing their own particular types of equipment. From these installations a vast amount of experience was to be accumulated for the future, both by Industry and by the engineers of the Post Office. The provision and change-over to common-battery working also continued to some extent and a number of large new exchanges were provided by the manufacturers.

Cables.

The National Telephone Co. had installed loading coils experimentally on a number of short trunk and junction circuits, and in 1913 the first long-distance telephone cable to be installed in Europe was made in the United Kingdom and laid between Leeds and Hull. It was a 54-pair loaded multiple-twin cable, carefully balanced at each jointing point. The cable proved to be very successful and was followed by a number of other cables, London–Birmingham–Liverpool, London–Brighton, London–Colchester and Birmingham–Leeds.

BETWEEN THE WARS

When the First World War was over, the telephone system of the country was very ripe for development. Experience was available of the manufacture and working of automatic telephone exchanges and long-distance cables. Thermionic valves had been developed for war purposes and a new era began in this field, in which there was now considerable activity. Long-distance cables, one of the most notable being the London–Liverpool–Glasgow cable, were made and laid, and many automatic telephone exchanges were manufactured and installed.

This period also saw the first demonstrations of radio-telephony from the United States to England carried out by the manufacturers, and it was on the 14th January, 1923, that in one of our factories a number of important people in the telephone and radio world heard the first telephone communication from the United States. Previous demonstrations had been undertaken as early as 1915 between the United States and Paris, and in 1919 between Ireland and Vancouver, but the state of valve development had necessitated the use of a large number of small valves, and the demonstrations cannot be said to have been on a commercial basis. On this occasion, however, the results were sufficiently good and the apparatus sufficiently developed to give hope of a future transatlantic telephone service, and it was not long after that a contract was placed by the Post Office for the necessary apparatus to set this working.

At this same time the Post Office were busily designing a long-distance high-power radio telegraph transmitter, using thermionic valves, for the first link of the Imperial Communications Scheme, the completion of which had been interrupted by the war. The manufacturers undertook to manufacture 10kW water-cooled valves in this country for use in this transmitter. This bold undertaking not only made the above-mentioned project possible but later provided the means for running the single-sideband wireless-telephone transmitter proposed for the transatlantic telephone service. Both these transmitters were installed at the Post Office Radio Station at Rugby. There is no doubt that the decision by the manufacturers to set up the necessary plant in this country made a very valuable contribution to both these schemes. Other manufacturers followed suit and the start thus made probably had a big effect on the whole electronic industry of the country. The first radio-telephone circuit between this country and America was opened by the Post Office in 1927, after about a year of exhaustive tests with the United States. It will be realized that this first circuit worked on long waves, and it is of interest to relate here that, during this period, another manufacturer was working on short-wave developments with very successful results. So much so that the so-called "beam" stations which had been erected as a matter of private enterprise were so successfully demonstrated to the Post Office as to lead to their purchase and operation by that organization. The installations at Bodmin and Grimsby used oil-cooled valves in their short-wave transmitters, and very highly directional aerials mounted on high masts of special construction. Power was led to the aerials through coaxial feeders made of copper tubes. It is said that it was this novel method of transmitting high-frequency power that gave the first hint leading to the later use of coaxial cables for telephone purposes. These experiments undoubtedly blazed a new trail towards more economical and improved long-distance telegraph and telephone communication, and a vast network now covers the Earth.

Standardization of Automatic Telephone Exchanges.

During this same period a considerable step forward had been made with the development of automatic switching, and several different makes and types of apparatus developed by the different manufacturers were working in the provinces and in London. The problem of telephones in London was a very difficult one owing to the large number of subscribers ultimately forecast. The step-by-step system had been used in the provinces on a considerable scale, but difficulties which had been foreseen in applying it to London were removed when one of the manufacturers introduced to the notice of the Post Office the so-called "director" system. Alternative systems were available, but in November 1922 the Engineer-in-Chief of the Post Office recommended the adoption of the step-by-step system, with the addition of the director for the densely populated areas, as a standard throughout the country. In adopting this system, a decision of momentous importance, the Post Office made sure that arrangements could be made for spreading the work among the manufacturers and so avoiding any monopoly of a particular firm, and the challenge was accepted in a broad and statesmanlike way. Arrangements were made to pool the patents involved, and the firms' engineers came into close liaison and harmony with the engineers of the Post Office in order to produce an efficient and adequate system. Complete standardization could not, however, be reached at one fell swoop, but it has gradually come nearer to realization.

A large number of automatic exchanges entirely manufactured in this country were installed during this period, both in this country and in many different parts of the world, and the British Automatic Telephone Industry became firmly and soundly established.

Repeaters for Long-Distance Cables.

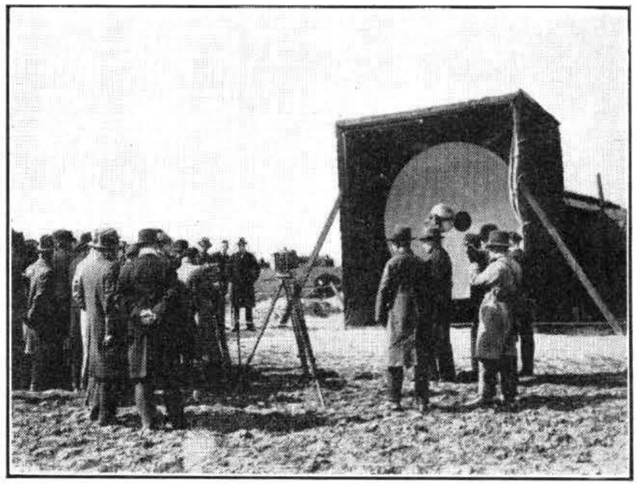
The rapid development of the valve during the war, combined with much pioneering work in the United States, had made it available for the revolutionary work that it was to bring about on the long-distance trunk system of the country. Experimental work had been carried out by Post Office engineers during the war, and the first repeaters made by the manufacturers were installed at Fenny Stratford and Derby in 1923. It was now possible to work the longest distance in the country with greatly reduced transmission loss, and the new era of easy trunk telephone conversation with no limitations as to distance had arrived.

Long-Distance Point-to-Point Radio Circuits.

As has been mentioned previously, the manufacturers had built the short-wave beam telegraph stations, and these were successfully working to Australia, India, South Africa and Canada, and attention was now devoted to the use of similar frequencies for long-distance telephone circuits; the manufacturers were not behind in this field. The first short-wave telephone transmitter, which was crystal controlled, was manufactured and supplied for the Post Office at Rugby Radio Station in 1928, and in 1930 this was followed by another transmitter which successfully opened the ship-to-shore telephone service with transatlantic liners. Other transmitters followed and the service became world-wide in its scope.

Early Use of Microwaves.

It may seem rather surprising to many that the first microwave telephone communication was demonstrated by the manufacturers as early as March 1931. At this demonstration the wavelength of 18 cm was used, and although this particular system was to grow and develop out of all recognition, this demonstration pointed the way for many future developments in the radar and radio-relay fields.



EXPERIMENTAL INSTALLATION OF MICRO-RAY SYSTEM, ST. MARGARET'S BAY, 1931.

Modernization of Telegraphs.

The Post Office telegraph system, which had worked on the basis of Wheatstone, Baudot, and other systems, was now due for modernization and after a comprehensive study of the question, including a visit to the United States, the Post Office decided that a system using a printing telegraph, combined with multi-channel voice-frequency transmission, should be adopted as standard and replace all existing telegraph circuits. Fortunately, the manufacturers were ready and offered prototype apparatus to meet this need, and in 1931 the first voice-frequency telegraph system, which provided 12 carrier telegraph channels and was capable of extension to provide 18 channels on one telephone circuit, was installed between London and Dundee. This was followed by many more similar systems until the whole country was covered by this means, teleprinters being installed at the same time where necessary. It is interesting to recall that this proved so successful that during the 1939-45 war it was decided to install similar plant on an even larger scale to meet the exacting requirements of the defence services of the country. The subsequent installation of automatic switching plant has further improved the high engineering efficiency of this service.

Carrier Telephone Systems.

After the First World War, a considerable amount of experimental work was carried out with the object of providing for a number of telephone channels on one cable pair with the hope of economizing in the cost of the long-distance trunk telephone service, and in 1936 the manufacturers had so far advanced their research and development as to supply the Post Office with the first 12-circuit carrier telephone cable and its accompanying apparatus, and this was installed between Bristol and Plymouth. At about the same time the Post Office was taking a great interest in the possibility of providing some hundreds of circuits on a coaxial cable, and it was a good example of the close co-operation between the Post Office and the Industry when the combined operations, in which the manufacturers supplied the cable and the Post Office the apparatus, constructed on an experimental basis, resulted in the first working coaxial cable to be installed anywhere in the world. We would like here to recall our appreciation of the foresight of the Post Office engineers in providing at that early date, when television had hardly left the cradle, a spare coaxial pair in this cable for ultimate use for television. Although never used for this purpose, owing to unforeseen growth in telephone traffic, it provided a means for experiment and led to the expansion of knowledge of this technique which was, no doubt, most valuable to the Post Office and Industry in later years.

This period also saw the birth of the submarine coaxial cable. The early cables of this type used para-gutta as insulation and were worked on the frequency-division-multiplex basis.

The 1939–1945 War Period

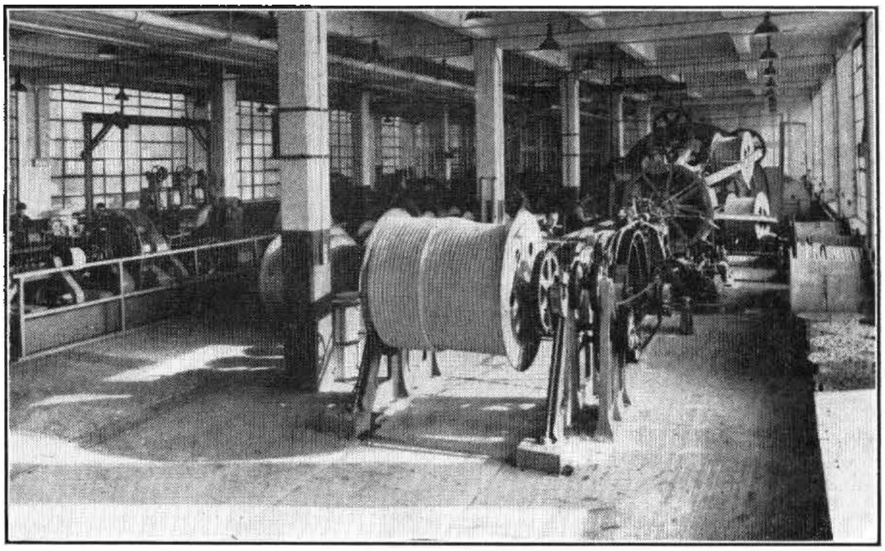
The developments mentioned in the previous paragraph were to prove of great value during the Second World War, which, unlike the First, gave rise to a very great deal of work in the telecommunications field. The economy and speed with which a large number of circuits could be provided on a coaxial cable led to a large demand, and a number of additional cables were made and laid by the industry for war-time purposes. This period was notable for the close collaboration of the manufacturers and the Services with the Post Office in order to use available resources to the best possible advantage, and the telecommunications system of the country was revolutionized for defence purposes. The Defence Telephone Network, which had been planned just before the war, was completed by this close co-operation in which the industry undertook to make, install, test and maintain much of the equipment. In addition, radar stations, airfields and command headquarters all needed special communication installations and equipment and some 60,000 private circuits, 10,000 of which were over 25 miles in length, had been set up by August 1944 on cables. Long-distance public services were also developed during this period, since the removal of factories to safer areas, the erection of huge government ordnance plants and other extensions to meet the demands of war production all needed their quota of long-distance circuits: but it is not possible in the space available to detail all this great activity; suffice it to say that it was done and done in time to serve its purpose in the Battle of Britain, the Battle of the Atlantic and during the invasion period, and also to cope with the flying bombs. The tremendous amount of work and the necessity for this close co-operation will be realized at once by the fact that before the end of the war, circuits greater than 25 miles in length had increased approximately threefold in number.

The Post-War Period

Coaxial Cable Extensions.

When the war was over attention was turned to the requirements of peace. The question of the television standards was under consideration, but was not settled for several years and the possibility was envisaged that it might be necessary to provide television channels for much wider bands than the three or four megacycles per second previously envisaged. The Post Office, as a result of their experience on the original coaxial cable, had prepared a stringent specification for the production of a 1-in. diameter coaxial tube suitable for a bandwidth of about 30 Mc/s, and industry set about meeting this specification with energy and, in due course, a new coaxial cable was made and laid between London and Birmingham. Preliminary tests of the cable showed the necessity for modifications in methods of manufacture which led eventually to the production of a very satisfactory cable, thus demonstrating the advantage of close co-operation between manufacturer and user.

But of even greater importance has been the laying of an extensive trunk network of cables containing up to six coaxial pairs of the normal 0·375-in. diameter. A number of the pairs in these cables provide for television connecting links instead of the 600 to 960 telephone channels of which they are capable. The coaxial cable has proved its worth as an economical means of providing long-distance trunk-telephone circuits and television distribution circuits. The rapidly developing radio-relay system is, however, now beginning to find its place in the trunk network. In the meantime, however, many of the 12-channel carrier systems have been converted to 24-channel systems, thus doubling the circuits available from these installations.



Laying-up the First Coaxial Cable, 1935.

Submarine Cables.

With the manufacture on a large scale in this country of polythene—a truly British development—a new era began in submarine cable development. Additional cables had been made for use between this country and the French coast for the D-day offensive and these were followed after the war by other cables to Belgium, Germany and Holland. A considerable amount of work had also been carried out on submarine repeaters, and the manufacture of these was undertaken with considerable success, so giving a distinct lead to Great Britain in this direction. It is interesting to record that the whole of the polythene, the bulk of the cable, and some of the submerged repeaters to be used in the great transtlantic telephone cable project, which is now nearing completion, were manufactured in this country.

Microwave Links.

Before the outbreak of war an experimental radio-relay link for television transmission between London and Birmingham had been the subject of a development contract, but the work had been dropped at the outbreak of hostilities. The war, with its tremendous radar developments, had taken communications up into the higher bands of frequency and opened up further possibilities on frequencies of the order of 1,000 Mc/s and upwards. It was, therefore, decided by the Post Office to install a television radio-link between London and Birmingham, making use of these frequencies. Industry again showed its willingness to produce the goods and tendered to a stringent specification prepared by the Post Office. The B.B.C. television station at Sutton Coldfield was linked to London by means of this radio link for its opening ceremony, since it was ready before the coaxial cable, and gave quite satisfactory results. The next television requirement, at Holme Moss, was provided by means of a coaxial cable and the next, between Manchester and Kirk O' Shotts, by means of a radio-relay link working at a still higher frequency, i.e. about 4,000 Mc/s. The specification for this link was even more stringent but was duly met and the necessary stations made and installed to specification. For the manufacture of these two links the different manufacturers set up special organizations of designers and engineers and, in one case, a shop was specially equipped at the works for the purpose. This pioneering work is proving most valuable in the export field, and equipment is now being provided all over the world. It is proving particularly suitable for communications over undeveloped country, where it would often be difficult and very expensive to lay cables. Similar links are being produced for multi-channel telephony, and the necessity for close integration of communications, whether for telephony or television distribution and whether by coaxial cable or radio relay, is clearly recognized by the Industry and by the Post Office.

Long-Distance International Radio Communications.

Long-distance international telephone communications have increased enormously since the end of the war and the recent installation of a new Rugby Radio Station gives another example of co-operative effort. The installation of the new station at Rugby with 28 all-purpose four-channel independent-sideband transmitters marks the latest stage in the development of this class of equipment. Methods of leading-in and remote switching and control of aerials and transmitters from a central point have been worked out by the manufacturers in co-operation with the Post Office and have resulted in a highly developed installation which, in conformity with the times, requires a minimum of operating staff.

SUBSCRIBERS' INSTRUMENTS

This article would not be complete without some reference to the subscriber's instrument. This instrument is the principal link between the Post Office and its customers and many of them, who have not had the opportunity of visiting their local exchange, imagine it to be the "be all and end all" of the telephone service. In the magneto telephone age, hand-microtelephones, i.e. instruments which combined the receiver and microphone in one body, were available. Some of these were rather elegant, the switch hook being supported above the nicely curved permanent magnets of the magneto generator. A rather ugly type of wall telephone was available, but for the C.B. exchanges the standard instrument was the candlestick-type telephone. This was not only ugly, but also very cumbersome and awkward to use in many circumstances, and both the manufacturers and the Post Office were seeking a new form of instrument which would replace this and improve upon it both in appearance and efficiency. Many designs were considered, but it was the Industry that produced the type which finally became the standard and superseded the candlestick telephone. It is said that the idea of it came when the engineer responsible saw an Edwardian silver inkstand in a shop window in London. As the "Story of the Telephone"[1] says, "Its simple, elegant curves pleased him." This, with certain modifications, became known in the Post Office as the hand combination set. It was, perhaps, the dawning of the plastic age which made its construction possible and its adoption revolutionized the manufacture of subscribers' instruments, and required the installation of many new and modern machines and the use of new techniques on the part of the manufacturer. It has been modified since that time both in appearance and from a telephone efficiency point of view.

TELEPHONE EXCHANGE EQUIPMENT, INSTALLATION AND DESIGN

In the early days of the telephone system, telephone-exchange contracts for the Post Office were placed as a result of competitive tender invited from all the firms engaged in this class of work, and each telephone manufacturing firm negotiated direct with the Post Office. There was perhaps some advantage in those days since the design of telephone equipment and apparatus was at the pioneering stage and competition was not only in price, but also in types of apparatus and circuitry. From a manufacturing point of view, however, a great deal of effort in preparing the tenders was expended by the unsuccessful tenderers without any return, and the system gave rise to big diversities in types of equipment and practice which, in a large system such as that of the Post Office, led to a great deal of trouble. When, however, in 1922 the Post Office decided on the standardization of the step-by-step system, and the complete conversion of the London telephone network to automatic working was envisaged, it was decided that there would be many advantages if the supply of equipment could be co-ordinated. This process would also enable the standardization which was very desirable from the Post Office point of view to be much more readily approached. A system of bulk contracts was therefore instituted by which the manufacturers divided the work among themselves and suitable arrangements were made by the Post Office to safeguard prices. Five firms entered into a bulk contract agreement for telephone switching apparatus and eight firms into a telephone apparatus agreement, and these agreements are

ASSEMBLY OF HANDSET TELEPHONES.

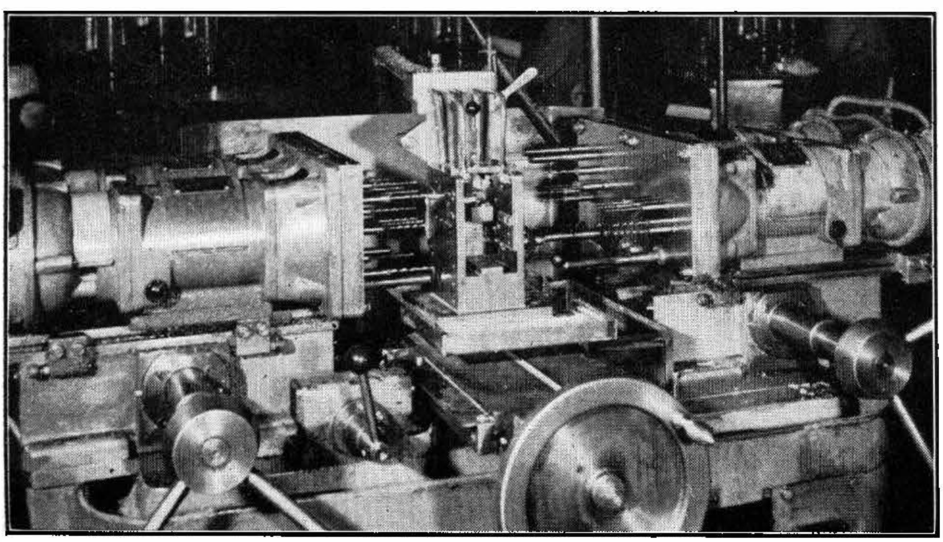
[1] ROBERTSON, J. H. The Story of the Telephone, (Pitmans, 1947).

Main Assembly and Wiring of 2,000-Type Selectors.

still maintained. Costs are controlled by cost investigation at contractors' works, carried out by the Post Office staff, to which is linked a cost variation system to cater for any changes in costs of raw materials and labour.

This agreement then, formed the basis whereon a scheme for the standardization of equipment could gradually be built, and a joint committee of manufacturers and Post Office staff known as the British Telephone Technical Development Committee (B.T.T.D.C.) was set up under the chairmanship of an Assistant Engineer-in-Chief of the Post Office to carry out this work.

The question of production policy and distribution of contracts and agreement as to prices is dealt with on the manufacturers' side by the Bulk Contract Committee (B.C.C.) on which each manufacturer is represented. This has its counterpart in the Telephone Apparatus Committee (T.A.C.) to deal with the telephone apparatus. Any development work required is discussed by the B.T.T.D.C., and the necessary work allocated to one of the manufacturers, who has, in most cases, produced a prototype in an advanced state of development on which future consideration can be based. The committee as a whole keeps in touch with the progress of the work, the cost of which is borne by the manufacturer concerned and which continues until all can agree to the new design. Arrangements are then made for the production of full manufacturing drawings. It is obvious that all the firms have slightly different techniques of manufacture which have been developed over a long period of years and the work needs a big element of compromise among the parties concerned. It forms, however, one of the best examples of close co-operation between a Government Department and Industry. Questions of future development are also discussed by these committees so that the industry can be kept informed of the lines of future development. The effect of any international proposals by the C.C.I.F. are also discussed. These main committees are supported by a number of sub-committees, which consider the questions in more detail, and the whole structure is co-ordinated by an Organization Sub-Committee which determines constitution and terms of reference of the sub-committees to prevent any overlapping and to indicate clearly their respective responsibilities. Examples of apparatus standardized by this procedure are relays type 600 and 3,000, subscribers' uniselector, two-motion switch



Multiple-Spindle Drilling Machine for 2,000-Type Selector Frames.

2,000-type, regenerator No. 1, motor uniselector and hand-combination telephone sets.

This system of working has been advantageous both to the Post Office and to the manufacturers since it facilitates mass production, simplifies maintenance and training and leads to a more uniform loading of the various factories, and greater productivity. It is of the utmost importance that highly developed productive works, such as are required in the telephone industry, should be kept uniformly loaded if efficiency of production is to be maintained. Uniform and adequate loading of the plant is also a most valuable prerequisite for economical production for the export market, where competition is becoming more and more acute. The production of items for the home market which will also have their sale in overseas markets is also very important and this point is borne in mind by the committees concerned. Telephone apparatus of all kinds is one of the most valuable forms of export owing to the relatively large labour element compared with the imported raw materials in the end-product, and its encouragement is, in present circumstances, of paramount importance in the national interest.

Cable and Loading-Coil Design and Manufacture

Until 1931 the supply of cable to the Post Office was dealt with by means of competitive tenders, except for the period from 1920 to 1930, when the cable for local lines was covered by a series of short-time price arrangements. In 1931 the Post Office entered into a bulk agreement with the telephone cable manufacturers which facilitated a rationalization of the industry by concentrating production in fewer factories and thus increasing efficiency. The agreement embraces a total of six manufacturers, four of whom supply local and trunk cables and also install cables in the trunk and junction networks, and two of whom supply only local cables.

With so many common problems it is natural that the co-operation on the technical side has reached a very high level. This co-operation is carried out by means of two committees, the Joint Committee (Technical) and the Joint Committee (Installation). To these committees are referred the many problems of design and installation of cables and it can safely be claimed that only through the willing co-operation of the Post Office and the Industry have many of the advances in cable technique been carried to successful conclusions. Cable development is now proceeding more rapidly than ever and the closest collaboration between the Post Office and the Cable Industry will be even more necessary in the future than it has been in the past.

A similar agreement was negotiated with loading-coil manufacturers in 1933, and it has worked successfully since then. This agreement embraces four manufacturers. A joint committee of the Post Office and the Industry deals with the technical problems arising and agrees specifications. Recent work of this committee includes the development of new loading coils and cases and of "unicoil" loading, i.e. the insertion of small coils in joints.

Testing and Inspection of Products

Developments in the manufacture of telecommunications equipment, which now involves the production and assembly into complex units of a great number and variety of piece parts and components, have necessitated parallel developments in inspection techniques.

Inspection, which in its primitive form existed simply to reject defective products, is now primarily concerned with controlling the quality of production at all stages of manufacture. That is to say, with preventing the production of defective items instead of attempting to reject them when produced. Quality control methods, involving statistical sampling techniques, are now widely used in the Telecommunications Industry. They enable the quality of output at each stage of production to be watched, and potential causes of defective production to be detected and eliminated before their effect becomes serious, thus minimizing waste of material and effort and maintaining the quality of the end-product at the desired level.

The employment of quality control by the manufacturers has largely removed the necessity for the Post Office to inspect in detail the bulk of the equipment it purchases. Instead, the Post Office inspectorate now extensively employs batch sampling and similar techniques, which are complementary to those employed by the manufacturers and which provide, at minimal cost, the necessary assurance that the supplies purchased are of a quality that will satisfactorily meet both service conditions and economic requirements.

The Future

The future of the telephone industry is bright indeed, if wise statesmanship will allow the service to develop freely. If the telephone density in this country were the same as in the United States, where the service is still developing at a very rapid rate, there would be about 15 million telephones here instead of seven million, with all that that implies in increasing productivity and export potentialities. Electronics have already played a big part in making the service more economical and efficient, and they are likely to play a bigger part in the future. The telephone problem is a specialist one and its ramifications demand a special "know-how" which is available in the manufacturers' organizations and can be applied to the new methods in the future with great advantage.

It is not possible to forecast the "shape of things to come" in the field of electronic switching. But the adoption of these new techniques, possibly incorporating new modern components such as transistors, magnetic drums, printed circuits, miniature long-life valves and other components and other new devices, will make heavy demands not only on manufacturers' research development resources, but will require major changes in the realm of workshop practice and organization.

In the advances that have been foreshadowed we are ready and willing to play our full part and help to keep British telephones and telegraphs in the forefront of progress.

Conclusion

It will be clear from the brief descriptions given above of the highlights in the development of telecommunications in all its phases during the last 50 years that industry has played its full part alongside the Post Office in helping to reach the present highly developed state of the art. It is the strong hope of the Industry that the close co-operation will be maintained and even, if possible, strengthened in the years to come, so that together we shall see still greater expansion and, by the further application of electronic and other new techniques, a more and more efficient aid to the general productivity and prosperity of the country.

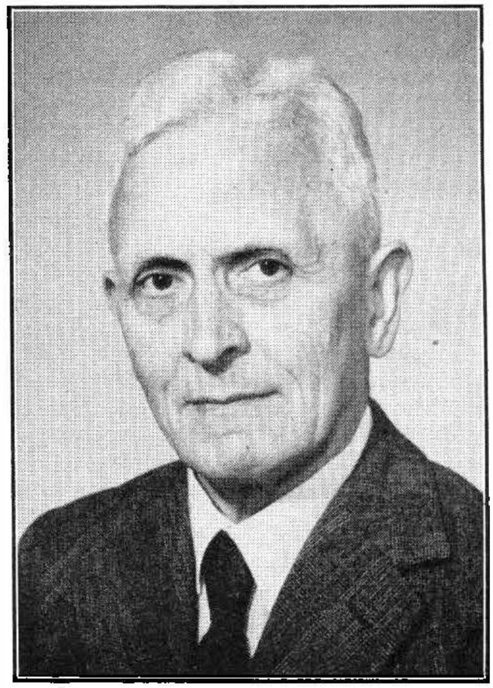
Notes and Comments

The Transatlantic Telephone Cable—Special Issue of the Journal

The January, 1957, Journal (Vol. 49, Part 4) will be another special and enlarged issue and will be devoted entirely to articles dealing with the Transatlantic Telephone Cable. It will contain articles by authors drawn from the manufacturing industry and the Post Office and, by permission of the Council of the Institution of Electrical Engineers, will include 12 papers of American and British origin that are to be presented at a joint meeting of the I.E.E., A.I.E.E. and the Engineering Institute of Canada in January 1957. Thus our readers will receive a full technical account of this historic project in a single issue of the Journal and, although it will contain nearly three times as many pages as the normal Journal, Post Office employees and other regular subscribers will receive their copy without extra charge. Because of the additional cost of producing the much enlarged January 1957 issue of the Journal, it will, however, be necessary to increase the price of that particular number to 12s. 6d. (post free) per copy for copies sold to readers who are neither regular subscribers nor Post Office employees, and for extra copies purchased by regular subscribers.

Readers will wish to note that publication of the "Transatlantic Telephone Cable" (Jan. 1957) issue of the Journal will be deferred until after the joint meeting of the I.E.E., A.I.E.E., and Engineering Institute of Canada, and copies will not therefore be distributed before the end of January, 1957.

Retirement of Mr. C. A. Beer, Whit. Sch., A.C.G.I., D.I.C., A.M.I.E.E.



Mr. Beer received a thorough grounding in engineering at the Royal Dockyard School, Devonport, and obtained a Whitworth Scholarship in 1914 which he was not able to take up till the end of the First World War. During the war he worked in the Electrical Engineering Manager's Office as a draughtsman on all types of electrical installations on naval ships.

He then studied electrical engineering at the Imperial College of Science and was awarded A.C.G.I. and the Diploma of the Imperial College.

In 1920 he entered the Post Office as a Temporary Inspector and was posted to the Marshalsea Road laboratory of the Research Section, where he took part in pioneer work on telephone repeaters and experimental work in the field on repeatered trunk circuits. In 1922 he gained first place in the open competition for Assistant Engineers (old style)—the first competition after the commencement of the war. In 1924 he joined a small team working on the interconnexion of "go" and "return" paths of the first (long wave) transatlantic radio telephone circuit extended by land lines from the radio transmitting and receiving stations (Rugby and Wroughton) to the London terminal. He moved to the Research Station at Dollis Hill when the Marshalsea Road laboratory was closed in 1931. In 1932 he was promoted to Executive Engineer (old style) in charge of the Transmission Group, which made notable contributions to carrier techniques (loaded lines and overhead routes), echo suppressors and voice frequency signalling systems.

In 1937 Beer was promoted to Assistant Staff Engineer in the Lines Branch, where he took charge of circuit utilization work. He transferred the following year to Cardiff (South Wales District) as Assistant Superintending Engineer, becoming Regional Engineer on the formation of the Wales and Border Counties Region in 1939. In December, 1940, he returned to London as a Principal in the Headquarters War Group.

In 1945 he was appointed as a Chief Regional Engineer in the Post Office and seconded to the Control Commission for Germany in the rank of Assistant Controller General of the Posts and Telecommunications Branch. In this capacity he served as the British member of the Quadripartite Telecommunications Committee and can tell many interesting and humorous stories of their meetings. A Quadripartite meeting could, and did on occasion, last for as long as ten hours without getting beyond agreement to the Minutes of the last meeting; evidence of the infinite patience, tact and diplomacy required, which Beer demonstrated to an admirable degree. When the famous Berlin Air Lift started in 1948 he remained in Berlin as the Communications Adviser to the Military Governor. In 1949 he succeeded to the post of Controller General and remained in Germany in that capacity until he returned, in 1952, to take up the post of Chief Regional Engineer, North Eastern Region.

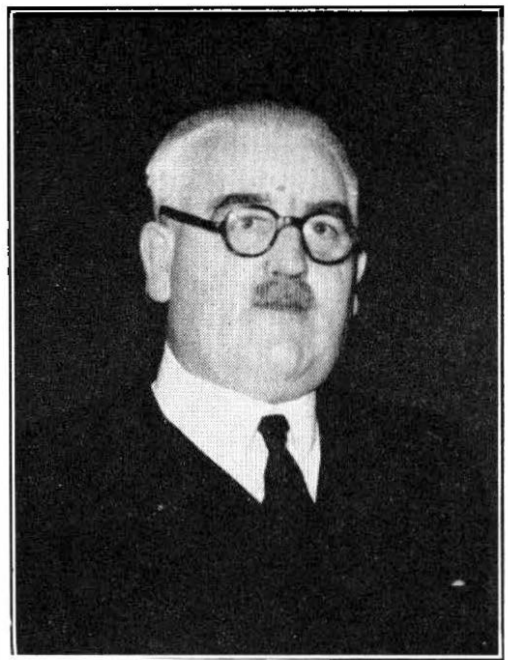
Backed by wide experience, he took up this new role with great enthusiasm and set out to meet as many of his staff as soon as possible: his pride in the N.E. Region was soon apparent and his desire to publish it abroad was the more impressive coming from a South-West countryman. He took a comprehensive view of all his problems and, although he was apt to outline a case in the complex form of "$a + jb$," he readily reduced it to simple terms and reached a firm and clear decision by "adding up and dividing by two."

Beer retired at the end of May and will be remembered in the N.E. Region, above all, for his sense of fairness and his high moral courage. He leaves the Post Office with the good wishes of a wide circle of friends.

G. J. S. L.

Obituary—

Col. A. G. McDonald, O.B.E., T.D., B.Sc. (Eng.), A.C.G.I., A.M.I.C.E., M.I.Mech.E., M.I.E.E.



His many friends, both inside and outside the Post Office, heard with very deep regret of the death of Col. A. G. McDonald, O.B.E., T.D., Chief Motor Transport Officer, on the 11th July, 1956, after an illness of some months' duration.

Col. McDonald served an apprenticeship in mechanical engineering at Woolwich Arsenal, graduated at the City & Guilds Engineering College, and was for two years on the staff of a firm of consulting engineers concerned with the expansion and reconstruction of the City & South London Railway. He was successful in the Open Competition for Assistant Engineers in 1924, and, on entry into the Post Office, joined the small group in the Dollis Hill laboratory of the old wireless section. For the next nine years he served as a member of the team concerned with the development of the rapidly expanding radio services. He left the Engineer-in-Chief's Office in 1933 to take up the post of Power Engineer at Newcastle, and was promoted to Sectional Engineer, Middlesbrough, the next year; he came South in 1937 as Executive Engineer in the London Engineering District and in 1938 returned to the Engineer-in-Chief's Office, Equipment and Accommodation Branch, where he was promoted to Assistant Staff Engineer in that year.

In addition to his departmental responsibilities, Col. McDonald found time to give to the Territorial Army. He was commissioned in the 44th (H.C.) Divisional Signals (T.A.) in 1925, transferring to the Royal Army Ordnance Corps in 1933 when he moved from London. He was mobilized for six years from September, 1939, and became the Deputy Director of Mechanical Engineering in the Royal Electrical and Mechanical Engineers. In recognition of his war service he was awarded the O.B.E.; in addition, he held the Territorial Decoration.

On his return to the Post Office late in 1945, Col. McDonald was appointed Chief Motor Transport Officer, a post which provided scope for his organizing ability, and in which he could use his wide wartime experience of motor transport. During the following ten years, he was fully occupied with the development and expansion of the Post Office motor transport system, which owes much to his personal efforts.

Col. McDonald leaves a widow, a daughter and a son. He was a kindly man, with a good sense of humour and he was well adapted to getting on with people. His death at the comparatively early age of 56 came as a great shock; he will be missed by many of his colleagues in the Post Office and by his friends in the Motor Industry, where he had become a respected figure.

C. F. B.

Institution of Post Office Electrical Engineers

Commemoration of 50th Anniversary

The Council of the Institution and the Board of Editors of the Journal wish to take this opportunity of expressing their gratitude to all those who have contributed, in so many ways, both to the production of this special issue of the Journal and to other arrangements for celebrating the Institution's Jubilee. In particular, thanks are due to the following:—

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Finally, it is desired to thank Mr. R. MacWhirter for the very considerable help he has given in the editing of this special issue of the Journal.

Essay Competition, 1956-57

To further interest in the performance of engineering duties, and to encourage the expression of thought given to day-to-day departmental activities, the Council of the Institution of Post Office Electrical Engineers offers five prizes, a First Prize of Five Guineas and four prizes of Three Guineas, for the five most meritorious essays submitted by members of the Engineering Department of the Post Office *below the rank of Inspector*. In addition to the five prizes the Council awards five Certificates of Merit. Awards of prizes and certificates made by the I.P.O.E.E. are recorded on the Staff Dockets of the recipients.

An essay submitted for consideration of an award in the Essay Competition and also submitted in connexion with the Associate Section I.P.O.E.E. prizes, will not be eligible to receive both awards.

In judging the merits of an essay, consideration will be given to clearness of expression, correct use of words, neatness and arrangement, and although technical accuracy is essential, a high technical standard is not absolutely necessary to qualify for an award. The Council hopes this assurance will encourage a larger number to enter. Marks will be awarded for originality of essays submitted.

Copies of previous prize-winning essays have been bound and placed in the Institution Central Library. Members of the Associate Section can borrow these copies from the Librarian, I.P.O.E.E., G.P.O., Alder House, London, E.C.1.

Competitors may choose any subject relevant to current telephone or telegraph practice; foolscap or quarto size paper should be used, and the essay should be between 2,000 and 5,000 words. An inch margin is to be left on each page. A certificate is required to be given by each competitor, at the end of the essay, in the following terms:—

'In forwarding the foregoing essay of .... words, I certify that the work is my own unaided effort both as regards composition and drawing.'

Name (in Block Capitals) ....

Signature ....

Rank ....

Departmental Address ....

Date ....

The Essays must reach
The Secretary,
The Institution of Post Office Electrical Engineers,
G.P.O., Alder House, London, E.C.1,
by the 31st December, 1956.

The Council reserves the right to refrain from awarding the full number of prizes or certificates if in its opinion the essays submitted do not attain a sufficiently high standard.

Review of Prize-winning Essays—1955-56 Competition*

The Council of the Institution is indebted to Mr. W. S. Procter, M.I.E.E., F.R.S.E., Chairman of the Judging Panel, for the following review of the five prize-winning essays:—

"The Panel of Judges had no hesitation in selecting 'Problems and Personalities at Maintenance Control,' by Mr. E. F. Taunton, Perth, as the first prize winner. His essay is a study of the human relations existing between the various members of a team directed from a Maintenance Control, and he bases his analysis on the different types of personality that a Maintenance Control Officer is likely to encounter. Each is drawn true to type, and it is obvious that the author is well able to appreciate the difference between them. The problems that may confront a Maintenance Control Officer are legion, but the author has selected typical occurrences and shows how the decisions made by the Control Officer can smooth the way for the Repair Staff. Mr. Taunton takes the first prize for the clever way in which he has dealt with an unusual subject and shown how problems and personalities can even affect one another in a Maintenance Control.

Second in order of merit is an essay by Mr. H. F. Bentley, of Edenbridge, Kent, entitled 'The Long Arm of Dual Maintenance.' This is an analysis of the widely different conditions that a Dual Maintenance man has to meet, ranging from the clearance of overhead faults to the adjustment of equipment in a U.A.X. He deals, too, with the more common types of fault that occur in various parts of the plant, from braided cables to cords, dials, transmitters and selector wipers and banks.

The essay by Mr. J. R. Haggart, Edinburgh, entitled 'The Development of the Telephone' was awarded third place. This is an historical account commencing with the invention of the telephone by Alexander Graham Bell, and ending with the modern telephone instruments in use to-day. The author also takes a brief look at the possibilities of further development in the future.

Next is the essay by Mr. J. O. Rogers, of Rugby Radio Station, entitled 'How Far is Automation a Good Idea?' In attempting an answer to this question, the author compares the 'A' and 'B' buildings at Rugby Radio Station, describing the automatic equipment available in the new building to enable one individual to control the operation of 28 transmitters. He directs attention to the greater concentration of skilled work in maintenance and fault clearing through the increased complexity of the automatic control equipment, but he is not quite sure that automation is all that good.

Finally, 'Conducting the Public around a Telephone Exchange,' by Mr. J. L. Care, of Eltham, Kent, describes the way in which the local staff can undertake an important aspect of public relations. He analyses the visitors into various categories and shows the best program for a visit by each. He comments on the value of demonstration equipment of various kinds and makes some attempt to assess the value of visits of this kind to customer relations."

H. E. WILCOCKSON, *Secretary.*

* The full list of Awards was published in the *P.O.E.E.J.* July, 1956, p. 137.

Additions to the Library

2356 *Services Textbook of Radio, Vol. 3: Electronics.* J. Thomson (Brit. 1955).
Primarily designed for the beginner, and deals with the subject in its relation to radio. (The other volumes are to be issued later.)

2357 *Concrete Materials and Practice.* L. J. Murdoch (Brit. 1955).
Provides a broad outline of the science of concrete making.

2358/9 *Advanced National Certificate Mathematics, Vols. 1 and 2.* J. Pedoe (Brit. 1954).
Vol. 1 covers the requirements of the A1 examination of the H.N.C. and Pt. 1 of B.Sc.(Eng.). Vols. 1 and 2 together cover A1 and A2 H.N.C. courses and Pts. 1 and 2 of B.Sc.(Eng.).

2360 *Municipal Law for The Engineer.* S. F. Rich (Brit. 1955).
A brief survey of Municipal Law in those matters of most concern to the engineer in local government service.

2361 *Building Technique for Domestic and Similar Structures.* E. Gunn (Brit. 1955).
Deals fully with the construction and fitting of small houses.

2362 *Electronic Transformers and Circuits.* R. Lee (Amer. 1955).
Deals with the design of transformers for electronic apparatus and attempts to provide an understanding of the effects of transformer characteristics on electronic circuits.

2363 *Principles of Communication Systems.* W. D. Hershberger (Amer. 1955).
Presents the basic material common to both the older and newer communication systems.

2364 *The Modern Building Encyclopaedia.* Ed. N. W. Kay (Brit. 1955).
A comprehensive reference book.

2365 *Magnetic Recording Handbook.* R. E. B. Hickman (Brit. 1956).
Designed for the enthusiastic amateur and the skilled worker; covers the theory, practice and servicing of domestic and professional tape and wire recorders.

2366 *Basic Mathematics for Science and Engineering.* P. G. Andres, H. J. Miser and H. Reingold (Amer. 1955).
Presents very comprehensively the mathematics required for the pursuit of elementary science and engineering courses and serves as a preparation for a course of the calculus.

2367 *Mains Practice: Transmission and Distribution of Electric Energy.* T. H. Carr (Brit. 1956).
Covers the broad field of mains practice, taking in both overhead and underground systems.

W. D. FLORENCE,
Librarian.

Book Reviews

"Information Theory: Third London Symposium, 1955." Edited by Colin Cherry. Butterworth's. 401 pp. Ill. 70s.

Thirty-six papers and four summaries of papers presented to the Symposium are collected in this volume; in most cases a brief record of the discussion of the paper is appended. A first impression is the wide variety of the subjects treated. The editor has grouped them into five sections: Fundamentals; Coding, Taxonomy, etc.; Language Analysis and Mechanical Translation; Meaning and the Human Senses; Behaviour and its Mechanism. Marcou's and Daguet's "New Methods of Speech Transmission" (no longer so new) is in the fourth of these sections, as also are two substantial contributions by Licklider and by Allanson and Whitfield to the discussion on the auditory sensation of pitch, started by Helmholtz more than a century ago. Zetterberg's "A Comparative Study of Delta and Pulse Code Modulation" is in the section on Coding, as are papers by Laemmel and by Elias relative to electronic switching and to telegraph codes respectively.

For the rest, it is fair to say that about half the book is not intelligible to the ordinary reader on account of extensive use of mathematical or other strange symbols or unfamiliar terminology. On the other hand a dozen or so of the papers might find a place by the bedside of those who enjoy reading philosophical essays, irrespective of the subject matter.

The reporting of the discussions deserves special mention. In total they occupy only about a tenth of the book and less than half the papers have more than one page for the discussion, yet for the ordinary reader they are often revealing and informative out of proportion to their length. It may be remarked that the most keenly controversial of the discussions occur in the section on Fundamentals.

It would be a mistake to pick up this book expecting to learn much about Information Theory. It is not a text book. In fact, with so wide a field of coverage "Information Theory" must mean different things to different people. In MacKay's paper it means "broadly the theory of processes by which representations come into being, together with the theory of those abstract features which are common to a representation and that which it represents." Other authors are not so specific; many don't even mention it.

It is tempting to add a few brief extracts from the book. Did you know that statistics have been used to compose the music of cowboy songs (p. 169)? Or that "in every voting procedure where voting is open there exists an equilibrium, a result such that each voter can say 'If I had known exactly how all the others were going to vote, I wouldn't have had any incentive to vote otherwise than I did' " (p. 50)? Or that it is "easier to do a little about several things than to do very much about a single one" (p. 366)? In one of the discussions the question is asked: "Could a system of rules be settled which would pick at random into existing literature about a subject to get sufficient relevant good literature to cover practically the whole field considered?" (p. 132). Believe it or not, the question is well answered—with reference to the climate of Alaska!

One of the papers is introduced by a quotation, which might well have appeared on the title page of the book: "To philosophize is hard, but not to philosophize is even harder" (E. Rogge).

W. W.

"Abacs or Nomograms." A. Giet (Ecole Nationale des Ingénieurs Arts et Métiers, Paris). Translated by J. W. Head and H. D. Phippen. Iliffe & Sons, Ltd. 235 pp. 152 ill. 35s.

It is sometimes necessary for an engineer to make a large number of calculations from the same formula. The use of a slide-rule or a table of logarithms may help to reduce the labour of computation; but if the formula contains several variables the labour involved may be very great. It is possible to avoid this computing labour by drawing once and for all a diagram representing the formula; in this diagram, each variable is represented by one or more graduated lines, and the solution of the formula for any given set of values can be read off at once by means of an index line. Such diagrams are called Abacs or Nomograms, and may be regarded as stationary slide-rules. They possess, however, certain advantages over ordinary slide-rules, for additive as well as multiplicative operations can be performed at the same setting.

The literature on the subject of nomograms is not large and most of it has been written for mathematicians and centres round D'Ocagne's highly analytical work, *Traité de Nomographie*. Consequently, an engineer who wishes to construct nomograms for his own use may not find this literature very helpful. The present work by M. Giet, however, is essentially practical and does not call for an expert knowledge of projective geometry or basic determinants, etc. It shows how an engineer without specialized mathematical knowledge may construct his own nomograms, and is illustrated by many practical examples. The style of the book is pleasing, and it is easy to read in spite of the fact that it is a translation of an original French text.

The first two chapters of the book deal with the graphical representation of relations between two variables. The choice of linear and non-linear scales and the part played by the concept of a scale modulus are clearly described and illustrated by specific examples. The following chapters deal with problems connected with the graphical representation of relations between three or more variables. Examples treated in these chapters have been drawn from the fields of physics and electrical engineering; in every case stress has been laid on the details of construction and methods of choosing auxiliary variables. Most of the nomograms described are scaled in the original French units; this is of small importance, however, for it is an easy matter to convert them to British units.

This book can be recommended to engineers interested in the construction of computation charts. It is hardly necessary to point out that only approximate results can be obtained from these charts. If accurate results are required from a formula a desk calculating machine may be used with advantage; if, however, a large number of accurate calculations are required from the same formula, it may be worth while to program the calculation for an electronic computer. It all depends upon the accuracy required.

H. J. J.

Books Received

"Electrical Who's Who 1956-57." Fourth Edition. Electrical Review Publications, Ltd. Distributed by Iliffe & Sons, Ltd. 458 pp. 21s. (postage 1s. 5d.).

This new edition has been considerably enlarged and now there are about 7,000 entries. They include men and women in every branch of the electrical industry and profession—electricity supply, electrical manufacturing, contracting, consulting, research, transport, mining and trade associations, the Admiralty, the Post Office, the Ministry of Supply and other Government Departments.

Details are given of the positions and previous appointments of the men and women dealt with, as well as their qualifications and professional activities. An extensive section of the directory is an index in which all biographical entries are classified under the titles of their companies and other organizations.

"Theory and Practice of Rhombic Antennas." (In Portuguese). A. A. de Carvalho Fernandes, Eng.Dipl. (I.S.T.), M.I.R.E., A.M.I.E.E. Coimbra Editora, Lda., Coimbra, Portugal. XVI + 407 pp. Ill. Esc. 150.00.

The first four chapters deal with the propagation of electromagnetic waves based on Maxwell's equations. Chapters V to VIII deal with fundamentals on radiation and on typical linear antennas and antenna arrays, establishing the basis for the more detailed studies presented in Chapters IX and X, which refer to rhombic aerials and arrays of rhombics. Chapter XI refers to terminal impedance measurements and Chapter XII to pattern radiation measurements of rhombics and arrays of rhombics.

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THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

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The price per copy is 2s. 6d. (2s. 8d. post free) and Corporate Members of the Institution and Members of the Associate Section have the privilege of purchasing copies at the reduced price of 1s. 6d. net. (1s. 8d. post free).

No. 140. "SOME NON-METALLIC SUBSTANCES AND THEIR CHARACTERISTICS."—Capt. N. F. CAVE-BROWNE-CAVE, B.Sc., A.M.I.E.E. 1931.
†No. 146. "LAYING ARMOURED CABLE BY MEANS OF A MOLE-DRAINER."—L. G. SEMPLE, B.Sc.(Eng.), and R. O. BOOCOCK, B.Sc.(Eng.). 1932.
No. 148. "STORES SPECIFICATIONS AND ACCEPTANCE TESTING."—Capt. J. LEGG, B.Sc., A.M.I.E.E. 1933.
†No. 166. "CHEMISTRY AND COMMUNICATIONS."—D. W. GLOVER, M.Sc., A.I.C. 1937.
†No. 169. "CROSSTALK."—H. C. S. HAYES, A.M.I.E.E., R. A. SEYMOUR and P. R. BRAY, M.Sc.(Eng.), Graduate .I.E.E. 1938.
No. 173. "AUDIO-FREQUENCY RIPPLE FROM D.C. POWER SUPPLIES IN COMMUNICATION ENGINEERING."—H. R. HARBOTTLE, B.Sc., D.F.H., M.I.E.E., J. A. SHEPPARD, B.Sc., A.M.I.E.E., and D. L. RICHARDS, B.Sc. 1939.
No. 174. "METALLURGY AND COMMUNICATIONS."—E. V. WALKER, B.Sc., A.R.S.M. 1940.
No. 177. "RECENT APPLICATIONS OF THE QUARTZ AND X-RAY SPECTROGRAPHS TO POST OFFICE PROBLEMS."—R. TAYLOR, M.A., PH.D., B.Sc 1941.
No. 179. "INTRODUCTION OF U.A.X. MULTI-METERING IN THE LEEDS AREA."—H. G. COPE. 1941.
†No. 182. "LONDON INLAND TRUNK SERVICES."—W. H. SCARBOROUGH, A.M.I.E.E. 1943.
†No. 187. "CABLING PROBLEMS IN SUBWAYS AND TUNNELS."—T. G. TURLEY, A.M.I.E.E. 1945.
†No. 191. "PIEZO-ELECTRIC QUARTZ AND ITS USE IN TELECOMMUNICATIONS."—C. F. BOOTH, M.I.E.E., and J. L. CREIGHTON, A.M.I.E.E. 1946.
†No. 193. "IMPROVEMENTS IN TELEPHONE SIGNALLING."—S. WELCH, M.Sc.(Eng.), A.M.I.E.E., and C. H. J. FLEETWOOD, A.M.I.E.E. 1949.
†No. 196. "WIRE BROADCASTING."—F. HOLLINGHURST, B.Sc.(Eng.), A.C.G.F.C., M.I.E.E., and W. PRICKETT, A.M.I.E.E. 1949.
†No. 197. "THE POSSIBILITIES OF SUPER-HIGH FREQUENCY RADIO AND WAVEGUIDE SYSTEMS FOR TELECOMMUNICATIONS." —W. J. BRAY, M.Sc.(Eng.), A.C.G.I., D.I.C., A.M.I.E.E. 1948.
No. 198. "INTRODUCTION AND APPLICATION OF TRANSMISSION PERFORMANCE RATINGS TO SUBSCRIBERS' NETWORKS."—G. A. E. FUDGE, A.M.I.E.E. 1949.
†No. 199. "SOME APPLICATIONS OF ELECTRONIC METHODS TO TELEGRAPH APPARATUS."—R. O. CARTER, M.Sc.(Eng.), A.M.I.E.E., and L. K. WHEELER, B.Sc.(Eng.), A.M.I.E.E. 1949.
†No. 200. "TRENDS IN THE DESIGN OF LINE TRANSMISSION EQUIPMENT."—R. J. HALSEY, B.Sc.(Eng.), A.C.G.I., D.I.C., M.I.E.E. 1949.
†No. 201. "TRUNK MECHANISATION."—A. J. THOMPSON and J. H. BROADHURST, A.M.I.E.E. 1951.
No. 202. "THE COLD-CATHODE TUBE IN TELEPHONE SWITCHING CIRCUITS."—J. A. LAWRENCE, A.M.I.E.E. 1952.
†No. 203. "SUBSCRIBER TRUNK DIALLING IN THE UNITED KINGDOM."—D. A. BARRON, M.Sc., M.I.E.E. 1952.
†No. 204. "A.C. SIGNALLING—A REVIEW OF CURRENT PROBLEMS."—B. R. HORSFIELD, A.M.I.E.E., and D. C. SMITH, B.Sc.(Eng.), A.M.I.E.E. 1952.
†No. 205. "COAXIAL CABLES—SOME PRACTICAL ASPECTS OF THEIR DESIGN AND MAINTENANCE."—G. E. ROSSITER, A.M.I.E.E. 1953.
†No. 206. "THE INFLUENCE OF SIGNAL IMITATION ON THE DESIGN OF VOICE FREQUENCY SIGNALLING SYSTEMS."—S. WELCH, M.Sc.(Eng.), A.M.I.E.E. 1953.
†No. 207. "TELEX SERVICE."—R. N. RENTON, A.M.I.E.E. 1954.

† The Council have awarded Institution Medals for these papers.

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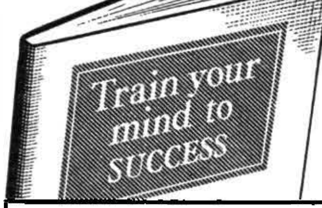

If you lack qualifications which would get you a better job, more pay and faster progress; if you really want to succeed in your studies for the City & Guilds Certificates . . . send *now* for this recently published, important book—"Train your Mind to SUCCESS."

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Preliminary Course
Telecommunications Principles I - V
Radio I - IV
Telegraphy I & II
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Mathematics *for Telecommunications*
Radio Servicing Certificate

TO THE FAMOUS BENNETT COLLEGE
(DEPT. J.24.F.), SHEFFIELD

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NAME________
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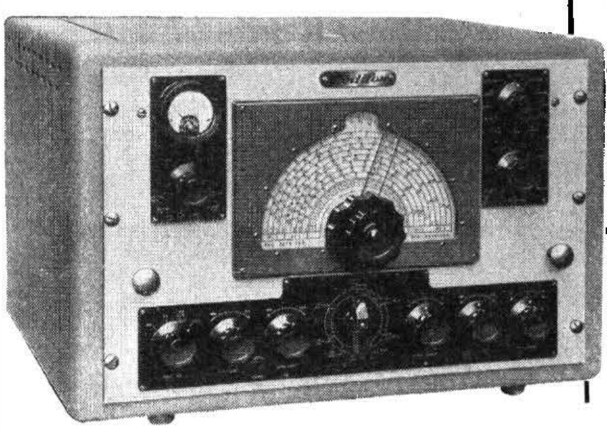
THIS DAY COULD BE THE TURNING-POINT IN YOUR LIFE.
THIS COUPON COULD BE YOUR PERSONAL PASSPORT TO SUCCESS.
Send it NOW!

New **Redifon** RECEIVER

WITH BUILT-IN POWER UNIT

THE R.150

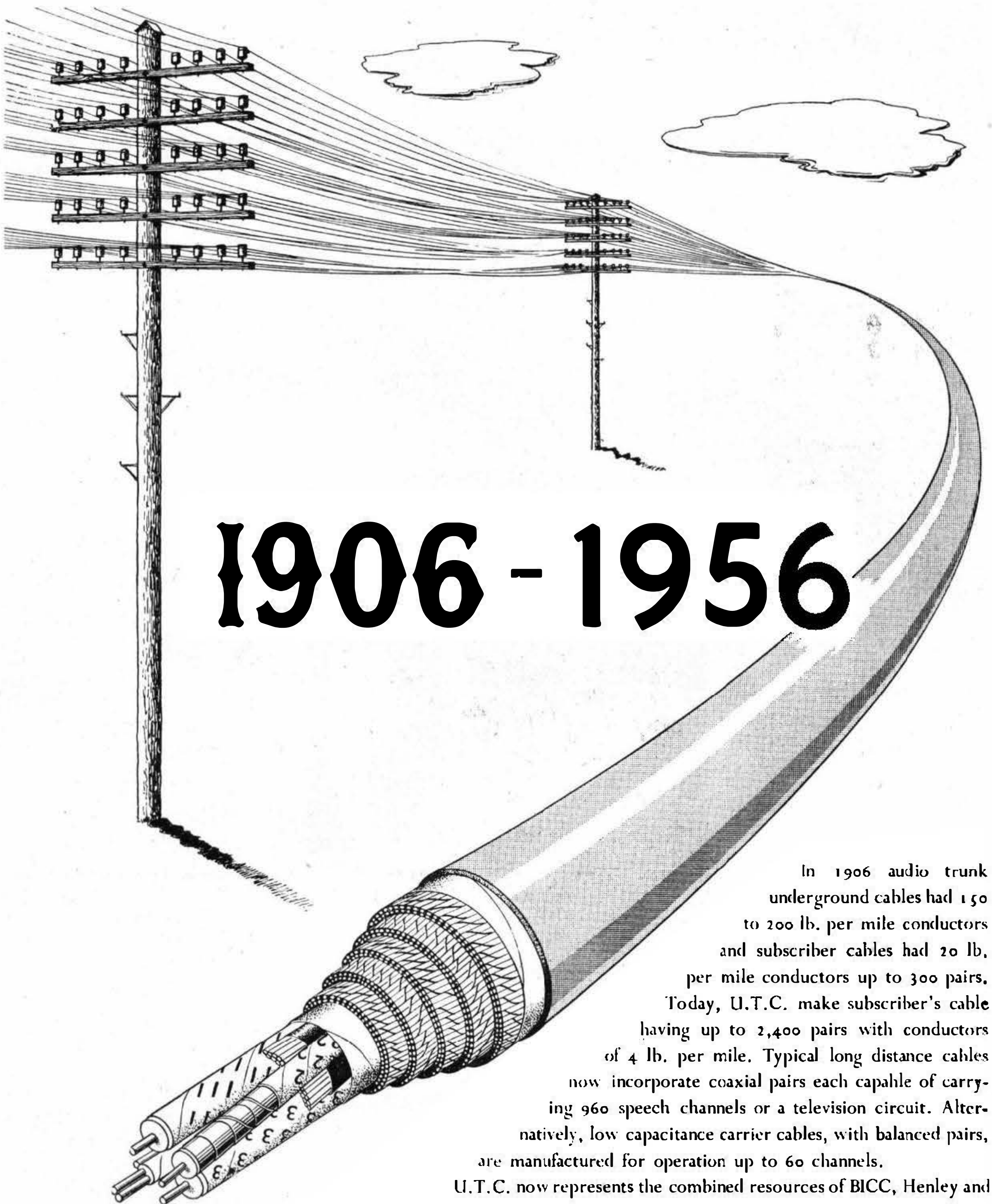


The Redifon R.150 is a general communications version of the world famous R.50 marine receiver, so extensively used by the leading British and European marine wireless communication companies. It gives complete coverage from 585 kcs to 32 m/cs. Two optional crystal calibrators are available, one at 500 kcs and the other at 100 and 1000 kcs. A crystal may be plugged in to give any accurate spot frequency in the range.

Radio Communications Division

REDIFON LIMITED, BROOMHILL ROAD, LONDON, S.W.18. VANdyke 7281

A Manufacturing Company in the Rediffusion Group



In 1906 audio trunk underground cables had 150 to 200 lb. per mile conductors and subscriber cables had 20 lb. per mile conductors up to 300 pairs. Today, U.T.C. make subscriber's cable having up to 2,400 pairs with conductors of 4 lb. per mile. Typical long distance cables now incorporate coaxial pairs each capable of carrying 960 speech channels or a television circuit. Alternatively, low capacitance carrier cables, with balanced pairs, are manufactured for operation up to 60 channels.

U.T.C. now represents the combined resources of BICC, Henley and Enfield who have made many contributions to this substantial progress during the past fifty years.

UTC

UNITED TELEPHONE CABLES LTD.

QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

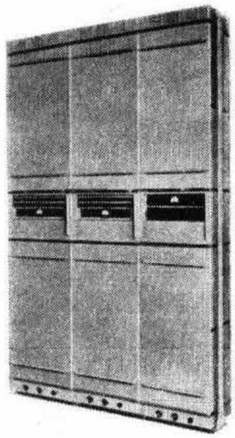
UTC

Transmission Equipment for

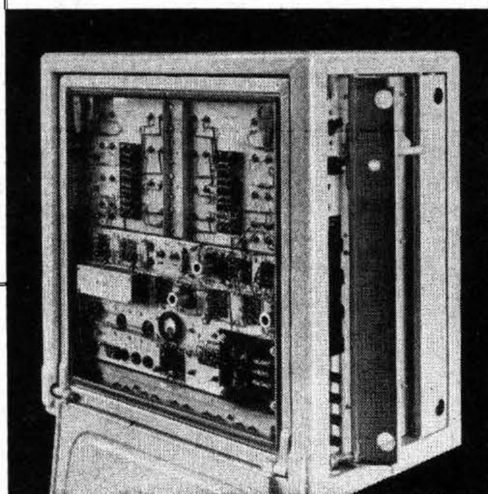
WORLD WIDE

Communications

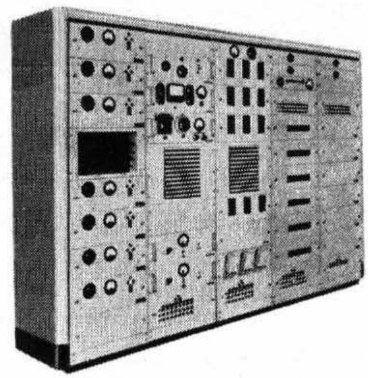
Transmission Equipment bearing the name of SIEMENS BROTHERS is in operation in most parts of the world—from Iceland to South America, from Africa to China.



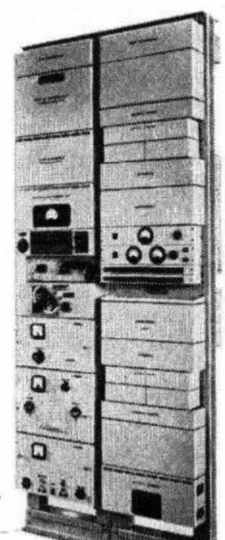
12-Channel Carrier Telephone Terminal



Portable Carrier Telephone Terminal (1 + 3)



Frequency Modulated V. F. Telegraph Terminal



Five Band Privacy Equipment

Carrier Telephone Equipment for Cable — Open Wire — Radio
including 4, 12, 60, and 120 channel systems
Programme Channelling and Portable Carrier Systems

Signalling Systems including 500 c/s, 1 V.F. and 2 V.F.

Voice Frequency Telegraph Equipment including
Single and Two Tone Amplitude Modulated Systems
and High Speed Frequency Modulated Systems

Radio Telephone Terminals for H.F. Radio Links
Five Band Privacy, Displacing and other
ancillary equipment associated with this apparatus

SIEMENS BROTHERS

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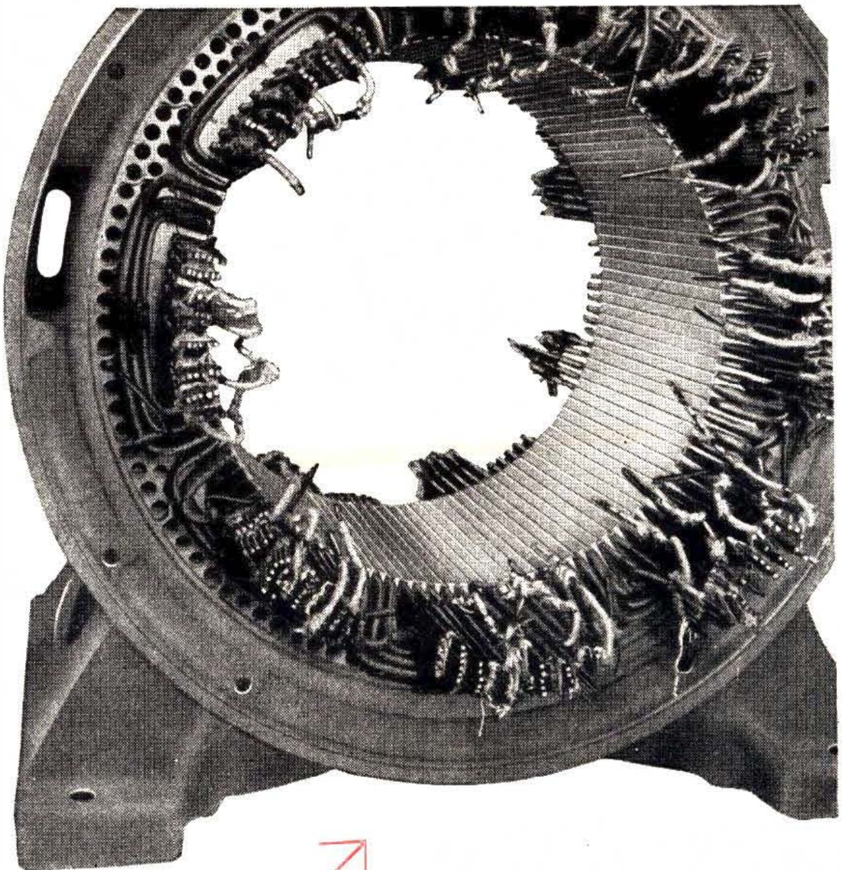


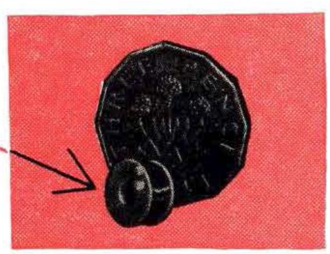
A partly wound stator for a 13,000 h.p. motor.

FROM HEAVYWEIGHT

TO MICRO-WEIGHT

BICC Winding Wires and Strips are available in a wide range of coverings for every type of coil: from giant stator windings to minute deaf aid coils weighing only .76 grammes.

Further information on BICC Winding Wires and Strips is contained in Publication No. 266. May we send you a copy?

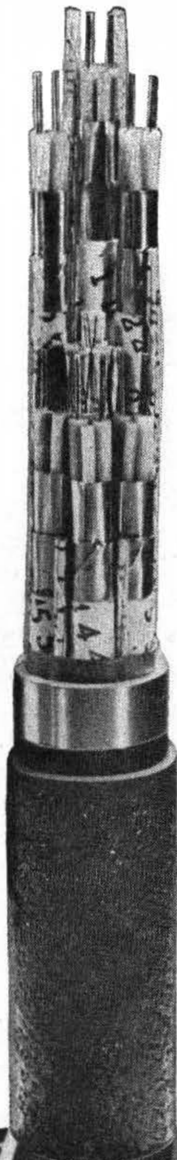


A deaf aid coil shown actual size.

BICC **WINDING WIRES AND STRIPS**

BRITISH INSULATED CALLENDER'S CABLES LIMITED 21 Bloomsbury Street, London, W.C.1

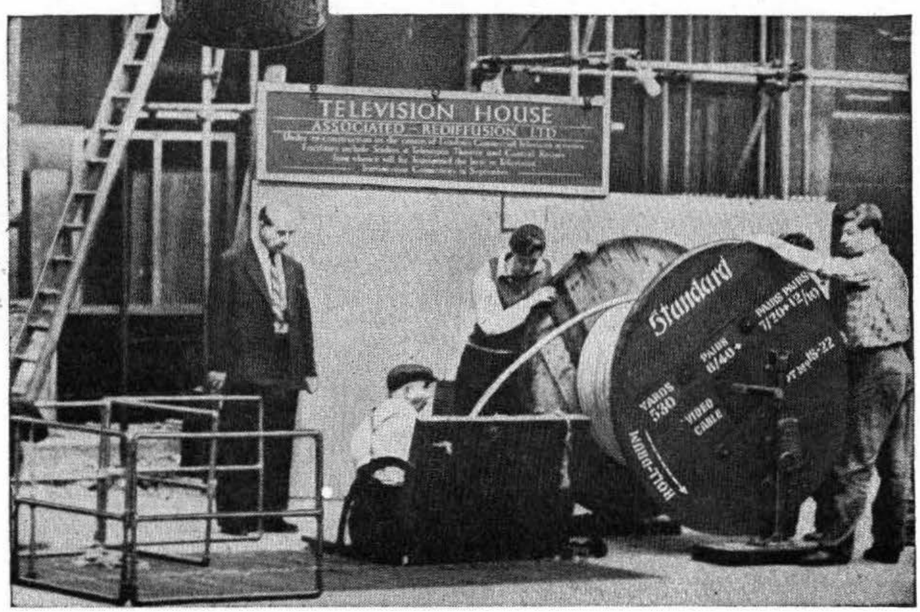
1923



The latest advance by *Standard* in the field of communication engineering is the balanced pair cable for video transmission, utilizing expanded polythene as an insulant. This dielectric by its greater mechanical rigidity allows a more uniform location of the conductors than previous designs and gives an improved impedance uniformity, while retaining the characteristics of low attenuation and cross talk. These screened circuits are ideal for short television cable links.

Standard VIDEO CABLES

One of the 'Standard' Video Cables is shown being installed at Television House, Headquarters of I.T.A. to connect the studios with the main television switching centre.



Standard Telephones and Cables Limited

Registered Office: Connaught House, Aldwych, W.C.2

TELEPHONE LINE DIVISION: NORTH WOOLWICH · LONDON · E.16

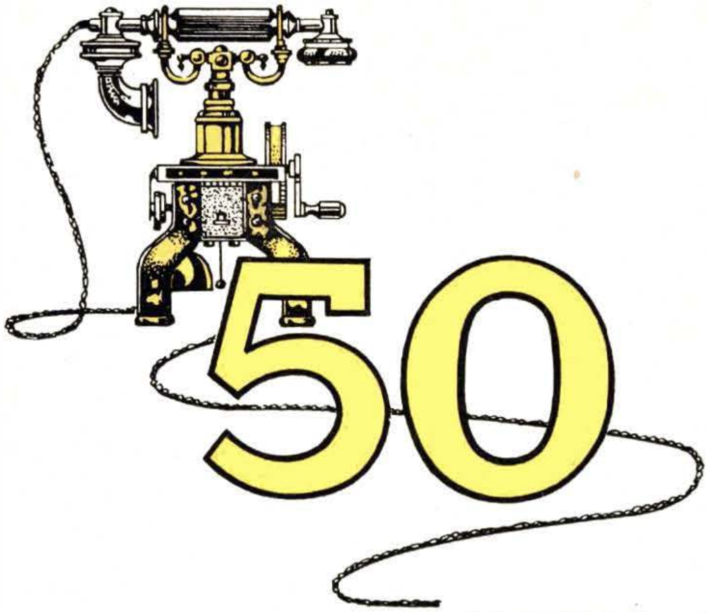
Down Alton way, when a fellow cycles home from work, the woods and fields and streams he sees are those his father knew. The people who lift a hand and exchange a word as he passes are people he knows and knew as a boy. He's a man with a name and a home and a place in his own community: and he feels—who wouldn't?—that life's the better for that. And the batteries men like him are making in Alton? Well, a storage battery is among the most tightly specified, uniform products made. And yet, year after year, come letters telling us our batteries serving overseas have a certain distinguishing overall merit of their own. It could be that what a life that's better than merely worth living puts into a man, comes out in the form of work which is just that vastly important bit better than 'up to specification'.

ALTON *Batteries of Merit*

Alton stationary batteries: 10 to 15,000 ah. Also in regular production, renewal plates for all makes of battery, British and Continental.

THE ALTON BATTERY COMPANY LIMITED, ALTON, HANTS *Telephone:* ALTON 2267 and 2268 *Telegrams:* BATTERY ALTON

A.29



50 *years of* ***progress***

Hansom cabs and ornate telephones typified the leisurely days of half a century ago. What a history of progress in the field of Telecommunications has been compiled in the pages of this Journal and symbolized by these illustrations!

Having celebrated our own Jubilee some three years ago, we like to think our contribution to this progress has played a useful part. To-day, within the extensive range of products manufactured by this Company, are included complete Telephone Exchanges, Switchboards, Telephone instruments, Carrier and Transmission systems and Electronic equipment.

For the future, expanding resources in our production and research will undoubtedly accelerate development. We will continue to serve and anticipate the needs of our Customers at home and overseas and to place at their disposal the results of a wide and comprehensive experience.

ERICSSON TELEPHONES LIMITED 22

WORKS BEESTON

Congratulations to

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

on its half century

in

Telecommunications

LINCOLN'S INN FIELDS LONDON W.C.2

AND SUNDERLAND

Quality, Sir, is a matter of detail.

Take a diesel engine and an alternator, bolt them down to a bedplate, couple them together and supply some switchgear. There you have a generating plant. Good enough for some jobs, perhaps, but not for the kind of job Austinlite plant is designed to do.

To see the difference you have to look closely. At the solid steel bearing housings with their special high speed bearings; at the patented bearing wear detection system; at the subsidiary emergency bearings which only come into play in the very unlikely event of main bearing failure; at the electrical equipment specially 'tropicalised' by methods developed as a result of much experience in the supply of plant designed to operate dependably in hot, humid climates.

It is detail of this kind which accounts for the high reputation of Austinlite wherever reliability is an essential. That, and one thing more; Austinlite engineers always enjoy tackling the jobs other people cannot fit. Because, although we make many standard types of generating plant, made-to-measure plant is our forte.

Austinlite **AUTOMATIC GENERATING PLANT**

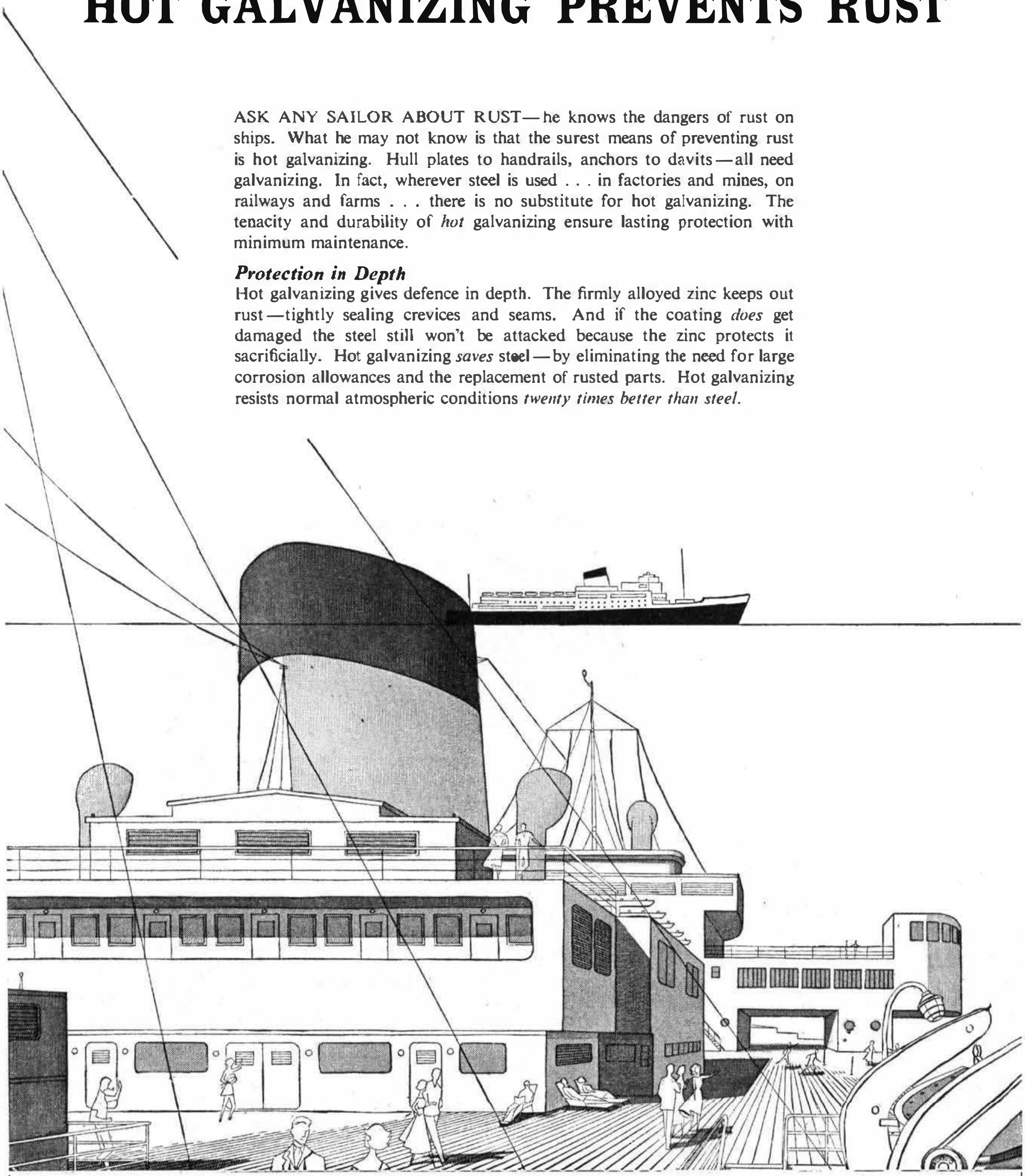
Tailor-made by STONE-CHANCE LTD.

(The Makers of Sumo Pumps & Stone-Chance Lighthouses) 28 St. James's Square, London, S.W.1 · Tel.: Trafalgar 1954

HOT GALVANIZING PREVENTS RUST

ASK ANY SAILOR ABOUT RUST—he knows the dangers of rust on ships. What he may not know is that the surest means of preventing rust is hot galvanizing. Hull plates to handrails, anchors to davits—all need galvanizing. In fact, wherever steel is used . . . in factories and mines, on railways and farms . . . there is no substitute for hot galvanizing. The tenacity and durability of *hot* galvanizing ensure lasting protection with minimum maintenance.

Protection in Depth
Hot galvanizing gives defence in depth. The firmly alloyed zinc keeps out rust—tightly sealing crevices and seams. And if the coating *does* get damaged the steel still won't be attacked because the zinc protects it sacrificially. Hot galvanizing *saves* steel—by eliminating the need for large corrosion allowances and the replacement of rusted parts. Hot galvanizing resists normal atmospheric conditions *twenty times better than steel.*



Hot Dip Galvanizers Association

The Hot Dip Galvanizers Association, a non-trading body, welcomes enquiries. Write to 34 Berkeley Square, London, W.1. Tel: Grosvenor 6636.

Member of the Zinc Development Association

A tradition of progress

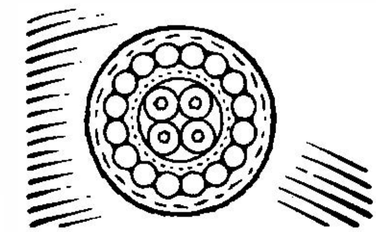
The steady progress in the development of telecommunication techniques over the past 50 years has resulted from the endeavour of manufacturers to meet and often anticipate the growing needs of operating Administrations. Siemens Brothers have established a tradition of being in the forefront of technical advancement from the earliest days of telephone communication, and certain achievements have been selected for special mention in this Jubilee issue of the Journal of the Institution of Post Office Electrical Engineers.

1906

The earliest types of "Multiple-Twin" underground telephone cables were manufactured by Siemens Brothers.

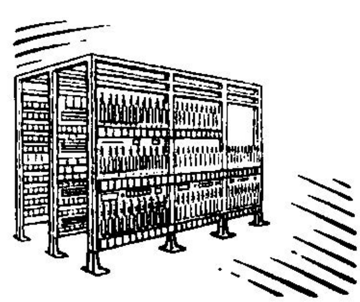
1910

The first coil-loaded submarine telephone cable was developed by Siemens Brothers and laid between Abbotts Cliff, Kent and Cap Gris Nez in France.



1913

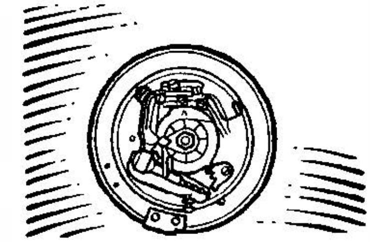
Among the first Private Automatic Exchanges installed by Siemens Brothers in this country was the Kings College Hospital P.A.X. London.



1918

The first Public Automatic Telephone Exchange supplied by Siemens Brothers was opened for service at Grimsby.

1921



The Siemens Brothers cam-type telephone dial was standardised by the British Post Office and has remained virtually unchanged in over 30 years service.

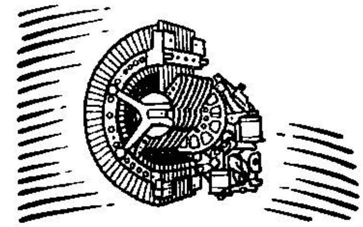
1929

Five large Director Exchanges were brought into service in London incorporating for the first time twin contact relays pioneered by Siemens Brothers and now adopted internationally.

1932

The Siemens Brothers famous Neophone telephone instrument was further improved by the addition of the Anti-Sidetone Induction Coil (ASTIC), a major contribution to speech performance.

1933



Siemens Brothers High Speed Motor Uniselector switches were installed at North Exchange, London, and marked the first of many uses of this outstanding and versatile mechanism.

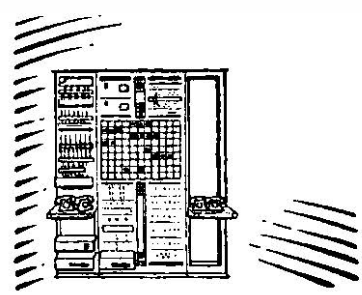
1939

During World War II whilst commercial development was retarded, Siemens Brothers made a major contribution to the communication equipment requirements of the services, and carried out many specialised development projects.

1954

The first equipment was installed by Siemens Brothers in London as part of the large scale automatisation programme for the trunk network in the United Kingdom, based on the use of the Motor Uniselector at main switching points.

1956



A model telephone exchange, using electronic means for call switching was demonstrated by Siemens Brothers and forms a basis for future advances in such techniques.

Our Customers throughout the World may be assured that our contribution to the advance of telecommunications will not lessen in the forthcoming 50 years.

SIEMENS BROTHERS & CO. LIMITED

Member of the A.E.I. Group of Companies

WOOLWICH · LONDON S.E.18 · ENGLAND

SIEMENS BROTHERS

TUNGSTONE Batteries

TUNGSTONE PRODUCTS LIMITED

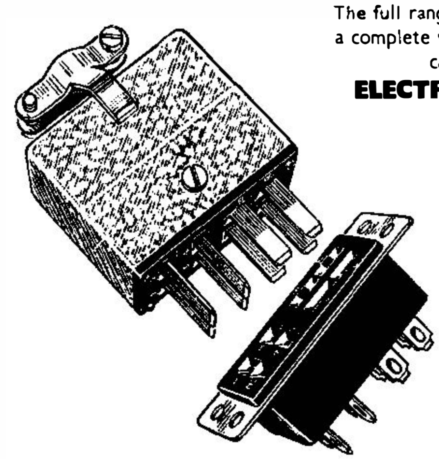
10 SALISBURY SQUARE, LONDON, E.C.4 · WORKS: MARKET HARBOROUGH, LEICS

TC 16

By Appointment to the Professional Engineer

'MULTICON' PLUGS AND SOCKETS

The full range consists of 2, 4, 6, 8, 10, 12, 18, 24 and 33-pole sizes, and there is a complete variety of Plugs and Sockets with alternative mounting arrangements, cable-fixings, retaining devices and cover earthing facilities.



ELECTRICAL SPECIFICATION AND PERFORMANCE

VOLTAGE RATING

1. Working Voltage : (a) 1,000 Volts D.C. or A.C. (peak). This applies to use in temperate climates under normal conditions.

(b) 500 Volts D.C. or A.C. (peak). This applies to tropical use.

2. Voltage Proof : All plugs and sockets will withstand a voltage proof test of 2.5 KV between contacts, and 3.0 KV between contacts and the mounting flange or cover.

3. Breakdown or Flashover Voltage : The breakdown voltage is approximately 3.3 KV.

The properties of the mouldings are such that even after flashover there is no evidence of tracking, and the plugs and sockets will still withstand the Voltage Proof specified above.

CURRENT RATING 5 Amps. D.C. or A.C. (R.M.S.) per contact.

CONTACT RESISTANCE 1. Average Contact Resistance : Below 0.002 Ohm.

2. Maximum Contact Resistance : 0.0025 Ohm.

DESIGN FEATURES

(1)
The terminal numbering is moulded into both the plug and socket bodies, and appears not only in proximity to the appropriate soldering-tag, but also on the mating face.
This not only facilitates wiring, but enables complete cable forms to be tested prior to inclusion in equipments without removing the plug or sock t covers.

(2)
Four small distance pips are moulded on to the plug body and they keep the mating faces slightly apart even when the plugs and sockets are fully engaged.
This eliminat s the possibility of free moisture remaining between the plug and socket face, and is instrumental in the superior tropical performance of " Multicon " plugs and sockets.

(3)
The single-piece body mouldings are nylon-filled ***to provide a high insulation and tracking resistance.***

(4)
All socket clips and plug blades are located in recessed cavities in the mouldings.
This also provid s a high tracking resistance between contacts, and, in the socket version, the enclosed contacts enable the maximum voltage to be safely utilis d (provided the direction of voltage supply feed is from socket to plug).

(5)
Each socket clip has split limbs, so that there are four individual areas in contact with each plug blade.
This ensures absolute reliability of contact, with a minimum life of 10,000 operations at low and constant contact resistance.

(6) Panel or chassis mounting flanges are available with side or end fixing holes. Cut-out information given relates to Panel thicknesses up to $\frac{3}{32}$".
This enables rows of plugs or sockets to be mounted either end-to-end or side-by-side with a maximum saving in panel or chassis space.

(7)
In the 24 and 33-pole sizes the plugs are normally supplied with a large pin locator, which is also an electrical contact.
This is provided to facilitate the engagement of these larger sizes, especially in unitor applications.

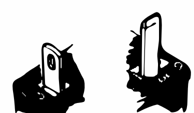
(8)
Covers are provided with either a top cable-entr hole and clamp or a side cable-entry hole and clamp, ***to suit the needs of particular equipments and designs.***

(9)
Two alternative facilities can be provided for earthing the plug or socket covers.

(9A.)
In one version an earthing tag attached to the moulding connects the inside of the cover to the highest numbered contact so that an earth lead in the cableform, connected to the highest numbered contact, automatically earths the cover.

(9B.)
In the alternative form, an earth tag is rivetted directly to the outside of the cover and is suitable for the direct connection of an earth lead.
By either method the cover is arth d to ensure the safety of the users of equipments in which " Multicon" plugs and sockets are incorporated.

(10)
All sizes of plug or socket covers can be fitted with retaining blades to secure the unit to the panel or chassis.
Even und r the most severe vibration conditions, therefore, or in the case of accidental interference with the cable-form, there is absolute reliability of contact.



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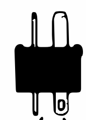
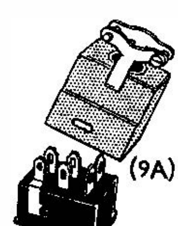


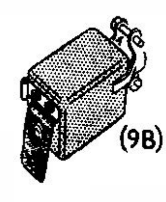
(2)

(5)

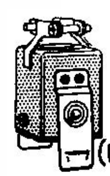
(7)



(9A)



(9B)



(10)

PAINTON
Northampton England

MARCONI'S

offer their congratulations

to the

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

on attaining their

50th ANNIVERSARY

and are proud to have had a hand in some of the Technical Achievements in Telecommunications recorded in this issue of the journal

THE LIFELINE OF COMMUNICATION

IS IN EXPERIENCED HANDS

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX

You're years ahead..... with the PYE

RANGER V.H.F. MOBILE

New channelling and specification standards for mobile radio are being introduced in the United Kingdom and many parts of the world. The "Ranger", Pye's latest V.H.F. mobile, has been designed to anticipate these and will, in fact, meet specifications for the next ten years. The Pye "Ranger" therefore combines superlative performance with the maximum technical life. No matter what your channelling requirements the Pye "Ranger" will meet them.

3 amplitude modulated versions are available

W = 100 Kc/s. channelling for aeronautical and multicarrier schemes.

N = 60 Kc/s., 50 Kc/s. or 40 Kc/s. channelling.

VN=30 Kc/s., 25 Kc/s. or 20 Kc/s channelling.

The Ranger has been designed to meet the following leading specifications.

U.S. Federal Communications Commission
Canadian R.E.T.M.A.
Canadian Dept. of Transport
British G.P.O. existing and proposed specifications

PYE Telecommunications
CAMBRIDGE ENGLAND

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Pye Radio & Television (Pty.) Ltd. Johannesburg, South Africa.

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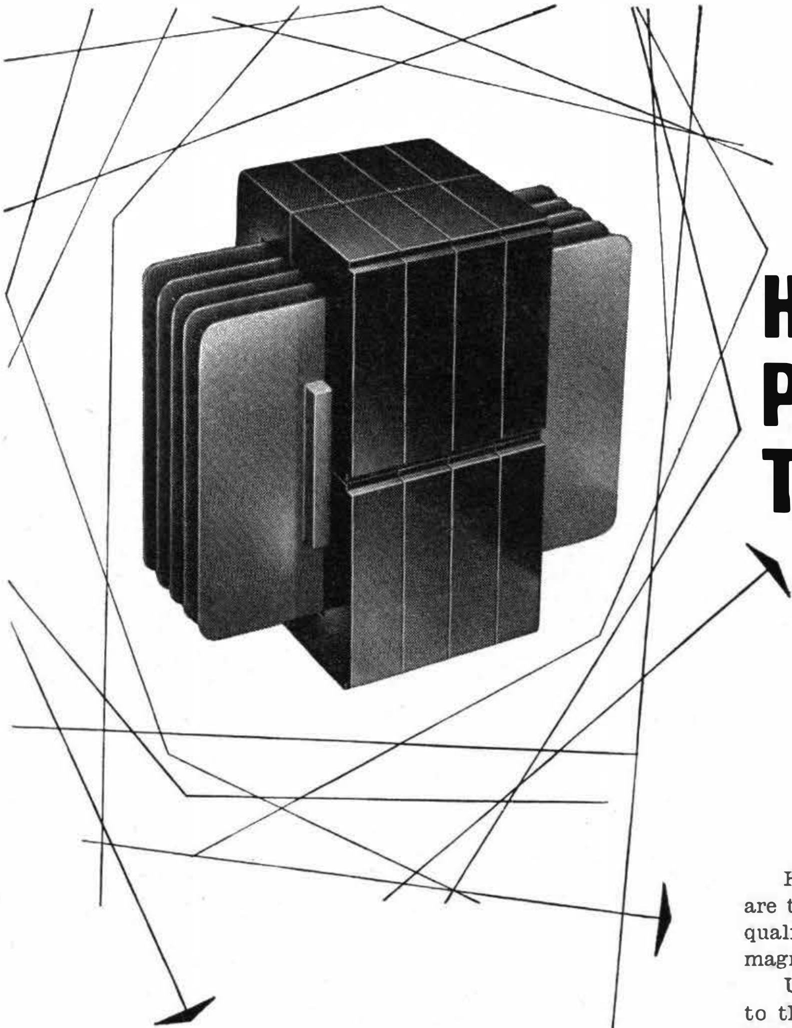


H.F. POWER TRANSFORMERS

H.F. power transformers of outstanding efficiency are the latest addition to the Mullard range of high quality components designed around Ferroxcube magnetic cores.

Utilising the unique characteristics of Ferroxcube to the full, Mullard H.F. transformers are smaller, lighter, and less costly than transformers using alternative core materials. These advantages are particularly marked in transformers required to handle powers of up to 2kW, between the frequency range 2kc/s to 2Mc/s.

Mullard transformers are already finding wide use in applications as diverse as ultrasonic H.F. power generators and aircraft power packs operating from an aircraft's normal A.C. supply. In the latter application, the low leakage field of Ferroxcube can eliminate the need for external screening, thereby reducing the size and weight of the transformer even further.

As with all Mullard high quality components, these H.F. power transformers are designed and built to engineers' individual specifications. Write now for details of the complete range of components available under this service.

RATING . . . . UP TO 2 kW

FREQUENCY RANGE . . . . 2 Kc/s to 2 Mc/s

Mullard

'Ticonal' permanent magnets
Magnadur ceramic magnets
Ferroxcube magnetic cores

MULLARD LTD · COMPONENTS DIVISION · CENTURY HOUSE · SHAFTESBURY AVENUE · WC2

MC I

TELECOMMUNICATIONS

More and more telephone administrations are recognising that Connollys are foremost in the development of new insulations and constructions. Many millions of pair miles of Connollys Cable, including Polythene and P.V.C. Insulated, are providing reliable communications throughout the world.

Take a lead from CONNOLLYS

P.V.C. & POLYTHENE TELEPHONE CABLES

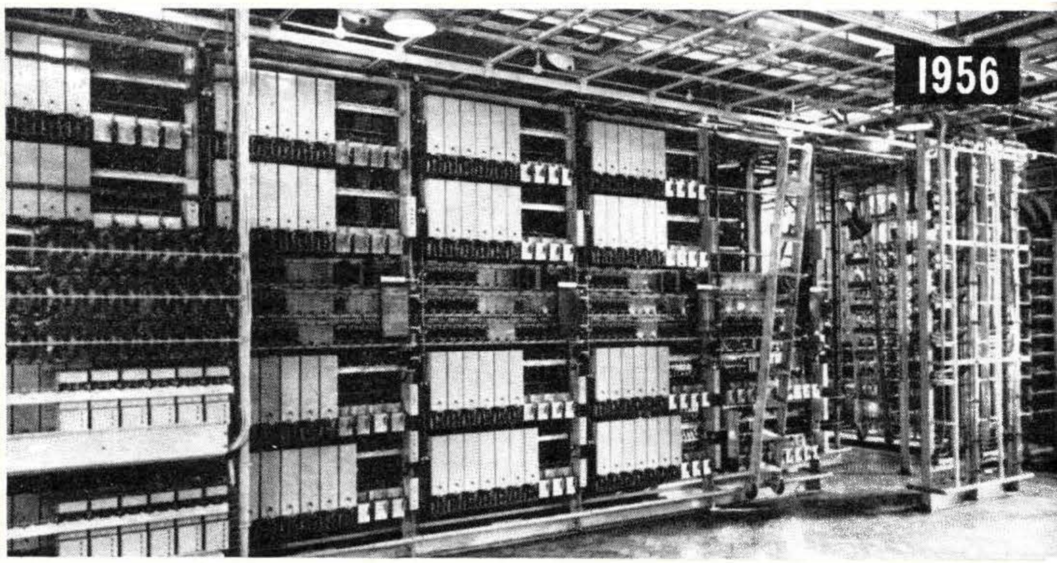
Full details of the range from:—CONNOLLYS (BLACKLEY), LTD. HEAD OFFICE: MANCHESTER 9. Phone: CHEetham Hill 1801. Grams: "Connollys, Blackley." Branch Sales Offices and Stores:—LONDON: 23 Starcross Street, N.W.1. EUSton 6122. BIRMINGHAM: 15/17 Spiceal Street. MIDland 2268. CARDIFF: 17 Dumfries Place. CARdiff 30561. GLASGOW: 46 West Princes Street. C.4. WESt 8022.

dm CL.7

G.E.C.

ABOVE: *Glasgow Central exchange was the first large battery exchange to be made entirely in Britain. It operated successfully for over 30 years.*

BELOW: *The same exchange nearly 50 years later. The equipment is automatic—but it's still by G.E.C., still the best of its day.*



1892 *A page out of the G.E.C. Catalogue of 1892; one of the first catalogues to list telephone equipment.*

111

TELEPHONE STATIONS WITH MOVABLE TRANSMITTERS AND RECEIVERS.

No. 200. The "Pony Hand" Microphone and Watch Receiver Combination, with Wire Cord £2 10 0

No. 205. The "Pony Hand" Microphone and Watch Receiver Combination, with Switch, and 4-Wire Cord £3 0 0

No. 210. Wall Box and Automatic Switch, with Induction Coil and Ringing Key £1 5 0

No. 215. 1 No. 200 Instrument ... £2 10 0
1 No. 210 Wall Box ... 1 5 0
1 [illegible] Bell or Buzzer ... 0 5 0
£4 0 0

No. 220. 1 No. 200 Instrument ... £2 10 0
1 Table Standard and Switch, with Induction Coil Ringing Key and Buzzer or Bell ... 2 0 0
1 Wall Plug, No. 470 ... 0 7 6
£4 17 6

No. 225. 1 No. 200 Instrument £2 10 0
1 Ornamental Table Switch complete, with Wall Plug, No. 470 4 10 0
£7 0 0

No. 230. 1 No. 200 Instrument £2 10 0
1 [illegible] Magneto and Induction Coil 3 10 0
1 Wall Plug, No. 470 0 7 6
£6 12 0

In 1908 The General Electric Company began the design and production of the first large central battery telephone exchange to be made throughout in Britain. It was installed in Glasgow to serve 10,000 subscribers.

Prophecy in 1910

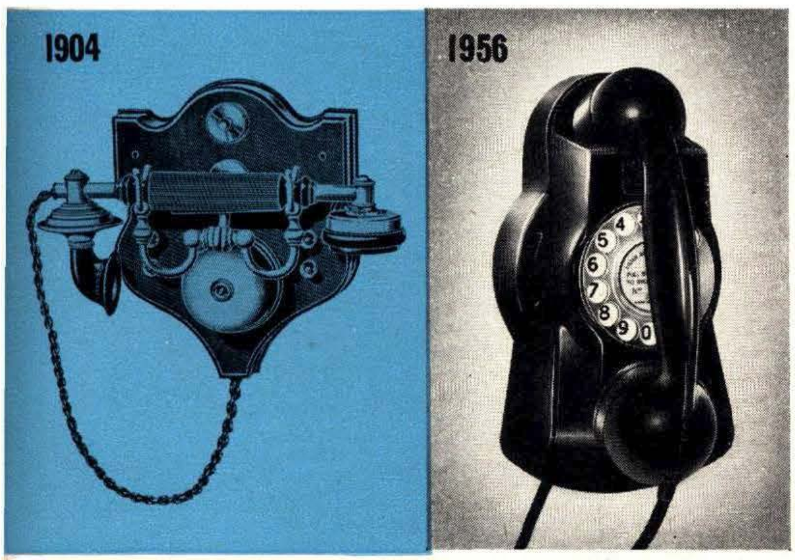
"It is the best central battery equipment in the world, and I know that with reasonable care it will continue to do its duty for at least thirty years."

Fulfilment in 1941

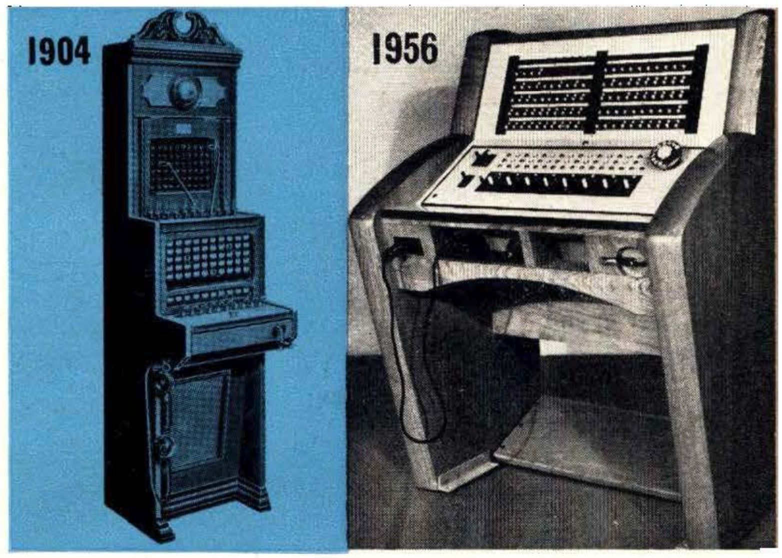
This sweeping forecast by one of the G.E.C. engineers at the opening of the Glasgow Central Exchange was fulfilled. Although the exchange was extended as the traffic increased, the original equipment was still operating when the exchange changed over to automatic working in 1941.

THE GENERAL ELECTRIC CO. LTD. OF ENGLAND *Telephone, Radio and*

(Left) G.E.C. table telephone fifty years ago; (centre) the Gecophone table telephone introduced in 1929, *and (right) the new "G.E.C.* 1000" *telephone, G.E.C.'s latest and the best in the world.*



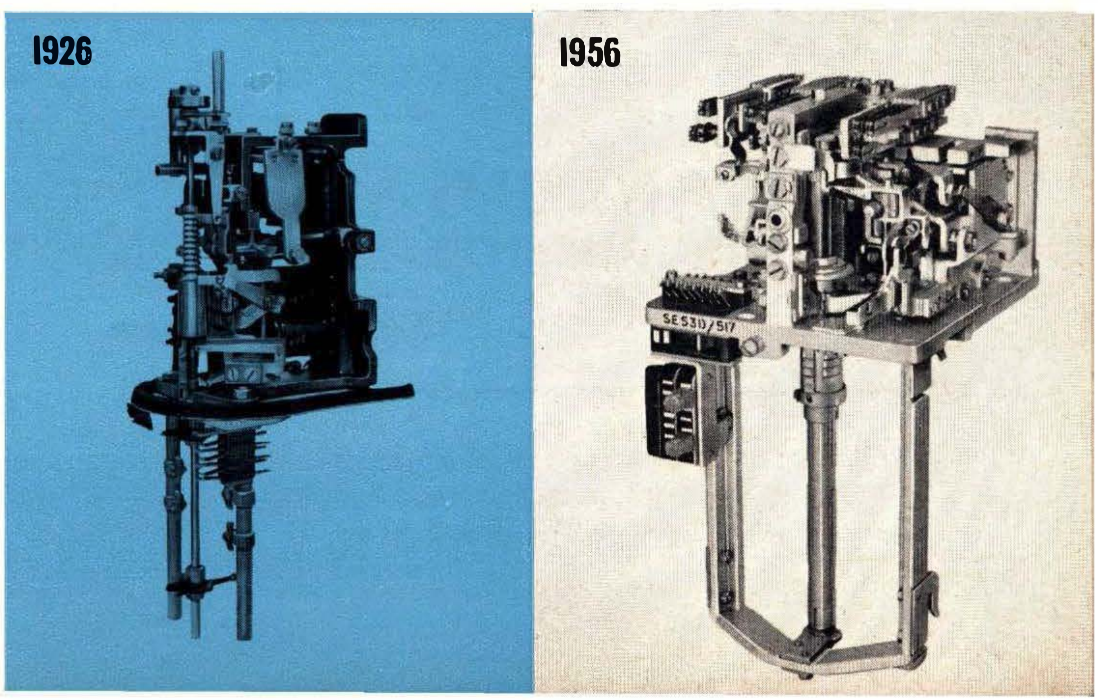
Even in 1904 *the G.E.C. wall telephone was not without considerable pretensions to good shape.*



A very early type of G.E.C. manual switchboard—a few of these boards are still in operation to-day—and (right) the modern G.E.C. press-button switchboard on the Royal Yacht.

(Right) An early G.E.C. Strowger selector still in service after 30 *years in a busy exchange.*

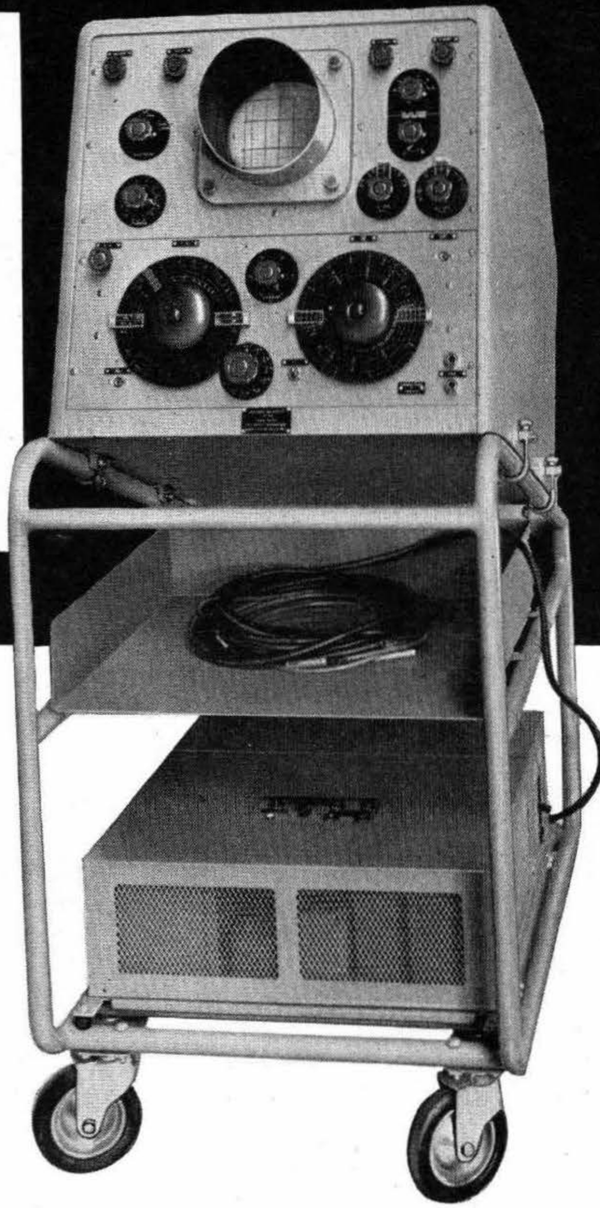
*(Extreme right) The modern G.E.C. Strowger selector SE.*50 *withstands five times the Post Office standard life-test. Combines all G.E.C. experience in designing completely reliable mechanism with outstanding ease of adjustment and maintenance.*



elevision Works, Coventry, England.

WELL DONE!

Marconi Instruments join all concerned with telecommunication progress in sending their congratulations to the Institution of Post Office Electrical Engineers on the occasion of its 50th anniversary.



H.F. SPECTRUM ANALYSER

TYPE OA 1094

The OA 1094 gives an immediate visual presentation of the frequency spectra of signals in the band 3 to 30 Mc/s. It provides a convenient and accurate means of measuring many of the important characteristics of h.f. communication transmission equipment. One of its principal applications is the measurement of intermodulation distortion in i.s.b. transmitters and drive units. Other important applications include the measurement of hum level and carrier compression, and the display of the frequency spectra resulting from on/off or frequency-shift keying.

Designed and developed by the G.P.O., and manufactured by Marconi Instruments under G.P.O. authority

MARCONI INSTRUMENTS

AM & FM SIGNAL GENERATORS · AUDIO & VIDEO OSCILLATORS · VALVE VOLTMETERS · POWER METERS Q METERS · BRIDGES · WAVE ANALYSERS · FREQUENCY STANDARDS · WAVEMETERS · TELEVISION AND RADAR TEST EQUIPMENT · AND SPECIAL TYPES FOR THE ARMED FORCES

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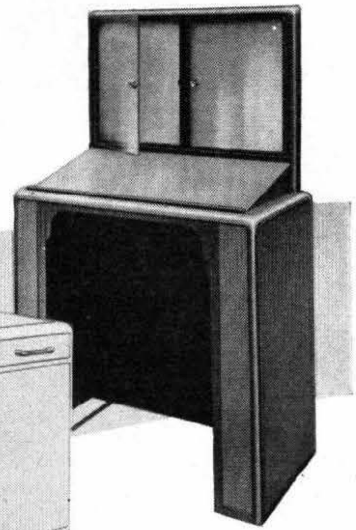
Midlands: Marconi House, 24, The Parade, Leamington Spa Tel. 1408 *North:* 30, Albion Street, Kingston-upon-Hull. Tel. Hull Central 16347

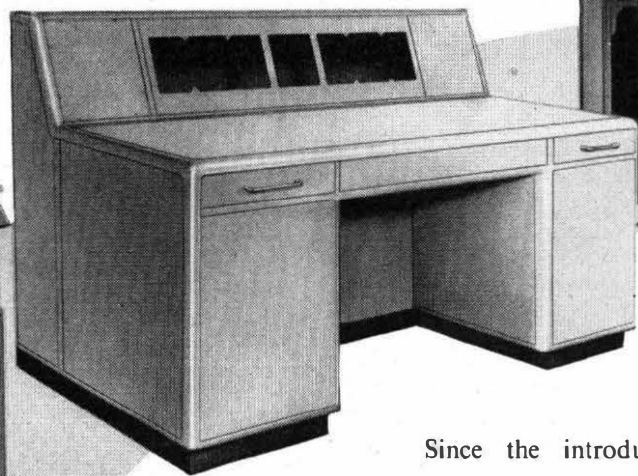
WORLD-WIDE REPRESENTATION

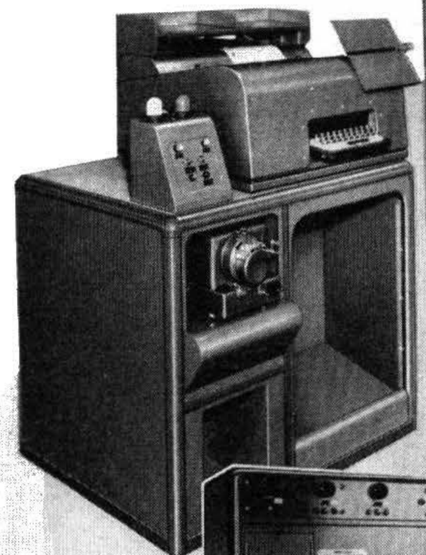
TC 83

Reliability and Service . . . .

has been the keynote for every issue of this Journal since its inception, and Hallam, Sleigh & Cheston, Ltd., who have served the Transport Industry for 60 years, are proud to be represented in this, the Jubilee issue.







Since the introduction of Widney Dorlec in 1948, we have designed and manufactured Cabinets for Telecommunications, Electronic Equipment and Instrumentation Panels of every kind, in any size and in any quantity.

Widney Dorlec

CABINETS · TELESCOPIC MOUNTINGS

WD

HALLAM, SLEIGH & CHESTON LTD., WIDNEY WORKS · BIRMINGHAM 4 · ENGLAND

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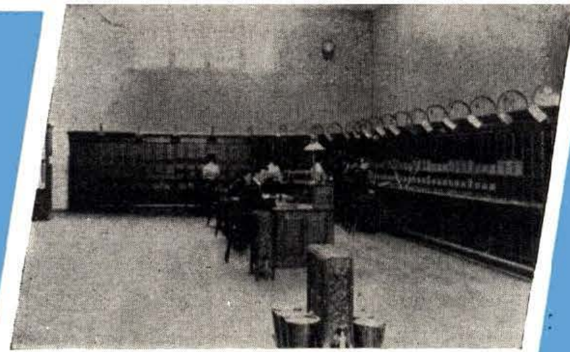
W.D.8.


The first common-battery telephone exchange at Bristol, 1900

OVER 50 YEARS OF in Telecommunications

S.T.C. congratulates the *Institution of Post Office Electrical Engineers* on its Golden Jubilee. Before and during the fifty years in which the journal has contributed to the technical advancement of communications, S.T.C. is proud to have been associated with the *British Post Office* in many notable developments which have helped to maintain Britain's lead in telecommunication techniques.

1900 First central battery telephone switchboard manufactured and installed at Bristol.

1914 First Rotary automatic telephone exchange in Great Britain installed at Darlington.

1915 First multiple-twin long-distance telephone cable in Europe embodying loading coils installed between London and Birmingham.

1922 First open-wire telephone repeater amplifiers installed at Leeds.

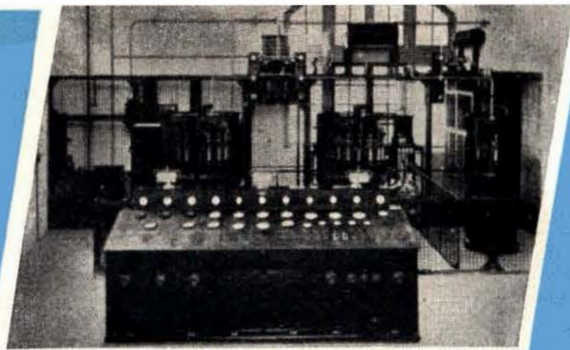
1923 First telephone repeaters made in England installed at Fenny Stratford and Derby.

1926 200-kW Long-wave single-sideband telephony transmitter installed at Rugby for British Post Office.

1932 Manufacture and installation of the first 18-channel 120-c/s V.F. telegraph system between London-Dundee and London-Glasgow-Belfast.

Standard Telephones and Cables Limite

SKYPORT PABX at London Airport, 1956



200-kW long-wave single-sideband telephony transmitter at Rugby, 1926

PROGRESS

A few of the contributions by S.T.C. to the development of British Post Office communications during the past half-century

1936 Manufacture and installation of first 12-channel carrier telephone cable and equipment between Bristol and Plymouth for the British Post Office.

1936 First coaxial cable between London and Birmingham.

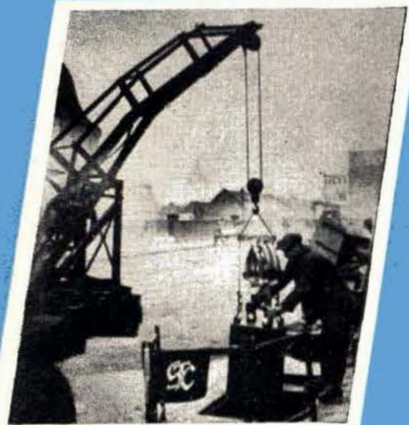
1937 First multi-channel 2-way radio telephone link service opened to the public between Belfast and Stranraer.

1949 Large tube coaxial television cable installed between London and Birmingham.

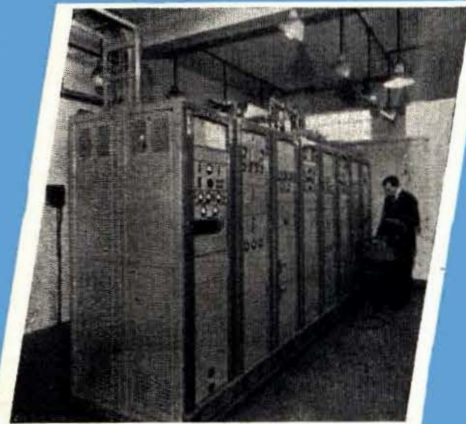
1952 Permanent SHF radio link designed, manufactured and installed for the British Post Office for television transmission between Holme Moss and Kirk o'Shotts.

1952 First direct-dialling scheme from London Trunk Exchange to Automatic Telephone Exchanges in Foreign Capitals.

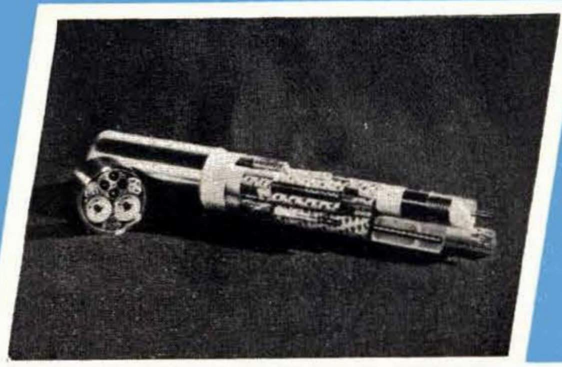
1955 Electronic Directors installed at Richmond (Surrey) on trial basis.



Loading coils being lowered into City street manhole

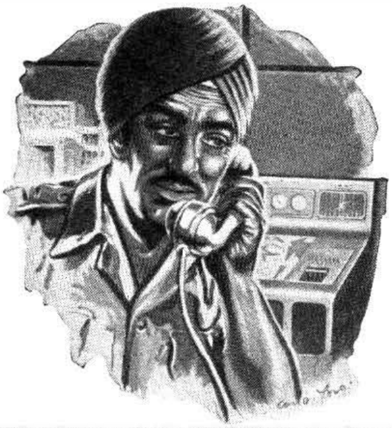


SHF repeater equipment—Manchester & Kirk o'Shotts T.V. link, 1952

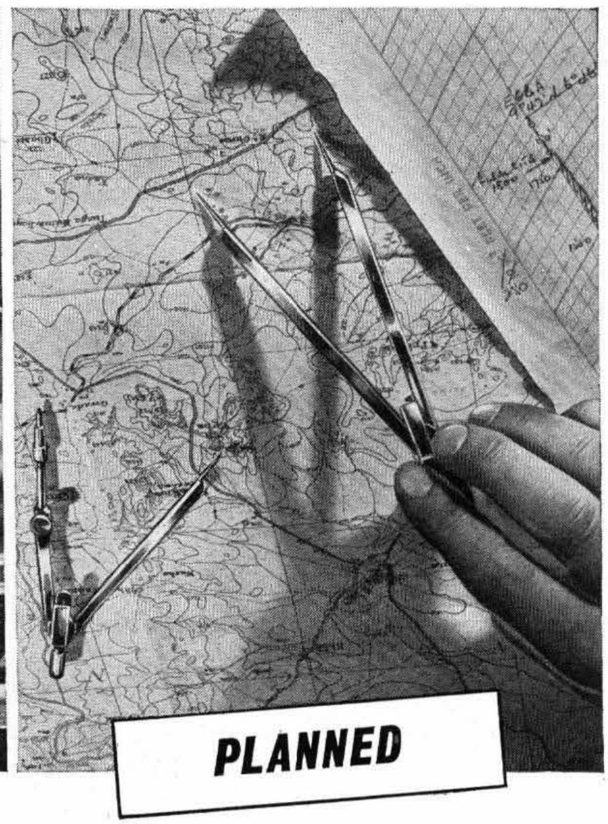


Section of the large tube coaxial cable—London to Birmingham T.V. link, 1949

CONNAUGHT HOUSE · ALDWYCH · LONDON WC2 · ENGLAND



MARCONI

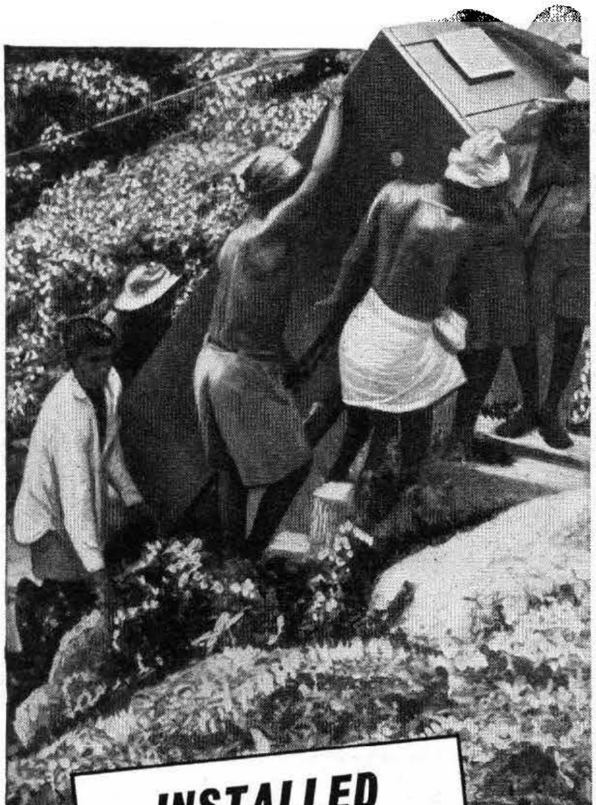


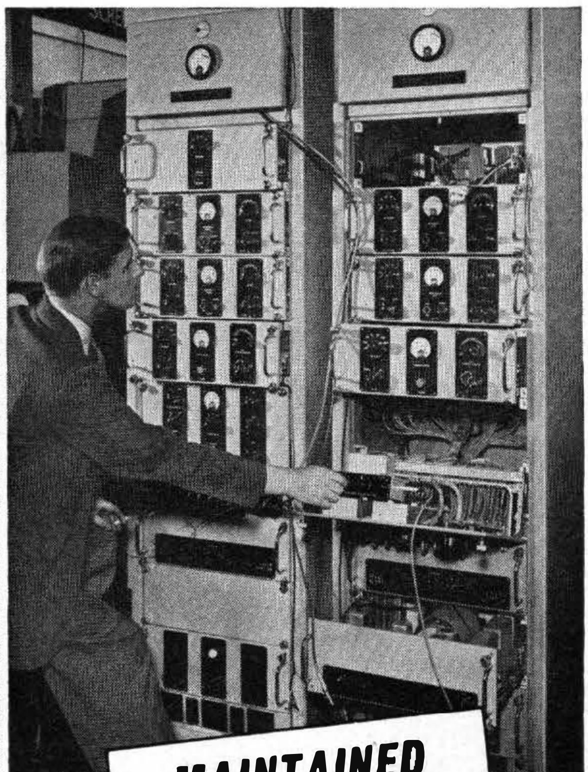
LONG-DISTANCE ISB TELEPHONY SYSTEMS

ISB telephony has made long-distance word-of-mouth communication possible between subscribers on widely separated local land-line or radio-telephone systems which are linked to a national or international HF radio-telegraphy service. Marconi's have been pioneers in developing ISB telephony facilities.

As with other types of communication systems, Marconi's can offer unrivalled facilities and experience to those contemplating ISB telephony. From the initial technical consultations to the maintenance of the system in service and the training of the staff to operate it, Marconi's alone can undertake the whole project.

COMPLETE COMMUNICATION SYSTEMS—*all the world over*





Over 60 countries now have Marconi-equipped communication systems. Many of these are still giving trouble-free service after more than 20 years in operation.

The lifeline of communication
is in experienced hands

MARCONI

Complete Communication Systems

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX

LC16

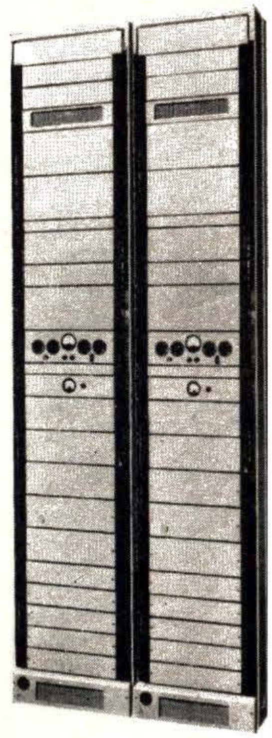
TRANSMISSION

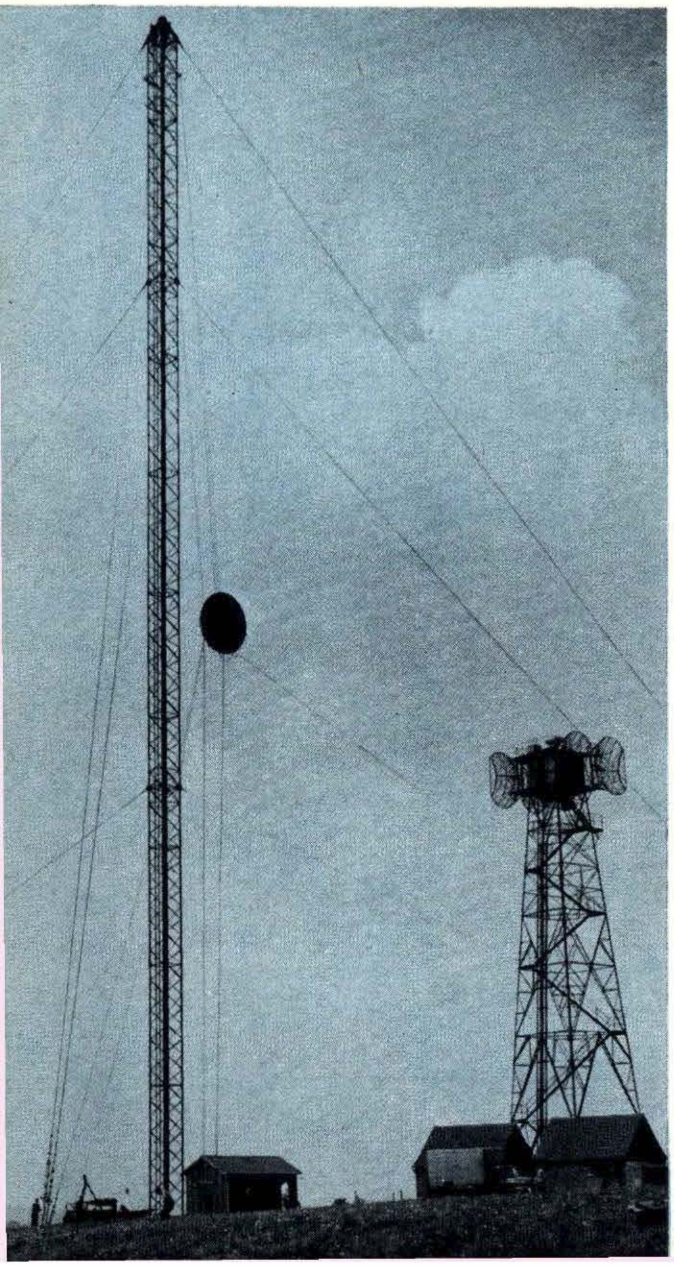
for Television, Telephony

Radio Systems

LONG-HAUL MULTI-CHANNEL TELEPHONY

Frequency-modulated systems for conveying up to 60 circuits and 240 circuits are being manufactured by G.E.C. for Overseas Administrations and the British Post Office. The systems operate in the frequency band 1700 to 2300 Mc/s, and up to three such systems can operate in frequency-division multiplex to give a system carrying 720 circuits. Long systems show a minimum of modulation distortion since non-demodulating repeater stations are used. The most modern construction practice permits all panels to slide into place on guides, and be connected into service by plug-in sockets. A complete terminal equipment for 240 circuits is mounted on two single-sided racks, each occupying only 20½ ins. × 8½ ins. floor space, and a complete terminal equipment for 60 circuits is mounted on one single-sided rack.





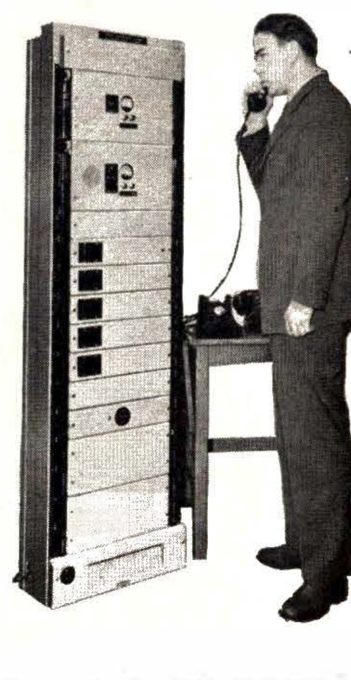
Right: Typical equipment racks for multi-circuit U.H.F. telephony system.
Left: Hoisting the aerial up the tower at Charwelton repeater station for the new London-Birmingham Television Link alongside the tower and aerials for the existing link, also supplied by G.E.C. some years ago.
Below: Complete terminal equipment for 5 circuit junction radio system.

TELEVISION

The first British microwave television link was installed some years ago by G.E.C. for the British Post Office. Since then the G.E.C. has supplied equipment for television links both to the British Post Office and to Overseas Administrations. These have included the cross-Channel link permitting the exchange of programmes between the B.B.C. and European Television Authorities, the link across the Alps between Chasseral and Monte Generoso in Switzerland, and the link between London and Windsor in Canada. Equipment is at present being manufactured to provide new coverage and to supplement existing systems.

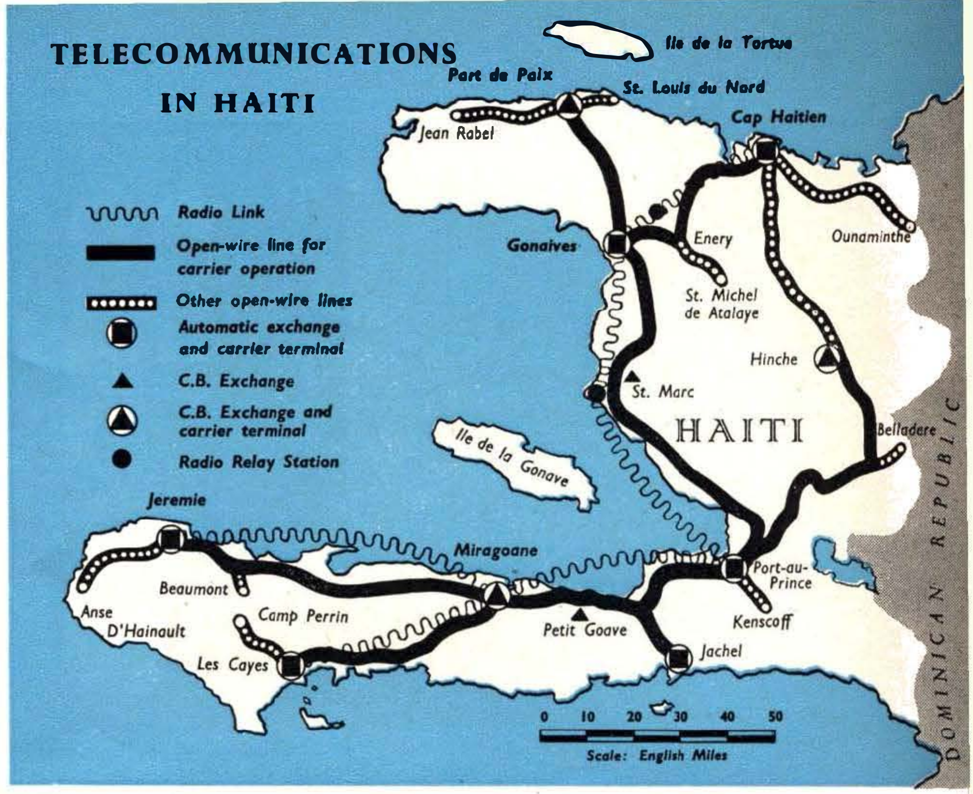
V.H.F. JUNCTION EQUIPMENT

G.E.C. 5-circuit junction radio equipment, which provides up to five circuits by frequency-division-multiplex operation over the frequency-modulated VHF radio link, has the advantage of a narrow occupancy in the congested VHF band. Components are mounted on panels of the slide-in type which are easily accessible for maintenance. The equipment is particularly useful where the terrain makes the construction of cable or open-wire routes difficult. The normal range is about 50 miles; this can be extended by radio relays.



EQUIPMENT
and Telegraphy*

Multiplex Equipment for Open-Wire Lines Cables and Radio Links



The network of open-wire lines, radio links and exchanges in Haiti. This system is one of the many systems throughout the world for which G.E.C. is responsible for the planning, manufacture and installation.

OPEN-WIRE LINES

A complete terminal or repeater equipment for a 3-circuit or 12-circuit transmission system, including channel equipment, signalling equipment, translating equipment, pilot equipment, and generating equipment, is mounted on one single-sided rack 9 ft. × 1 ft.8½ ins. × 8½ ins. (2·74m × 0·52m × 0·216m). The equipment provides for an out-of-band signalling frequency of 3825 c/s, and can give either "E" and "M" signalling or ring-down signalling. The equipment has a performance in accordance with CCIF recommendations.

Equipment is also in production for the transmission of 24-speech circuits over an open-wire line. In this equipment 12 circuits are included in the frequency band 160-300 kc/s, above the normal 12-circuit band 36-143 kc/s.

RADIO

G.E.C. equipment allows 36-speech circuits to be connected in multiplex within the frequency band of either 12-160 kc/s or 60-212 kc/s. The equipment, complete with out-of-band signalling circuits, is mounted on one single-sided rack, 9 ft. high. The group translating equipment can be fully duplicated and provided with automatic changeover, thereby affording a high degree of reliability.

Many advantages are obtained from the use of out-of-band signalling frequencies, since the speech and signalling channels are independent.

Other equipment allows for the multiplexing of 60-speech circuits and is extensible by the addition of further units to cater for a maximum of 240 circuits.

TRANSISTORISED EQUIPMENT

The use of transistors in transmission equipment has many advantages, for example:—

The power consumption is low.

The physical size is small.

The heat dissipation is negligible.

The following indicates some of the latest G.E.C. equipments, now in production, which benefit from the use of transistors:—

Rural Carrier System, enabling up to ten circuits to be transmitted over one pair of wires, with facilities for terminating one or more circuits at intermediate points.

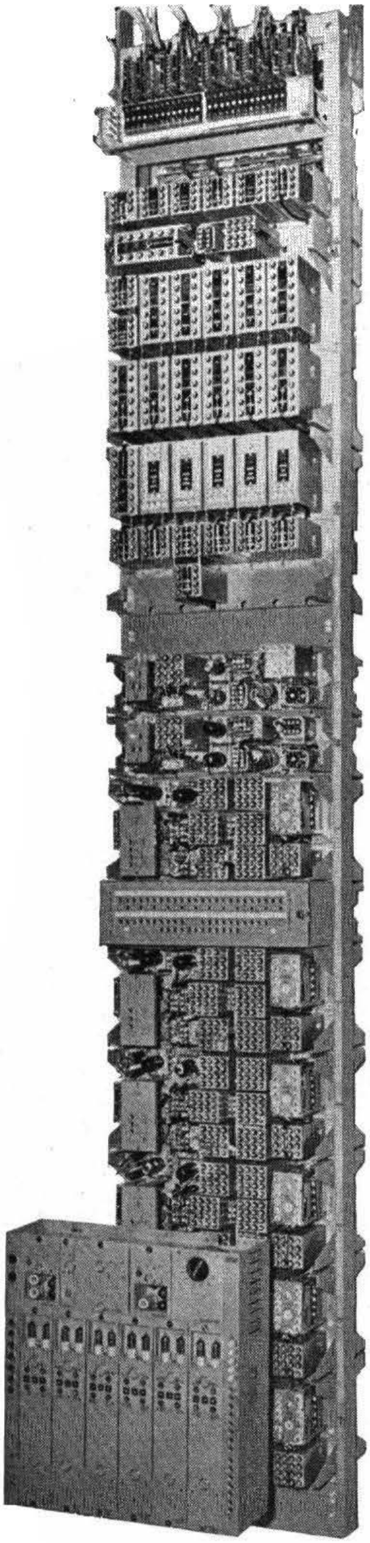
Audio amplifier for four-wire circuits.

Voice-frequency telegraph equipment using frequency modulation.

★ EVERYTHING FOR TELECOMMUNICATIONS BY OPEN-WIRE LINE, CABLE, OR RADIO, SINGLE OR MULTI-CIRCUIT, OR TV LINK, SHORT, MEDIUM OR LONG HAUL, AUTOMATIC OR MANUAL EXCHANGE

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND

TELEPHONE RADIO AND TELEVISION WORKS · COVENTRY · ENGLAND



SKILLMAN Short Distance Carrier

With FULL 3,400 Cycle Band

* Six channels per pair of single cable or twelve channels per pair of double cable. Old type inter-exchange cables in city networks can be counted on to give at least 30% pairs suitable for carrier working, i.e. cable capacity is doubled.

* No repeaters required on most city networks. Hence extra circuits obtainable in a few hours.

* The equipment often proves economic over distances as short as 2 miles by providing temporary extra traffic capacity, and thus delaying investment of funds until traffic has grown enough to occupy a reasonable proportion of new cable capacity (e.g. 12 extra carrier channels may easily he cheaper than the minimum economic new cable providing, say, 100 extra channels).

* Signalling is by low-level tone, present continuously during speech, and having a frequency of 0 cycles (i.e. the carrier frequency). Thus the circuits are the same as for D.C. paths, and voice operation troubles non-existent.

* All channels adjustable to low or zero transmission loss, and when required can give a gain.

The small panel on the left is the same as that on the right and replaces the entire bay shown behind.

T. S. SKILLMAN & CO. LTD., 199 Uxbridge Road, Hanwell, London, W.7

T. S. SKILLMAN & CO. PTY. LTD., Cammeray, Sydney, N.S.W.

SKILLMAN CARRIER EQUIPMENT HAS BEEN SUPPLIED TO ENGLAND FOR OTHER THAN G.P.O. APPLICATIONS, TO AUSTRALIA, NEW ZEALAND, BELGIUM AND EGYPT, AND ENQUIRIES ARE INVITED FOR REPRESENTATIVES ELSEWHERE

We now announce the removal of the last difference between our very simple and cheap short-distance carrier equipment and the usual long-distance equipment. We can now offer the equipment with a full 3,400-cycle band, in every respect being identical with the earlier equipment but with 5-Kc/s spacing. Even wider bands can be obtained if required.

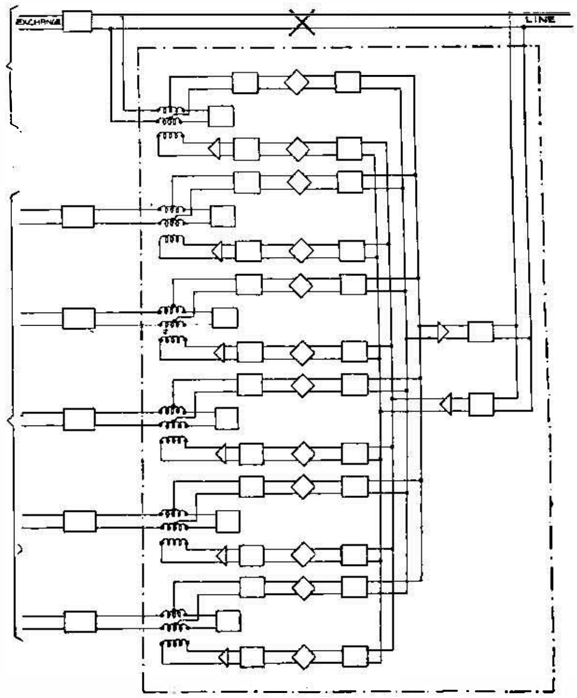
6 Kc/s spacing
4,100 cycle circuits

5 Kc/s spacing
3,400 cycle circuits

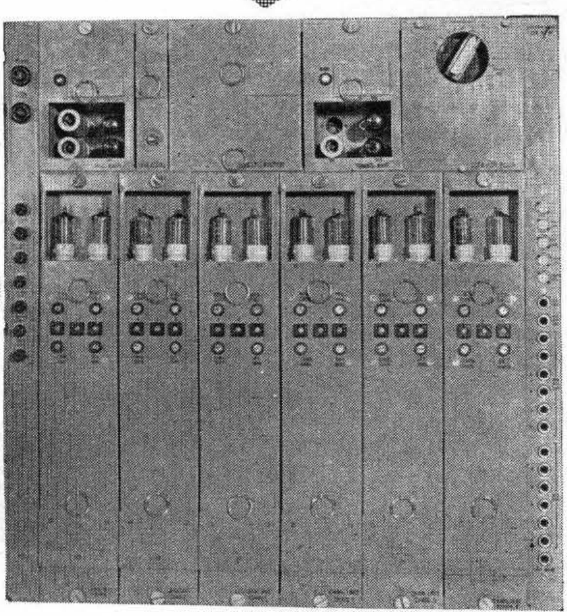
4 Kc/s spacing
2,800 cycle circuits

Normal copper inter-office line with small relay group for repeating impulses. This is cut at X and reconnected as shown.

Five new lines indistinguishable from D.C. lines in all respects, except superior speech transmission performance. Relay groups identical with those on D.C.



All the equipment within the dotted line is mounted on the panel shown below.



SKILLMAN's are world pioneers of short haul or "junction" carrier systems. Over £500,000 worth of the old style equipment indicated opposite is in service, much of it for over 4 years.

The miniaturised form is now available, on a 21" panel with 60 channel ends plus power supply on one 19" rack. Installation involves connecting only new junction relay groups, power (A.C.) and carrier supply and deloading the junctions.

The NEW Marconi

GENERAL PURPOSE RECEIVER Type NS. 702

Combines exceptional versatility with rugged reliability

—an integral part of an efficient communications system

- Continuous frequency coverage 15 Kc/s to 28 Mc/s in ten bands.
- Directly calibrated main tuning and band-spread scales with built-in crystal oscillator for precise band-setting. 80 : 1 flywheel action tuning drive, and electrical fine tuning control of ±3 Kc/s above 800 Kc/s.
- Magneto-striction filter providing the narrowest of four I.F. bandwidths of 8 Kc/s, 3 Kc/s, 1000 c/s and 100 c/s.
- Unwanted beats between interfering signals minimized by balanced demodulator for C.W. reception.
- Facilities for working with an associated transmitter include desensitizing, either electronically or by internal high-speed relays, and reproduction of transmitter sidetone on C.W., M.C.W., or telephony.
- Very low level of oscillator radiation and spurious whistles.
- Can operate direct on 110v. or 220v. D.C., or 115v. or 230v. A.C. supplies, without vibrator or rotating machine.
- Meets the latest international regulations and complies with the G.P.O. specification for General Purpose Receiver for ships.

Write for descriptive literature.

Lifeline of Communication

MARCONI

Complete Communication Systems

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX

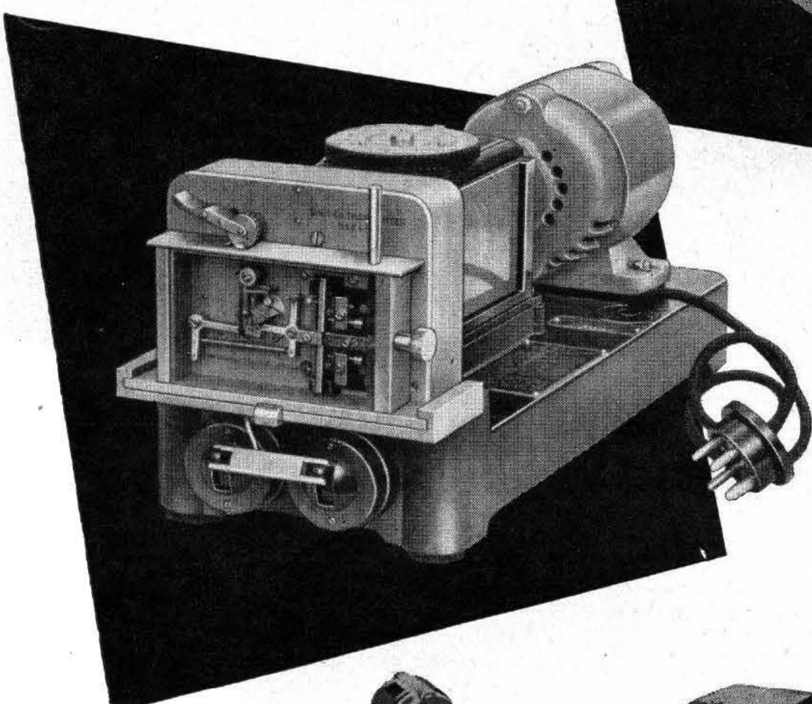
LN2

G.N.T.

MORSE TRANSMITTERS

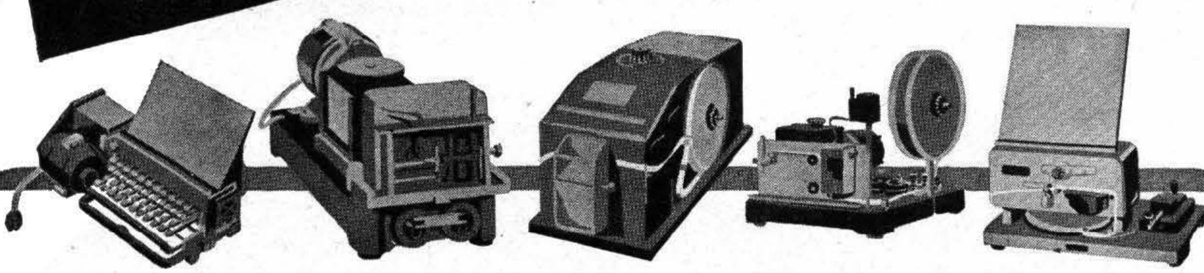
MODEL 113 Speed range: ▶
5-35 words per minute

MODEL 112 Speed range
13-250 words per minute
▼



Absolutely constant speed at all settings notwithstanding large voltage variations.

Noted for easy maintenance and quick adjustment.

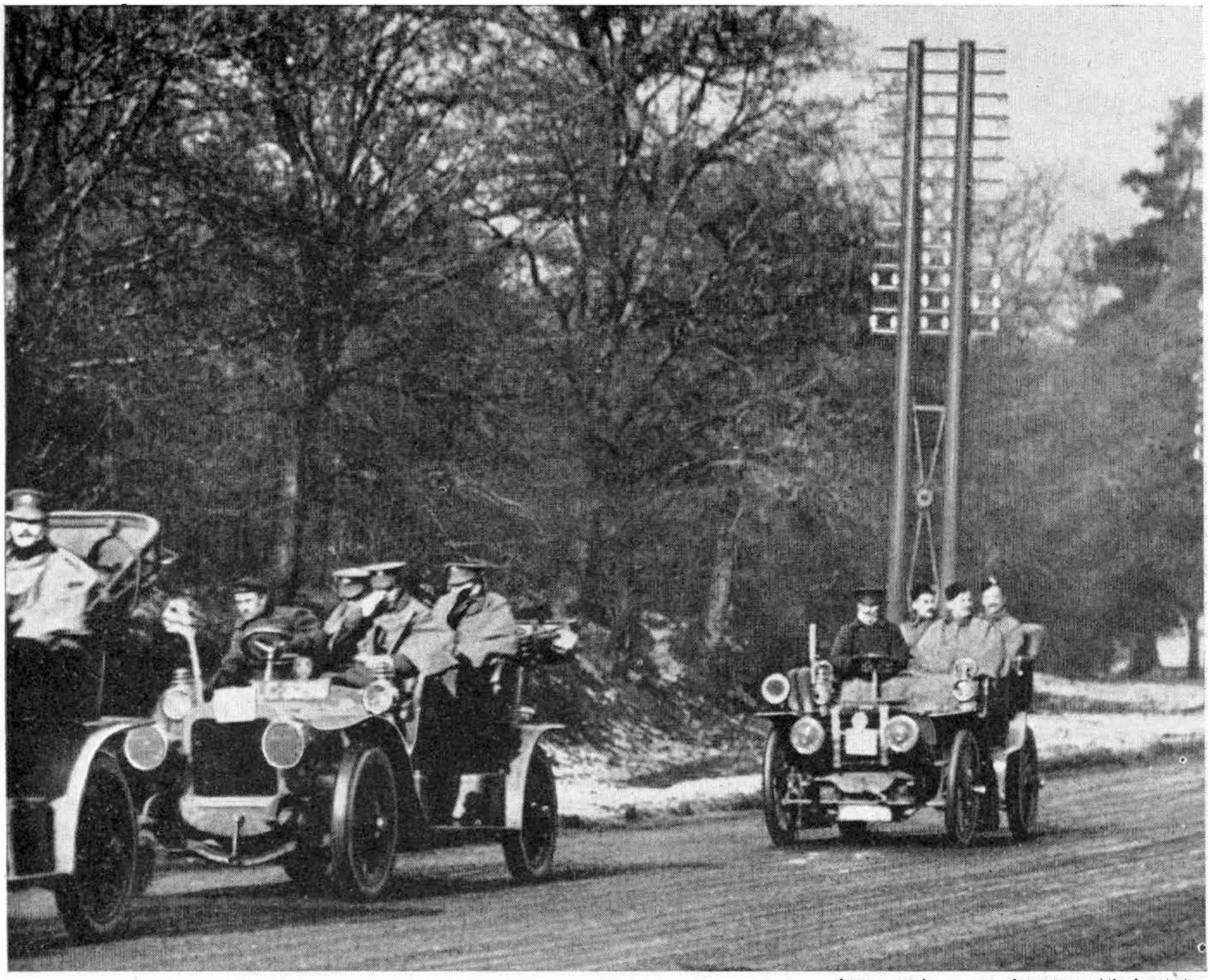


GREAT NORTHERN TELEGRAPH WORKS

DIVISION OF THE GREAT NORTHERN TELEGRAPH CO. LTD.

4, SYDHAVNS PLADS
COPENHAGEN SV, DENMARK

LONDON OFFICE: 5, ST. HELEN'S PLACE
LONDON E. C. 3.



Photograph by courtesy of the Automobile Association

Lines of communication

If the Guards who took part in the famous drive to Hastings nearly 50 years ago had counted the telegraph poles which monotonously passed them by, they would have reached a mammoth total. Today, if you set out to repeat the exercise you would note a startling difference. The vital wires, the lines of communication, are still there. But they have gone underground. There they stay, doing their job, unseen, secure —in tough, acid-resistant Vitrified Clay Conduits.

Every year, Post Office Engineers take down many miles of overhead wires. Every year, they install thousands of miles of new telephone and telegraph cables. And they run them through Salt Glazed Vitrified Clay Conduits.

The Post Office has many good reasons for this policy. It has proved over the years that Vitrified Clay Conduits are cheaper in the long run. They keep down maintenance costs, accommodate large numbers of lines, and, being unaffected by the weather and corrosive substances in the soil, are utterly reliable. When you put down Salt Glazed Vitrified Clay Conduits—they stay down for good.

Salt Glazed Vitrified Clay Conduits Stay Down for Centuries

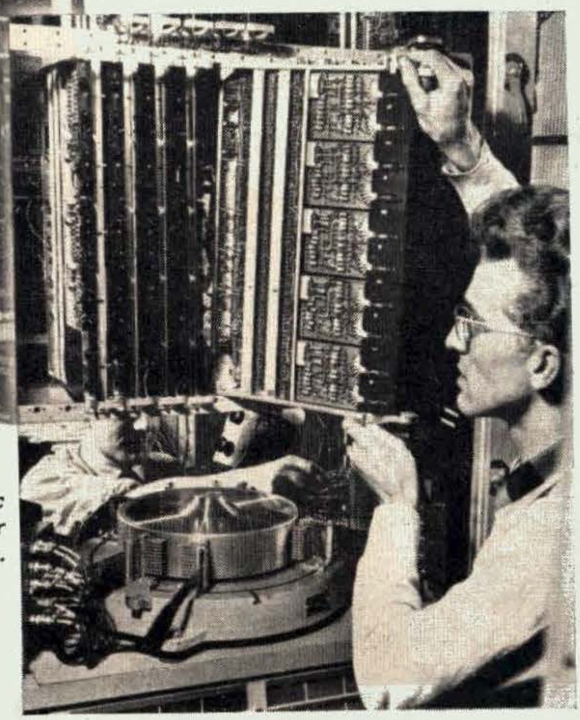
NATIONAL SALT GLAZED PIPE MANUFACTURERS' ASSOCIATION


GREETINGS TELEGRAM
A 18 GTG 3.24PM LIVERPOOL 10
GREETINGS
POEE ALDER HOUSE LONDON EC1
CONGRATULATIONS ON FIFTY YEARS PROGRESS
STROWGER +
TELEPHONE
ATM

Holborn Exchange where the first directors were installed in 1927 and are still in use.

IN 1912 the British Post Office ordered its first automatic exchange from Automatic Telephone Manufacturing Co. Ltd. (now A. T. & E. Co. Ltd.). The exchange equipment was Strowger. Twelve years later the Post Office standardised the Strowger system for Great Britain because of its flexibility, simplicity and adaptability—qualities also inherent in the "Director" invented by A.T.M. at this time to facilitate the conversion of the London area to automatic working. The Company has continued to be one of the major suppliers of automatic equipment to the Post Office and has enjoyed fruitful collaboration with them in many important developments. One of

Lee Green Exchange commissioned in 1952.



Part of the Magnetic Drum Register Translator Device.

the latest of these is the application of the magnetic drum as a register translator device. The Company will be supplying the Post Office with an equipment based on drum technique for trials in this laboratory prior to installation in a London exchange.

AUTOMATIC TELEPHONE & ELECTRIC COMPANY LTD.

LONDON & LIVERPOOL

AT 1821—AAA

Hackbridge Cables

for every purpose

Contractors to the G.P.O., National Coal Board, British Railways, C.E.A. and British and Dominion Government Departments.

HACKBRIDGE
Cable Company Limited

KELVIN WORKS · HACKBRIDGE · SURREY

In Association with Bryce Electric Construction Company Ltd.

ADCOLA

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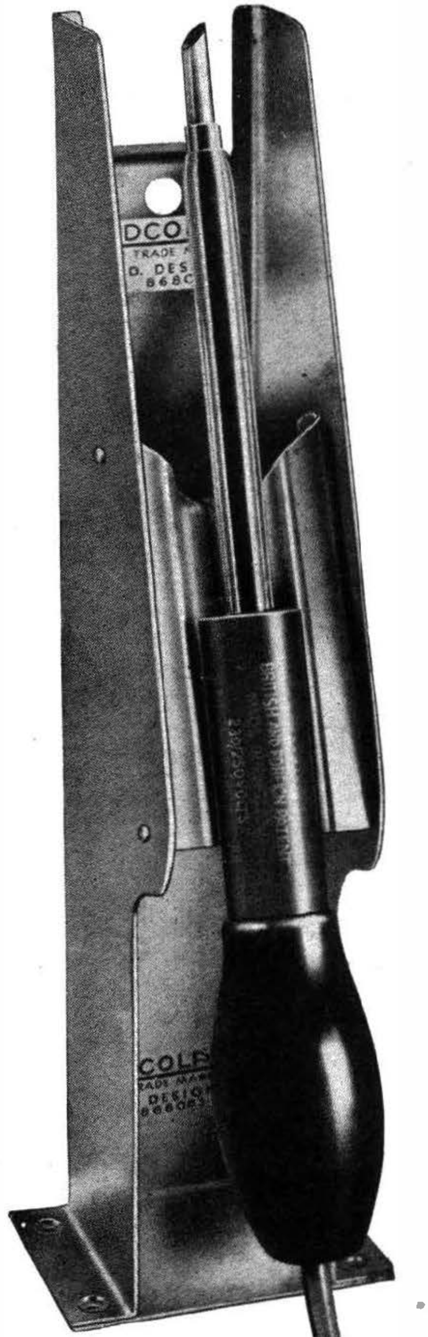

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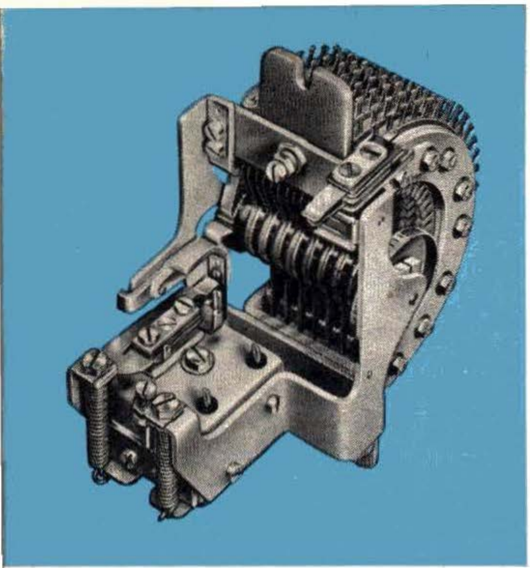

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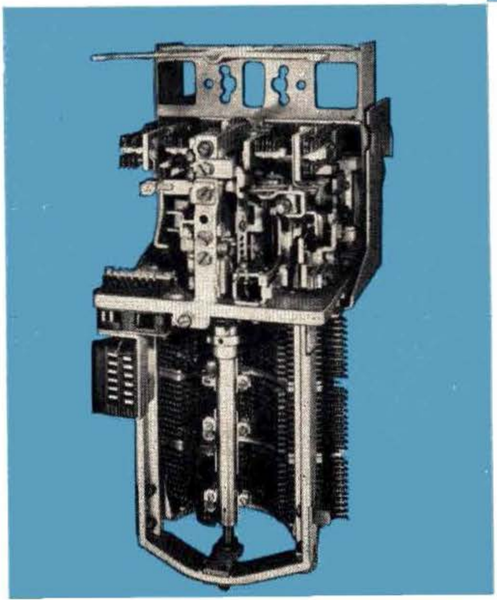

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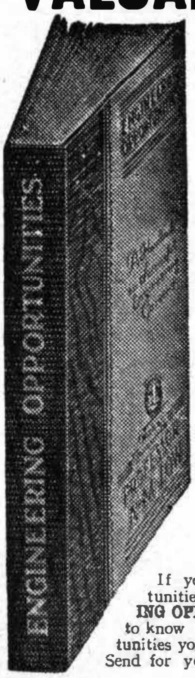

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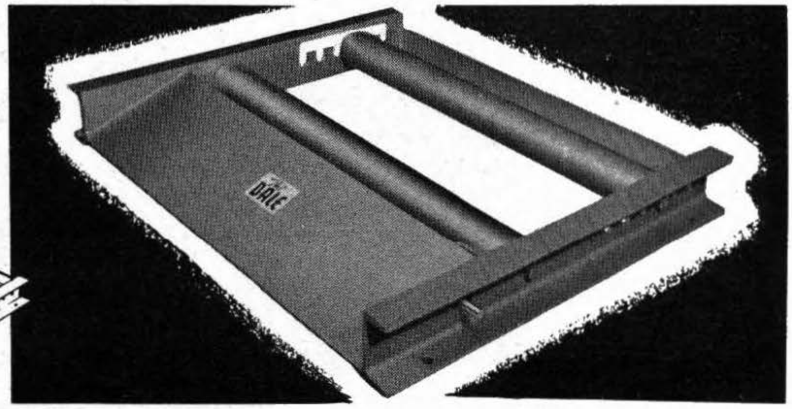

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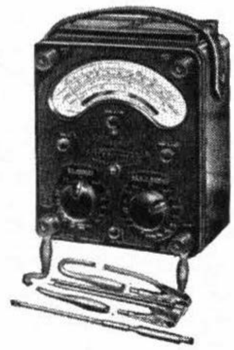

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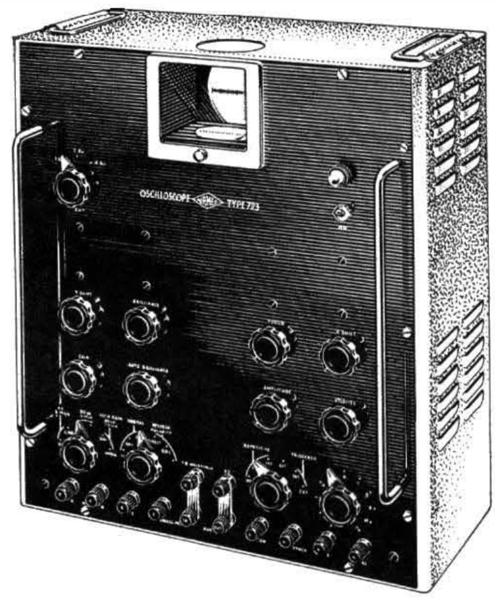

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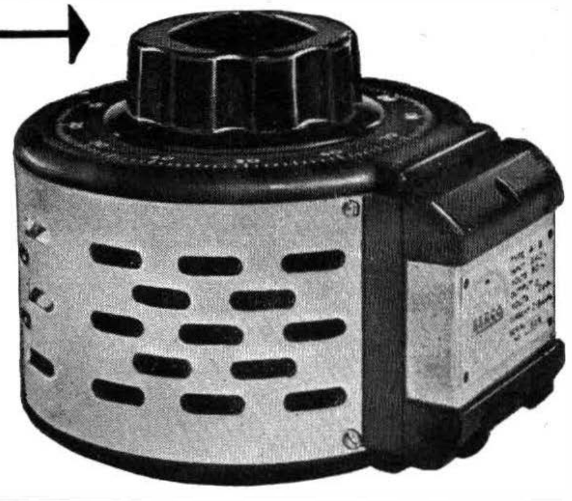

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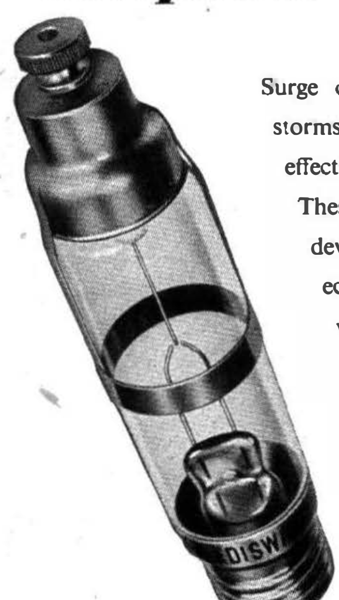

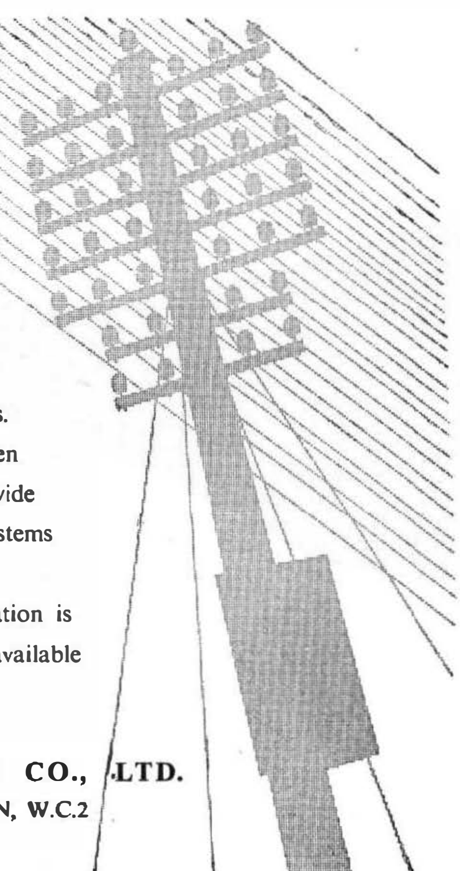

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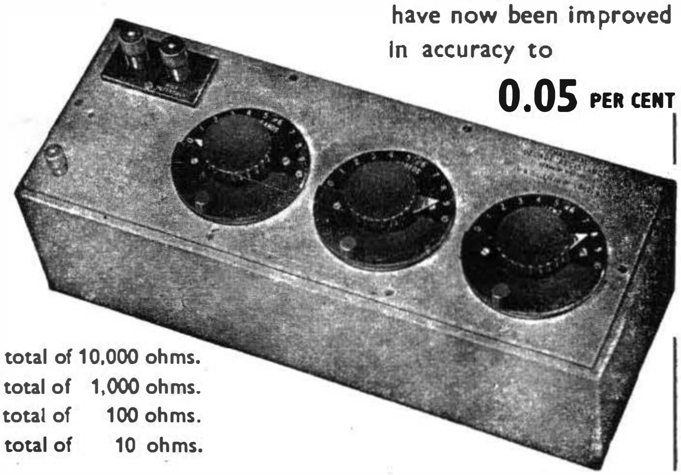

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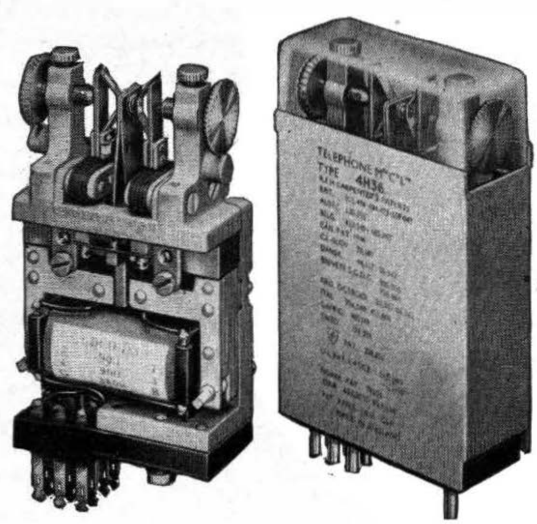

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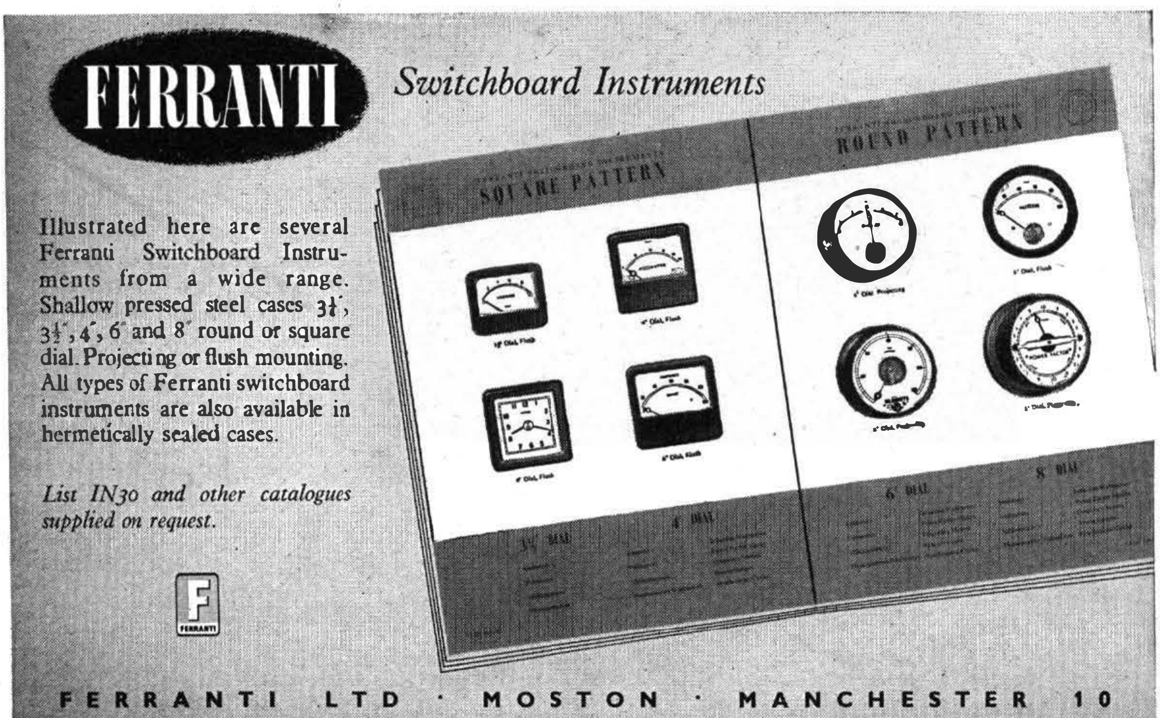
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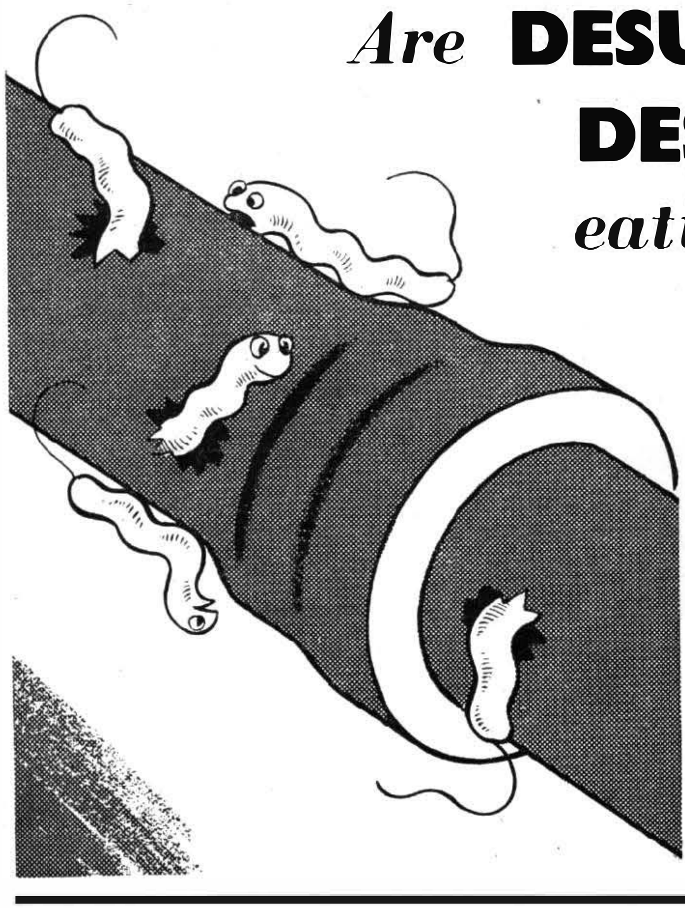

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