THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

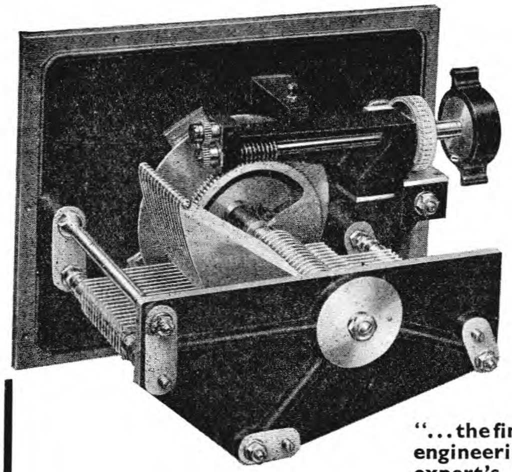
VOL. 30 OCTOBER, 1937 PART 3

CONTENTS

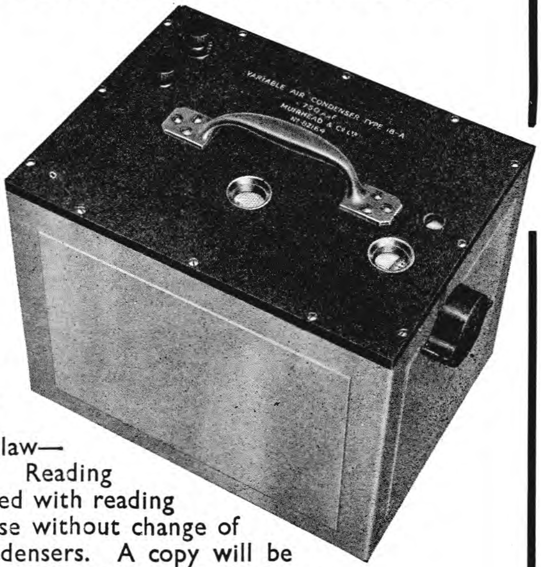
Price 1/- net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

AIR CONDENSERS



"...the finest example of instrument engineering I have ever seen"—an expert's opinion of the Muirhead, type 11, Variable Air Condenser.



This condenser is now available with a straight line frequency law—Type 18—as illustrated. *Salient Features*: Quartz Insulation. Reading accuracy 1 part in 20,000 of total scale. Backlash negligible compared with reading accuracy. Robust construction capable of withstanding constant use without change of calibration. Section 7 of our Catalogue describes these Air Condensers. A copy will be supplied free on request; it should be in the possession of every Communication Engineer.

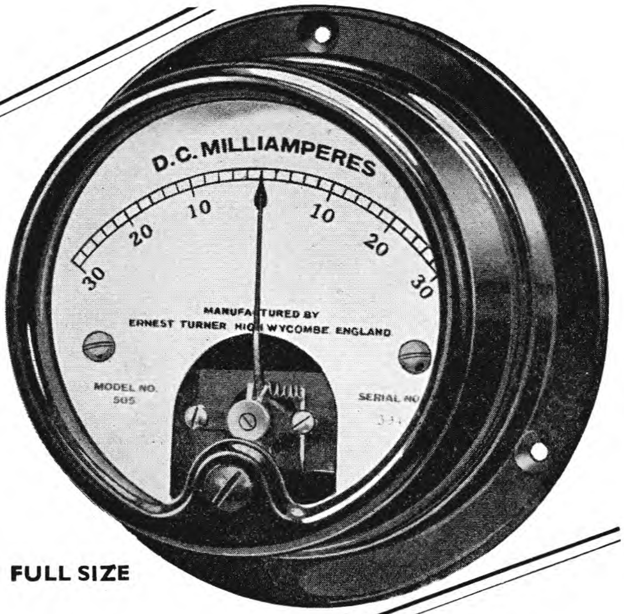
MUIRHEAD & CO., LTD.

MAKERS OF PRECISION INSTRUMENTS FOR OVER 50 YEARS

ELMERS END KENT
TELEPHONE: BECKENHAM 0041-2

TURNER DIFFERENTIAL MILLIAMMETERS G.P.O. No. 17 & No. 18

Meet the most exacting demands for balancing currents in multiplex telegraph circuits. —A quality product of outstanding merit—



FULL SIZE

Also manufacturers of G.P.O. Detector No. 4, and a comprehensive line of instruments for precision electrical measurements.

ERNEST TURNER ELECTRICAL INSTRUMENTS, Ltd.

CHILTERN WORKS,
55-73 TOTTERIDGE AVENUE,
HIGH WYCOMBE,
BUCKS, ENGLAND

Telephone: High Wycombe 301.
Telegrams: Gorgeous, High Wycombe.

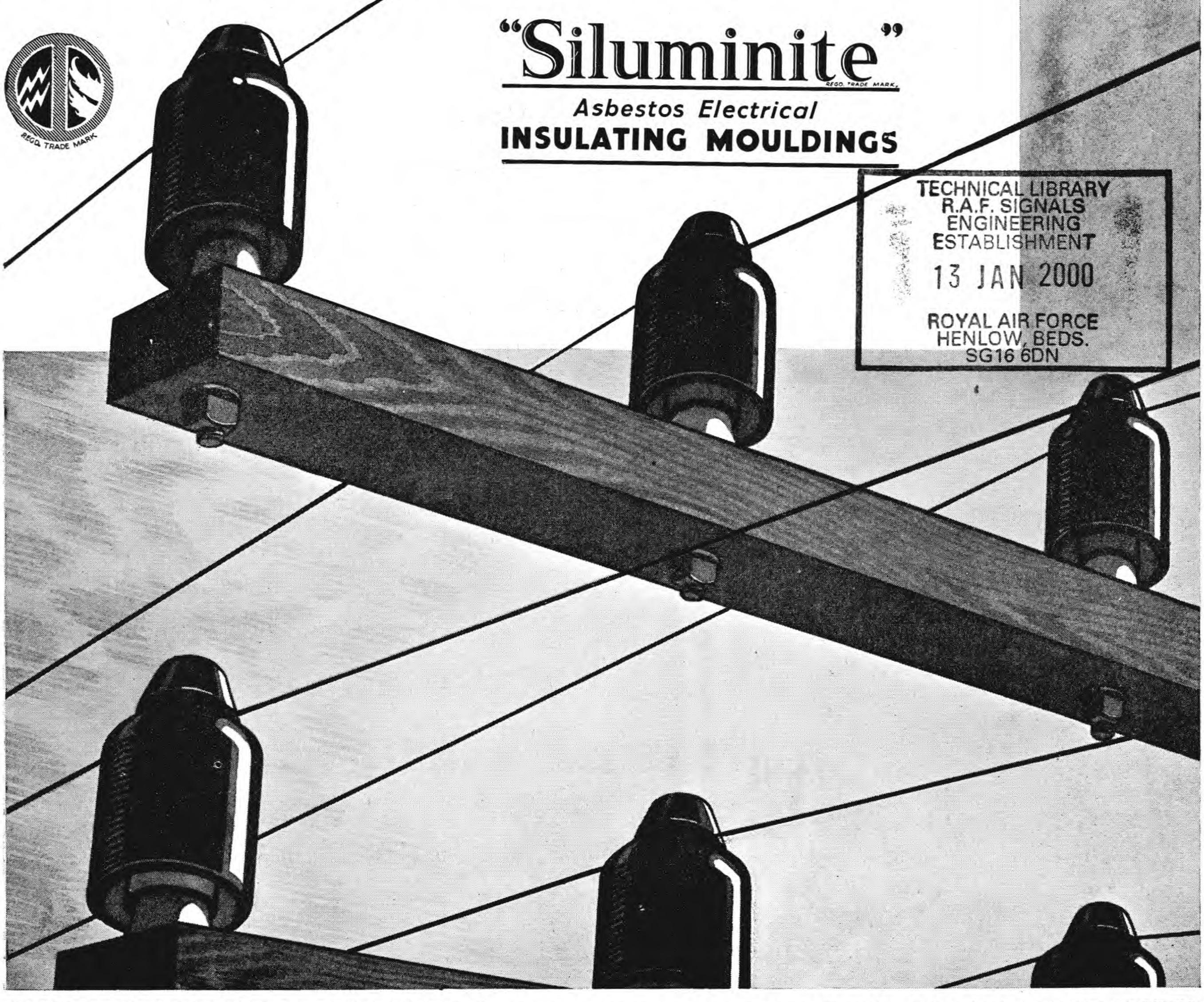
For situations demanding high mechanical strength, "SILUMINITE" asbestos electrical insulators are ideal. They can be relied upon to withstand the most arduous conditions and give years of trouble-free service. Write for full information & details of searching tests carried out

REGD. TRADE MARK

"Siluminite"

REGD. TRADE MARK

Asbestos Electrical
INSULATING MOULDINGS



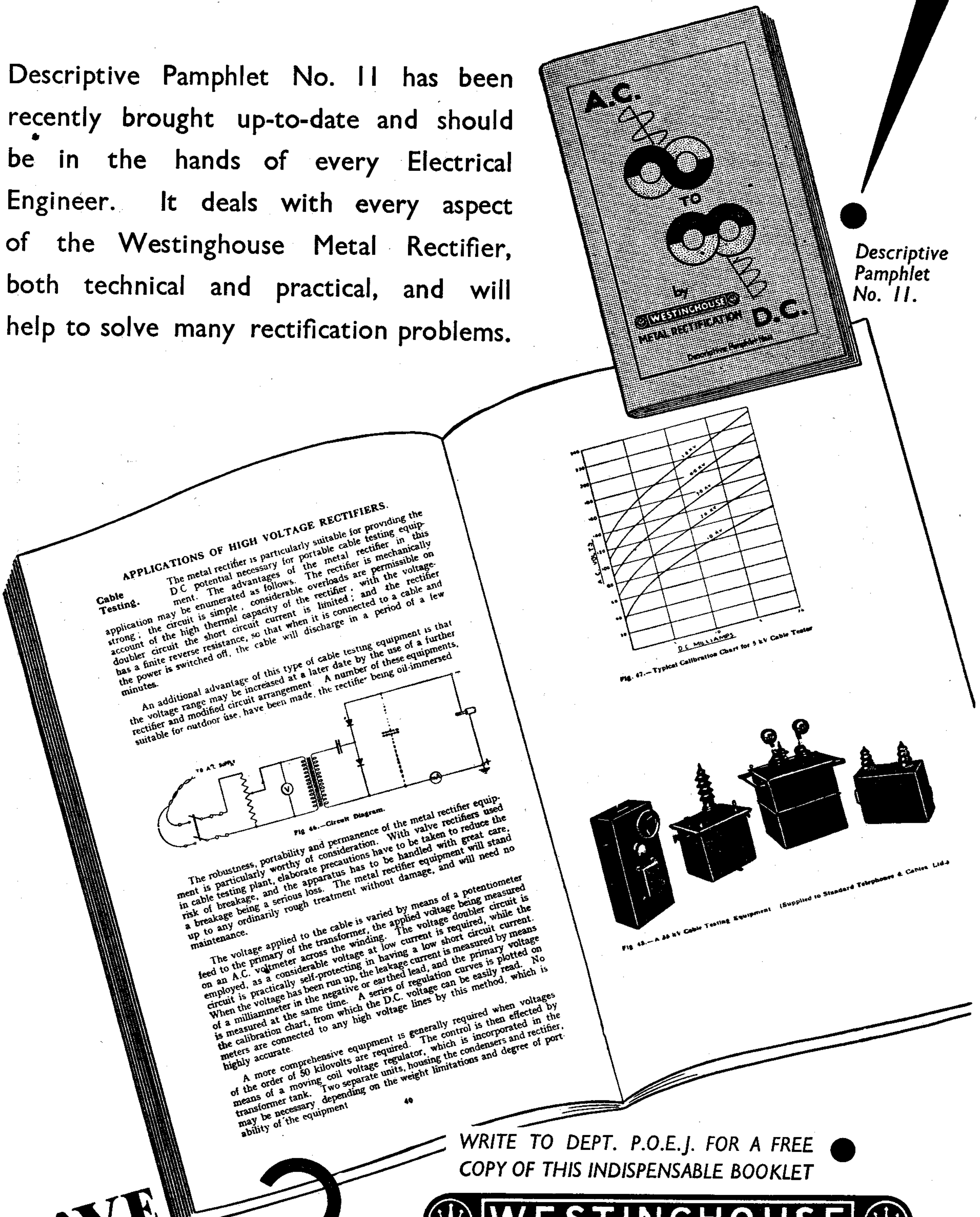
TURNERS ASBESTOS CEMENT CO. (Branch of Turner & Newall Ltd.) Trafford Park, MANCHESTER


SIEMENS
LONDON


SIEMENS
BROTHERS
LONDON

A NEW EDITION!

Descriptive Pamphlet No. 11 has been recently brought up-to-date and should be in the hands of every Electrical Engineer. It deals with every aspect of the Westinghouse Metal Rectifier, both technical and practical, and will help to solve many rectification problems.



Descriptive Pamphlet No. 11.

APPLICATIONS OF HIGH VOLTAGE RECTIFIERS.

Cable Testing. The metal rectifier is particularly suitable for providing the D.C. potential necessary for portable cable testing equipment. The advantages of the metal rectifier in this application may be enumerated as follows. The rectifier is mechanically strong; the circuit is simple; considerable overloads are permissible on account of the high thermal capacity of the rectifier; with the voltage-doubler circuit the short circuit current is limited; and the rectifier has a finite reverse resistance, so that when it is connected to a cable and the power is switched off, the cable will discharge in a period of a few minutes.

An additional advantage of this type of cable testing equipment is that the voltage range may be increased at a later date by the use of a further rectifier and modified circuit arrangement. A number of these equipments, the rectifier being oil-immersed suitable for outdoor use, have been made.

Fig 46.—Circuit Diagram.

The robustness, portability and permanence of the metal rectifier equipment is particularly worthy of consideration. With valve rectifiers used in cable testing plant, elaborate precautions have to be taken to reduce the risk of breakage, and the apparatus has to be handled with great care, a breakage being a serious loss. The metal rectifier equipment will stand up to any ordinarily rough treatment without damage, and will need no maintenance.

The voltage applied to the cable is varied by means of a potentiometer feed to the primary of the transformer, the applied voltage being measured on an A.C. voltmeter across the winding. The voltage doubler circuit is employed, as a considerable voltage at low current is required, while the circuit is practically self-protecting in having a low short circuit current. When the voltage has been run up, the leakage current is measured by means of a milliammeter in the negative or earthed lead, and the primary voltage is measured at the same time. A series of regulation curves is plotted on the calibration chart, from which the D.C. voltage can be easily read. No meters are connected to any high voltage lines by this method, which is highly accurate.

A more comprehensive equipment is generally required when voltages of the order of 50 kilovolts are required. The control is then effected by means of a moving coil voltage regulator, which is incorporated in the transformer tank. Two separate units, housing the condensers and rectifier, may be necessary depending on the weight limitations and degree of portability of the equipment

40

Fig. 47.—Typical Calibration Chart for 5 kV Cable Tester

Fig. 48.—A 35 kV Cable Testing Equipment (Supplied to Standard Telephones & Cables Ltd.)

WRITE TO DEPT. P.O.E.J. FOR A FREE COPY OF THIS INDISPENSABLE BOOKLET

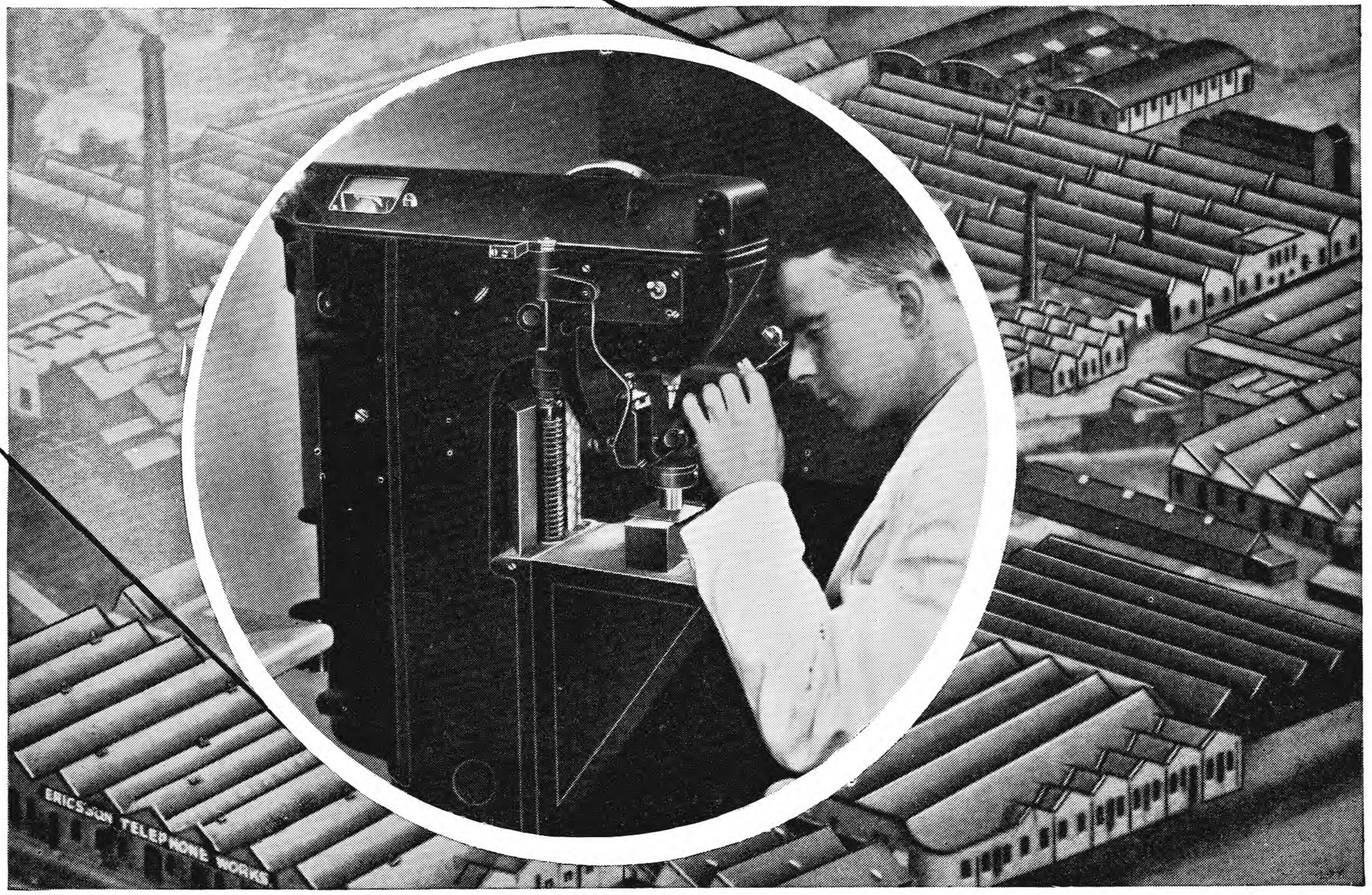
HAVE YOU HAD YOUR COPY?

WESTINGHOUSE

METAL RECTIFIERS

WESTINGHOUSE BRAKE & SIGNAL CO., LTD.,
82 YORK ROAD, KING'S CROSS, LONDON, N.1

2. *Testing the hardness of materials.*



BERCO

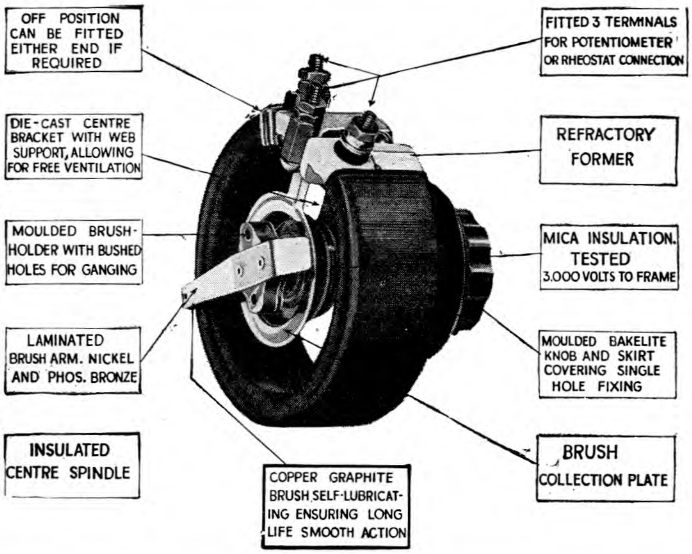
50 and 100 WATT Toroidal Wound Units

The new **BERCO** toroidal wound resistance and potentiometer units are available in two patterns—50 and 100 watts dissipation. They are specially designed for heavy duty power applications where small cubic capacity and high wattage dissipation are required.

The coil is toroidally wound on a special porcelain former and the unique design gives an air space all round the coil. The special contact arm has an extremely low contact resistance, a particularly smooth action, and is insulated from the main spindle.

Write for illustrated descriptive folder.

We are also manufacturers of
Transformers and Chokes



BERCO

THE BRITISH ELECTRIC RESISTANCE CO., LTD.
Contractors to H.M. Admiralty, War Office, Air Ministry, Post Office, etc.
OHMIC WORKS, QUEENSWAY, PONDERS END, MIDDX.
Telephone : Howard 1492.

A Selection of Books for Engineers and Students

FOUNDATIONS OF TECHNICAL ELECTRICITY
By E. Mallett, D.Sc., M.I.E.E., A.M.Inst.C.E., F.Inst.P., and T. B. Vinycomb, M.C., M.A., F.Inst.P. An invaluable book for students preparing for the National Certificate, City and Guilds, and other examinations. 188 pages. Illustrated. 5/- net (by post 5/5). " An excellent volume at a moderate price."—*Technical Journal.*

PRIVATE AUTOMATIC BRANCH EXCHANGES
By R. T. A. Dennison, of the Engineer-in-Chief's Office, G.P.O., London. 304 pages. Illustrated. 5/- net (by post 5/4½).

THE CALL INDICATOR SYSTEM IN AUTOMATIC TELEPHONY
By A. G. Freestone, of the Automatic Training School, G.P.O., London. 124 pages. Illustrated. 6/- net (by post 6/4).

PRACTICAL TELEPHONE HANDBOOK AND GUIDE TO THE TELEPHONIC EXCHANGE
By J. Poole, A.M.I.E.E., Wh.Sc. Seventh Edition, revised and enlarged. 895 pages. 685 illustrations. 18/- net (by post 18/6).

RELAYS IN AUTOMATIC TELEPHONY
By R. W. Palmer, A.M.I.E.E., Assistant Engineer, G.P.O., London. 190 pages. Illustrated. 10/6 net (by post 10/10½).

OUTLINE NOTES ON TELEPHONE TRANSMISSION THEORY
By W. T. Palmer, B.Sc., Wh.Ex., A.M.I.E.E. 176 pages. 4/- net (by post 4/5).

DEFINITIONS AND FORMULAE FOR STUDENTS (Telegraphy and Telephony)
By E. Mallett, D.Sc., M.I.E.E., A.M.Inst.C.E., F.Inst.P. States briefly the principal definitions and mathematical formulae required by the student of telegraphy and telephony. 37 pages. 6d. (by post 6½d.)

TELEGRAPHY
By T. E. Herbert, M.I.E.E., Superintending Engineer, Post Office Engineering Department. A standard text-book. 1,224 pages. 750 illustrations. Fifth Edition. 20/- net (by post 20/6).

Just Published
GENERATION, TRANSMISSION AND UTILIZATION OF ELECTRICAL POWER
By A. T. Starr, B.Sc., A.M.I.E.E. Covers the revised " Electrical Power " syllabus for the B.Sc. (Lond.). 480 pages. 18/- net (by post 18/6).

Order from a bookseller or direct from

PITMAN HOUSE, PARKER ST., **PITMAN** **KINGSWAY, LONDON, W.C.2**

Your . . .

BEST COMPANIONS FOR ELECTRICAL SECURITY

"wee-MEGGER TESTER" and MEGGER CIRCUIT TESTER

£14·0·0

Megger

registered Trade Mark

Complete your Wireman's Tool Kit by adding an outfit for every emergency in Insulation and Continuity Testing. Comprises wee-Megger Tester, Megger Circuit Tester, Set of three leads, Instruction and Log Books, and Leather sling case. Weight 6½ lbs. Size 8″x7″x4½″

Announcement of

Write for Publications to X.042

EVERSHED & VIGNOLES, Ltd., CHISWICK, LONDON, W.4

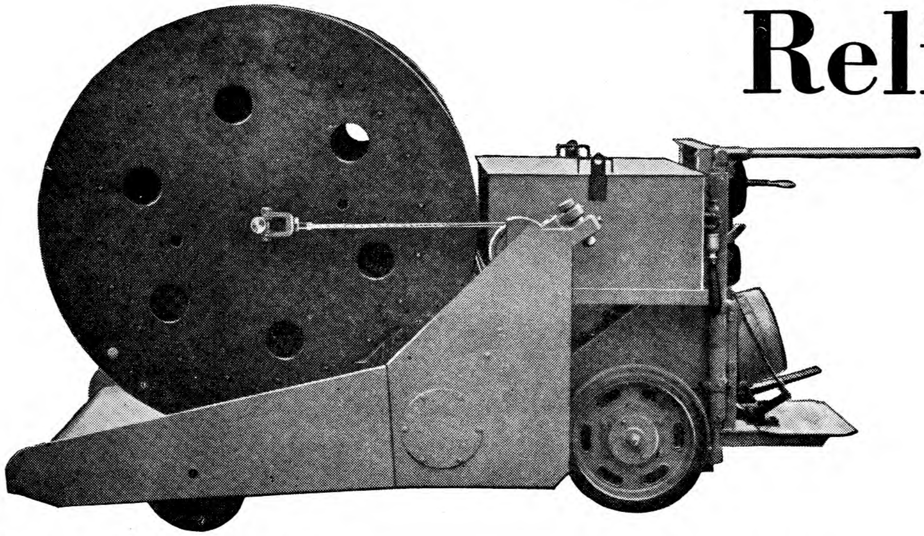
Telephone: Chiswick 1370

Telegrams: "Megger" Chisk, London

CIRCUIT SELECTOR
PURCHASERS NAME
VOLTS
AMPERES
MILLIAMPERES
ANALYZER
20,000 OHMS PER VOLT D.C.
PRESS FOR READING
ADAPTER

8500
8600
8700

For Economy, Speed and Reliability—



Cable-drum Carrying Electric Truck powered by Exide-Ironclad Batteries.

use the Electric Truck

Look through the facts given here and you will see why the electric truck is now universally used for railway, dock and works transport. It has no serious rival.

RELIABLE, FAST AND ECONOMICAL.

Electric power is far cheaper than any other form and it is consumed only when the truck is moving. There is no waste. Since there is no fire risk insurance is specially low.

An electric truck is so simple and strong that it outlasts two or three vehicles of other types. Over ninety per cent. of trucks supplied during the last twenty years are still in operation. Maintenance costs are negligible. Electric trucks have rapid acceleration and have large goods-carrying space.

SILENT AND CLEAN.

An electric truck runs dead silent and makes no fumes or smell.

MANŒUVRABILITY.

An electric truck is far quicker and handier than man power or other mechanically propelled vehicles. It is quickly and easily started for it has no gear-box or clutch.

'Electrics' are available for all special jobs such as stacking, tipping or lifting to lorry level. By employing separate platforms or skids idle time through loading can be abolished.

***ELECTRICS** ARE CHEAPER FOR RAILWAY, DOCK, WORKS AND MARKET TRANSPORT—*

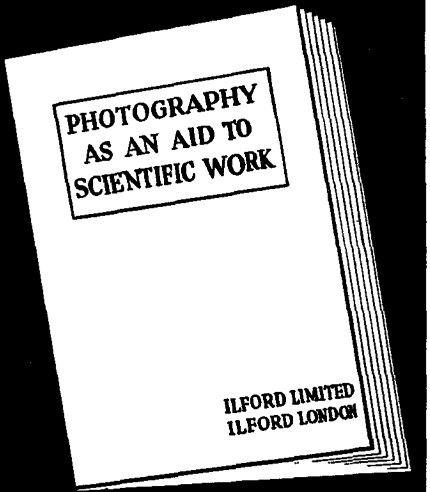
and THEY are best with **Exide-Ironclad BATTERIES**

Exide-Ironclad Batteries are used in the majority of electric vehicles.

THE CHLORIDE ELECTRICAL STORAGE CO. LTD., Battery Traction Dept., Exide Works, Clifton Junction, near Manchester.
London Office: 137 Victoria Street, S.W.1.

E.I.Tr.18.

ILFORD LIMITED



PHOTOGRAPHY AS AN AID TO SCIENTIFIC WORK

ILFORD LIMITED
ILFORD LONDON

Write for a free copy of "Photography as an aid to Scientific Work"

FREE to Post Office Engineers a concise guide to sensitised material for scientific uses.

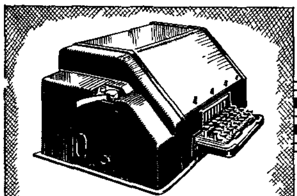
ILFORD
REGISTERED TRADE MARK

As an aid to engineers and research workers, Ilford Limited have prepared a practical book of reference containing particulars of their full range of photographic plates and films for Field and Survey Work, Laboratory Research and all Scientific Purposes.

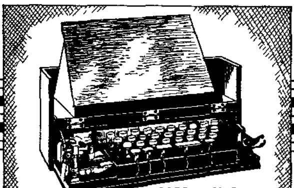
These materials are the outcome of some sixty years of specialised study and are world famed for their consistency and reliability.

ILFORD
PLATES - FILMS - PAPERS

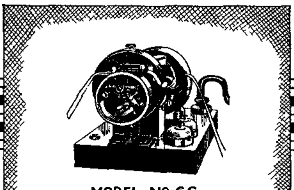
MADE IN ENGLAND BY ILFORD LIMITED, ILFORD, LONDON



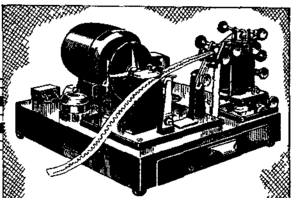
MODEL Nº3A TAPE TELEPRINTER



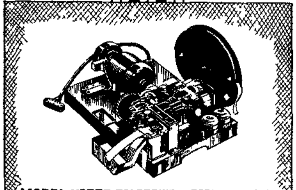
MODEL Nº5 PM.
MURRAY KEYBOARD PERFORATOR



MODEL Nº 6S.
TELEPRINTER AUTO TAPE TRANSMITTER



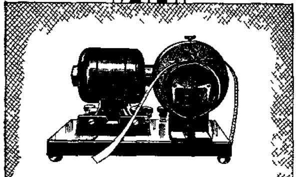
MODEL Nº10 UNDULATOR



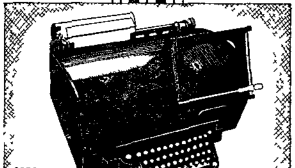
MODEL Nº7TR. TELEPRINTER REPERFORATOR

MODEL Nº 9
MORSE KEYBOARD PERFORATOR

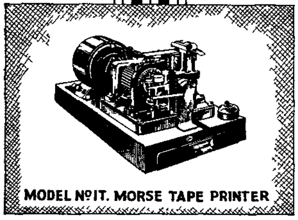
ILLUSTRATED are some of the instruments manufactured to provide printing telegraph machines to meet all modern communication requirements.



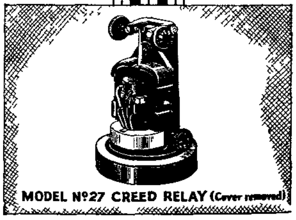
MODEL Nº11
MORSE AUTOMATIC TAPE TRANSMITTER



MODEL Nº7
PAGE TELEPRINTER
WITH COMMERCIAL TYPEWRITER KEYBOARD



MODEL Nº1T. MORSE TAPE PRINTER



MODEL Nº27 CREED RELAY (Cover removed)

CREED & CO. LTD.

Telephone :—
Croydon 2121

Telegraph House
CROYDON

Telex :—
Croydon Telex 1082

YOU HAVE BEEN WARNED BY RADIO

Professor Hilton on November 19th, 1936, from the B.B.C. broadcast a warning. The warning was to the effect that while there are many really good and reliable Colleges teaching by correspondence, there are many others which are colleges by name only. He said some so-called colleges rented a couple of rooms in a large building in a well-known street. Some made great promises which they did not intend to fulfil. Some claimed successes they could not prove. In some cases the names of prominent men were quoted who were in no way connected with the working of the College.

NOW BE ADVISED BY ME

The big name of a College is no proof of its national standing. The Bennett College has been established over 30 years and our entire building is devoted to Bennett College work. No other business of any kind is either on or attached to The Bennett College. We have seating accommodation for over 10,000. We have a permanent staff of over 190 people on the College premises. Our Professional Staff have all passed their examinations, and our tutors are all experts in their own specialised work. We do not send out any homework to be corrected by tired, spare-time tutors. All students' homework is corrected on the College premises the same day that it arrives, and is returned by evening post. This College is Technical, Scientific, General and Commercial, thus enabling us to cater for all requirements; this is important to Cost and Works Accountants, and all who have to deal with rate-fixing machining-allowance, and it is also of great importance in many of the Civil Service Examinations. This is an entirely British College. Most of our textbooks are written on the College premises by our professional staff, especially for tutorial purposes. Our tutors specialise in teaching students for the examinations they themselves have already passed.

THERE IS NO OTHER COLLEGE IN THIS KINGDOM THAT CAN CLAIM ALL THE ABOVE ADVANTAGES

It is not necessary for students to attend the College: we can send exactly the same tuition to you by post for a reasonable fee payable monthly. Anyone who reads the journals knows that there are many things advertised that one can study, and any kind of study is good. It is training for the brain, but the best thing to study, surely, is a course specially prepared to teach your own vocation, or prepare you for the examinations which you have in view. Knowing that you are master of your job gives you self-confidence and personality, but a Diploma from a College is absolute proof of your efficiency. We have agencies in all English-speaking corners of the world. The nature of our business makes us keep in touch with employment requirements in all parts of the world, therefore we specialise in preparing students for the good positions which we know exist, and for all worth-while examinations.

THE ABOVE VAST ORGANISATION CAN HAVE BEEN CREATED ONLY BY THE SUCCESS OF OUR STUDENTS

There is a tide in the affairs of man which, if taken at the flood, leads on to fortune and success. There are three things which come not back: the sped arrow, the spoken word and the lost opportunity—this is your opportunity. If it is your desire to make progress and establish yourself in a good career, write to us for free particulars on any subject which interests you, or if your career is not decided, write and tell us of your likes and dislikes, and we will give you practical advice as to the possibilities of a vocation and how to succeed in it. You will be under no obligation whatever. It is our pleasure to help. We never take students for courses unless we feel satisfied they are suitable. Do not forget that success is not the prerogative of the brilliant. Our experience of over 30 years proves *that the will to succeed* achieves more than outstanding brilliancy.

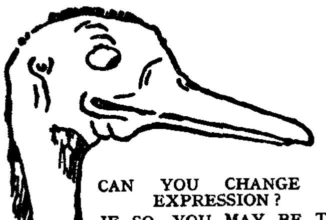
LET ME BE YOUR FATHER

Let me tell you how to make a success of your career. If your future is undecided or appears unsatisfactory, let us talk it over together.

I want to help, and it will cost you nothing to get my help; you will be under no obligation whatever.

J H Bennett

We are prepared to produce, on demand, over 10,000 unsolicited testimonials from successful students, or in default we wil hand over £100 to charity.



CAN YOU CHANGE MY EXPRESSION?

IF SO, YOU MAY BE THE ARTIST THAT COMMERCE IS WAITING FOR

Just try for yourself, trace or draw the outline and then put in the features.

There are hundreds of openings in connection with Humorous Papers, Advertisement Drawing, Posters, Calendars, Catalogues, Textile Designs, Book Illustrations, etc., etc. 60% of Commercial Work Art is done by "Free Lance Artists" who do their work at home and sell it to the highest bidders. Many Commercial Artists draw retaining fees from various sources; others prefer to work full-time employment or partnership arrangement. We teach you not only how to draw **what is wanted,** but how to make buyers **want what you draw.** Many of our students who originally took up Commercial Art as a hobby have since turned it into a full-time paying profession with studio and staff of assistant artists—there is no limit to the possibilities.

Let us send full particulars for a FREE TRIAL and details of our course for your inspection. You will be under no obligation whatever.

Art Dept. 24.

DO ANY OF THESE SUBJECTS INTEREST YOU?

Accountancy Examinations
Advertising and Sales Management
A.M.I. Fire E. Exam.
Applied Mechanics
Army Certificates
Auctioneers and Estate Agents
Aviation Engineering
Banking. Boilers
Book-keeping, Accountancy and Modern Business Methods
B.Sc. (Eng.)
B.Sc. (Estate Management)
Building, Architecture and Clerk of Works
Cambridge Senior School Certificate
Civil Engineering. Civil Service
All Commercial Subjects
Commercial Art
Concrete and Structural Engineering
Draughtsmanship. All branches
Engineering. All branches, subjects and examinations
General Education
G.P.O. Eng. Dept.
Heating and Ventilating
Industrial Chemistry
Insurance. Mathematics
Matriculation. Metallurgy
Mining, all subjects
Mining, Electrical Engineering
Motor Engineering
Motor Trade
Municipal and County Engineers
Naval Architecture, Pattern Making
Police, Special Course
Preceptors, College of
Pumps and Pumping Machinery
Radio Service Engineering
Road Making and Maintenance
Salesmanship, I.S.M.A.
Sanitation
Secretarial Exams.
Sheet Metal Work
Shorthand (Pitman's)
Shipbuilding
Structural Engineering
Surveying
Teachers of Handicrafts
Telephony and Telegraphy
Transport Inst. Exams.
Weights and Measures Inspector
Welding
Wireless Telegraphy and Telephony
Works Managers

If you do not see your own requirements above, write to us on any subject. Full particulars free

SIGNS OF THE TIMES

ARMAMENTS

means

MASS PRODUCTION

means

JIGS, TOOLS, FIXTURES, ETC.

Our extended course on DRAUGHTSMANSHIP teaches the Design. Our PRACTICAL ENGINEERING teaches the manipulation.

THE AIR FORCE

is to be increased. All branches of

ENGINEERING MUST DEVELOP

CIVIL SERVICE

Suitable to both sexes. Ages 15½ to 24. Pay Cuts have been restored.

G.P.O. ENG. DEPT.

CUSTOMS AND EXCISE; INSP. OF TAXES, Etc. NO EXPERIENCE REQUIRED. OPEN EXAMS.

TELEPHONY, RADIO and MOTOR ENGINEERING are expanding rapidly. There are lots of vacancies.

MATRICULATION

There are many ways of commencing a career, but Matriculation is the jumping-off board for all the best ones. We prepare Candidates for all.

INSTITUTE EXAMS.

TECHNICAL. ACCOUNTANCY.
SECRETARIAL. INSURANCE. Etc.

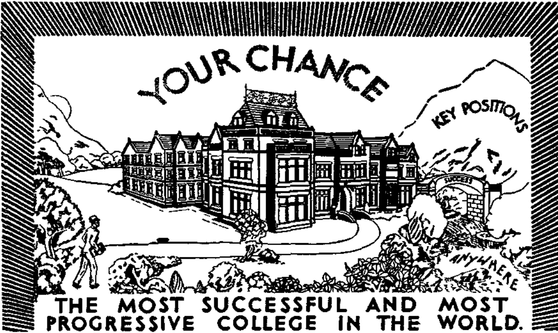
YOUNG MEN

Young men physically fit and whose careers are not definitely fixed should join the Police Force. We have special Courses for Entrance and Promotion. Full Particulars Free.

Address
POLICE DEPT. 24.

ENGINEERS

Engineers, now is your chance to dig yourselves into a Key position and make your future solid. It needs Technical Training; we can give you that by post. Full particulars free, Dept. 24.



THE MOST SUCCESSFUL AND MOST PROGRESSIVE COLLEGE IN THE WORLD.

HOW TO STUDY

In your spare time when it suits YOU. You fix your own time, you do **not** GO to your studies—the postman **brings** THEM TO YOU. There is nothing that a class-room teacher can show on a blackboard that we cannot show on a white paper. The lesson on a blackboard will be cleaned off, but our lessons are PERMANENT. A class-room teacher cannot give you a private word of encouragement. but a Correspondence Tutor can do so whenever your work deserves it. On the other hand, he can, where necessary, point out your mistakes PRIVATELY.

NOTE ADDRESS: DEPT. 24 BENNETT COLLEGE, SHEFFIELD

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXX October, 1937 Part 3

Lightning and Lightning Protection

W. G. RADLEY, Ph.D.(Eng.), M.I.E.E.

The author describes the modern theories concerning the production of lightning, quotes experimental data contributing to modern knowledge of the values of the power and current involved in a lightning stroke, and reviews the methods available for the protection against lightning of buildings, power lines, and communication lines and apparatus.

THE PHENOMENON

THERE is hardly any other natural phenomenon about which there has been such an increase of knowledge during the past 10 years as there has been about the lightning flash. Partly this has been due to the construction of high voltage power transmission lines in all developed countries. These lines are particularly a target for lightning which, breaking down insulation barriers, causes serious interruption to the service. Nevertheless, quantitative knowledge of the phenomenon would not have been obtained if there had not been developed during the past few years a number of devices, all of them essentially simple in conception, which have been attached to transmission lines in large numbers and which have enabled very many observations to be made of the currents and voltages involved when a line is struck. To such quantitative information must be added the timed picture which the Boys high speed camera has given of the happenings within the small fraction of a second occupied by the flash.

Electrification of the Thundercloud.

Nearly 200 years ago it was realised that lightning (Fig. **1**) was nothing more than an exhibition on a grand scale of the sparks that were then being drawn from primitive electrical machines. Franklin forced the idea upon the world by his daring experiment of drawing electricity from a cloud by means of a kite during a thunderstorm. Since then there has been much speculation as to how the thundercloud became electrified. Two of the best known theories will be described.

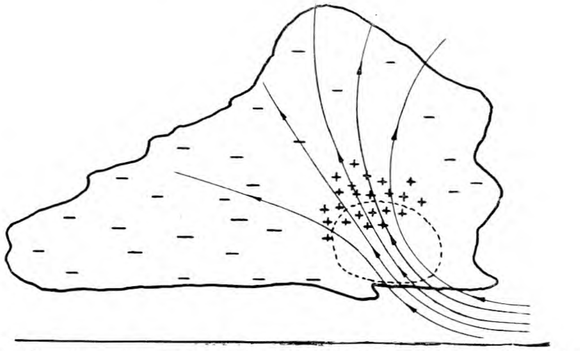


FIG. **2**.—AIR CURRENTS IN THE THUNDERCLOUD AND THE ACCUMULATION OF ELECTRIC CHARGES.

Simpson's Theory. In 1929 Sir George Simpson, delivering the Kelvin Lecture to the I.E.E., suggested a *modus operandi* based on the known physical characteristics of a thundercloud and on experiments which could be carried out in the laboratory. The theory gave results in accordance with the then known facts. Physically, the distinguishing features of a thundercloud are its great vertical depth and a turbulent current of air moving swiftly upwards through the cloud (as indicated on Fig. **2**). The velocity of this air current frequently exceeds 8 metres per second. It can be shown that a drop of water falling through free air acquires a limiting velocity which increases with the size of the drop. With drops of the largest size the velocity does not exceed 8 metres per second and above this size drops are unstable and tend to break into two. Rain cannot therefore fall through the region where the violent upward air currents exist. In the laboratory it has also been shown that, when water drops are broken up, the resulting droplets become positively charged while a

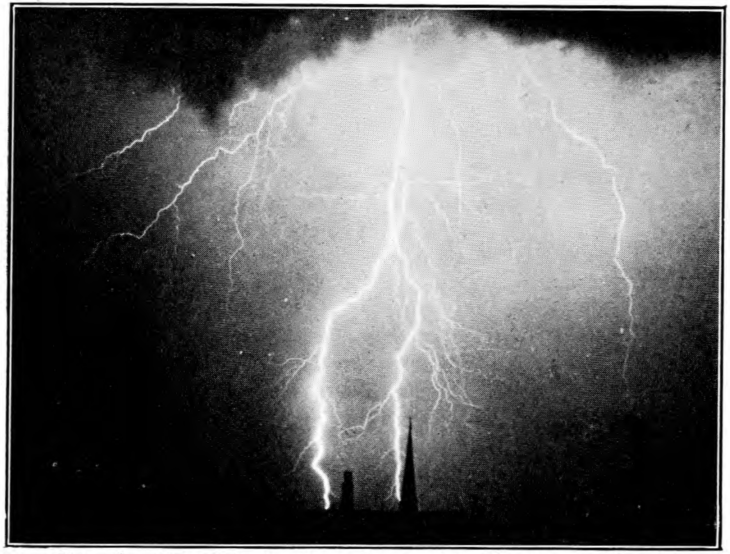


FIG. **1**.—PHOTOGRAPH OF A LIGHTNING FLASH TAKEN BY PROFESSOR WALTERS.

negative charge is transferred to the air. Drops entering the turbulent region are therefore broken up and the parts blown upwards positively charged. The corresponding negative charge is carried away by the air stream to accumulate elsewhere. Above the turbulent region the small drops which have been blown upwards recombine and fall back into the air stream only to be broken up again and receive an additional charge. If it is remembered that the air within the cloud is an excellent insulator it will not be difficult to picture, as Sir George Simpson did, a localised region becoming packed with very highly charged drops of water. From this region discharges may pass towards the negative electricity elsewhere in the cloud, but will more frequently pass downwards as discharges of positive electricity towards the ground. In spite of its attractiveness, however, this theory is no longer completely accepted since field observations over the past few years have shown that the great majority of lightning strokes come from a negatively charged region at the base of the cloud.

Wilson's Theory. Professor C. T. R. Wilson's picture of the happenings within a thundercloud is not so easy to visualise. The cloud becomes the bipolar structure shown schematically in Fig. **3** and in which the positive charge tends to be above the negative.

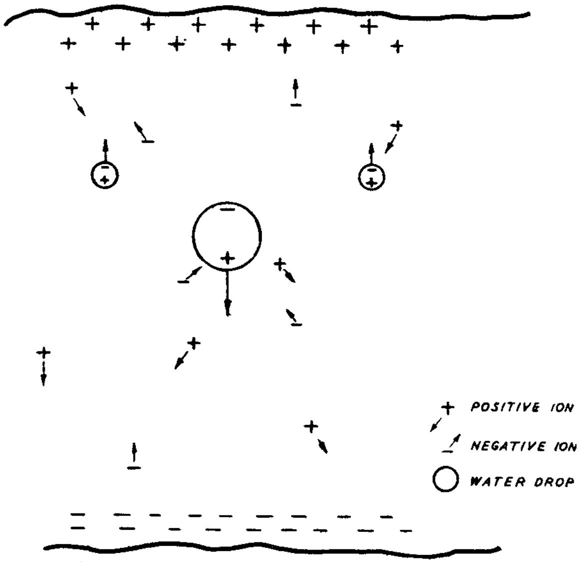


FIG. **3**.—INDUCED ELECTRIC CHARGES ON WATER DROPS IN A THUNDER CLOUD.

Now such a separation of charges would occur if the small raindrops, which fall slowly relatively to the air, are positively charged while the larger drops which fall more rapidly, are negatively charged. Assuming such a process does begin, ionisation currents will start to flow to dissipate the charges which accumulate near the top and bottom of the cloud. But, even when impelled by the maximum field strength which can exist before spark-over occurs, the mobility of the large downward moving positive ions is small. All rain drops more than one tenth of a millimetre in diameter will fall faster and will overtake some of the downward moving positive ions, but, because of the electrostatic field in the cloud, a negative charge will have been induced on the top and a positive charge on the lower surface of the drop. The latter will repel such positive ions as the drop overtakes, deflecting them to one side, but will aid in the capture of all upward moving negative ions which are encountered. Such drops will collect the majority of the negative ions and acquire an increased negative charge which they carry to the base of the cloud. The smaller and more slowly moving drops are able to capture positive ions on their top surfaces; but they, with their charges, will tend to be carried to the higher portions of the cloud by the upward air stream.

It has been estimated that there are between 1,800 and 2,000 thunderstorms in progress at any moment. Under each thundercloud the point discharge which precedes the flash, and of course the flash itself, will transfer positive charges from the earth to the cloud. It is interesting to note that these localised conditions may be balanced by the normal fine weather ionisation current over the rest of the earth's surface which is in the reverse direction and has been stated to be approximately 1,000 amperes.

The Mechanism of the Flash.

It is possible that the happenings within a thundercloud are more complex than those suggested by either of the theories outlined above. But, although the method by which the thundercloud acquires a localised charge is not fully known, much has been learnt of the mechanism by which a conducting path is established between the cloud and the earth. This has resulted from the use of the Boys high speed camera which is able to resolve events separated in time by less than one microsecond. In its earliest form the camera comprised a fixed photographic plate behind two lenses revolving at 3,000 r.p.m. in a circle of about 4 inches diameter. Two pictures are thus obtained of each lightning flash, but if the flash is not instantaneous these will be distorted in opposite directions by the motion of the lenses. From a comparison of the two pictures it is possible to deduce the direction and speed of the discharge.

Much patient waiting did not give Professor Boys real opportunity to use his camera in this country, but four years ago Schonland began to use a Boys camera in South Africa. Since then he has obtained photographs of over 200 lightning strokes. Much has been learned from these.

A lightning flash consisting of a single stroke is most common, but flashes consisting of as many as 27 separate strokes following the same path within about half a second have been recorded. To the naked eye a multiple stroke such as this appears simply as a flash which seems to flicker. If, as occasionally happens, all the strokes do not follow the complete path formed by the first, the flash appears to be forked. Each stroke comprises a sequence of two happenings; the preparation of an ionised channel from the cloud downwards to the earth and the main discharge which travels up from the earth directly the ionised channel has been completed. The ionised channel is prepared by a succession of "dart-like" leader strokes or "electron avalanches" as they have been called. Each of these consists of a streamer, about 50 metres long, which shoots down from the cloud towards the ground but becomes extinguished before it has

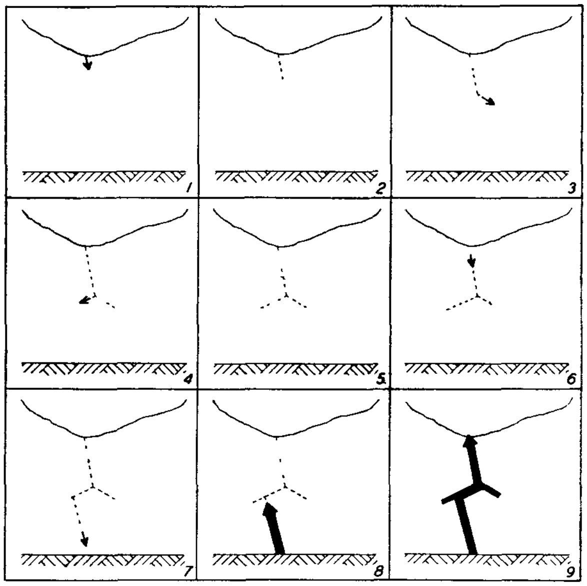


FIG. 4.—EVENTS DURING THE PROPAGATION OF A LIGHTNING STROKE.

travelled more than a part of the distance. However, it is rapidly followed by others which, taking the same channel, extend it (as indicated by Fig. **4**) further towards the earth. Although these streamers move downwards with great velocity it may take a large number of them (many more than suggested by Fig. **4**) to complete the channel as far as the earth. A certain amount of branching may arise from the intermittent downward progress of the channel. Schonland suggests that, while this is taking place, part of the charge becomes distributed over the channel and its branches. When the path blazed by the leader strokes reaches the earth an intense discharge takes place starting from the earth. In the course of its upward journey the main discharge branches outwards along the forks blazed by the leaders.

When other strokes follow in quick succession each is preceded by a downward moving leader. However, the first of these to leave the cloud finds an already ionised path prepared for it and completes the journey to the ground. In the majority of cases the second and subsequent main strokes are not so intense as the first.

The Electrical Power in the Stroke.

Direct experiment shows that an electric field in the neighbourhood of 10,000 volts per cm. is required to produce a discharge in the presence of water drops of the size to be expected in thunderclouds. This indicates a total potential difference between the earth and cloud of the order of a million kilovolts immediately before the flash takes place.

The advent of the Klydonograph has made possible the routine measurement of the voltage to which power transmission lines are raised when struck by lightning. This instrument depends for its operation on the production of figures similar to those which, in 1777, Dr. G. C. Lichtenberg saw formed by a powder, such as flowers of sulphur, when sprinkled on a plate of insulating material interposed between two electrodes. In the practical modern field equipment similar patterns appear on development of a photographic film if it has passed between electrodes which have been subject to a potential difference. There is a striking difference between the pattern of the Lichtenberg figures produced by positive and negative potentials. Further, within the range of voltages which produce these figures, their diameter can be used as a rough measure of the potential difference.

No sooner had the Klydonograph become a commercial device than very many of these instruments were connected to transmission lines by means of simple electrostatic potential dividers. The maximum potential recorded as a result of lightning rapidly advanced from one million to five million volts. In addition, the Lichtenberg figures began to yield statistical information as to the relative frequency of occurrence of lightning strokes of positive and negative polarity.

Although the object struck is rarely raised to a voltage above the general mass of the earth approaching one per cent. of the voltage difference giving rise to the stroke, it frequently has to carry the whole of the stroke current. To the engineer the current in the stroke is therefore much more important than the voltage behind it. During the past few years lightning stroke currents have been measured or estimated in various ways. There has been remarkable agreement between the results obtained. It seems as if the order of magnitude of the stroke current is fairly closely fixed.

First in importance among the current measuring devices must be placed the surge crest ammeter. In effect this consists of a bundle of alloy steel strips packed together in an insulating tube and suitably placed with respect to the path of the current. The packet is termed a " magnetic link." A current of the magnitude of that flowing to earth from a lightning discharge will produce an intense magnetic field around its path and have a permanent effect on any iron or steel present. Experiments in the laboratory have shown that the time of magnetic penetration of the alloy steel used in the magnetic link is less than half a microsecond, so that the links can be used to measure surge currents of short duration. With unidirectional surges the principles involved and the technique are obvious in their simplicity and directness. The method, however, is also capable of giving information regarding oscillatory surges. Because of the non-linear value of the magnetisation curve the magnitude of successive crests can be deduced from the magnetisation of two links placed at different distances from the conductor. Magnetisation of links is measured in a very simple method in the field. The link being tested is placed adjacent to a small permanent magnet forming part of a spring-controlled moving system. The latter deflects by virtue of the attraction and repulsion between the two magnets.

No less than 24,000 of these devices were distributed over the lines of the German power companies in 1934. In the United States 1,500 records accumulated from over 5,000 measurement stations show currents ranging to a maximum above 200,000 amperes with 50 per cent. of the strokes exceeding 36,000 amperes. Currents have been measured in transmission line towers, overhead earth wires, lightning arrestor down leads, radio masts, etc. It is instructive to note that 97 per cent. of all direct strokes recorded have been from clouds of negative polarity.

The value of the current may also be determined from the burning and fusing of conductors. As effects of this nature are also dependent on the time during which the current flows we must note in passing that in 1928 the cathode ray oscillograph was adapted to automatic operation so that it could be used for recording lightning surges on transmission lines. Since then numerous surges have been recorded and have led to the proposal that a surge rising to its maximum value in one microsecond and then falling to one half in 50 microseconds should be standardised for impulse tests. Taking this as representative of the time duration of the stroke, it is possible to calculate the magnitude of the current that would just fuse a wire of given size. There appears to be a very marked limit to the gauge of wire that is normally fused. The American Telephone and Telegraph Co. use a 65 lb./mile bronze conductor for overhead circuits as compared with the 70 lb./mile wire used by the British Post Office. Hundreds of instances are on record where such wires have been struck by lightning and fused. On the other hand only a very limited number of reports have been made of wires of heavier gauge having been fused and it is possible that in some at least of these the flash consisted of a multiple stroke. Assuming that wires of 70 lb./mile and lighter will be fused if struck but that heavier wires will not, the calculated magnitude of the stroke current is of the order of 100,000 amperes.

The development during the past decade of the surge generator has made it possible to produce in the laboratory short duration currents of approximately the same magnitude as lightning stroke currents. This has enabled a comparison to be made between many of the effects observed in the field as a result of natural lightning and those produced by known surge currents in the laboratory. For example, the tips of the electrodes of the de-ionising gaps which are provided for the purpose of discharging lightning currents in distribution transformers connected to high voltage lines are often found to be burnt after the line has been struck. Comparison of the effects with the burning of discharge gaps produced in the laboratory by currents of known magnitude and wave shape has led to the conclusion that the current is usually between 20,000 and 100,000 amperes.

The mechanical forces associated with the passage of a current of the order of 100,000 amperes are such that parallel conductors are violently crushed together and tubular conductors tend to collapse. An interesting example of the first of these effects was formed by a pair of vulcanised india-rubber insulated wires shown in Fig. 5. These formed the lead-in to a telephone subscriber's house in Australia. After the discharge had passed it was found that both conductors had cut their way through the surrounding insulation and been brought into intimate contact. Similar cases have been observed elsewhere and attempts have been made to reproduce the effects in American high voltage laboratories. It has been found that currents of the order of 100,000 amperes or more are required. Similar values have been deduced from tubular conductors found crushed after the passage of a lightning discharge.

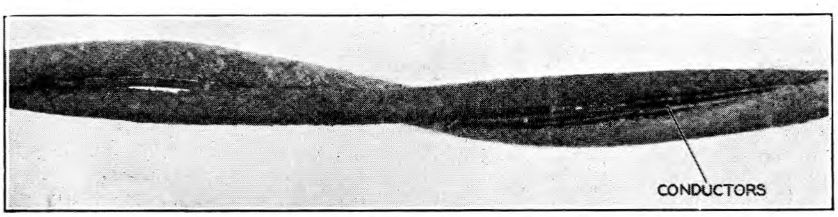


Fig. 5.—Insulated Wires Damaged by Lightning.

The shattering effect of a lightning stroke is familiar, wooden poles are splintered, trees split apart, concrete or rock in which guy wires are embedded is blasted and sometimes large holes are dug a few feet into the ground. It is not possible to calculate the stroke current from these effects, but Bellaschi has conducted very interesting laboratory experiments which give some idea of the explosive forces involved ; for instance, a discharge from an impulse generator of 140,000 amperes confined within a fibre tube having a bore of 2 cms. was found to give rise to an internal pressure of the order of 10,000 to 20,000 lbs. per sq. inch. Experiments of this nature and tests of surface burning have led him to the conclusion that the " core " of the lightning stroke channel is only a few centimetres in diameter.

Summing up then the present state of our knowledge, the most usual lightning stroke to earth consists of a current of 20,000 to 100,000 amperes flowing for about one twenty thousandth of a second and serving partially to discharge a cloud negatively charged with respect to the earth. The current follows a restricted and previously ionised path and a single flash sometimes consists of a series of strokes along this path. Wilson's theory accounts for the polarity of the cloud, but is possibly an incomplete picture of the happenings within it.

Protection Against Lightning

Publilius Syrus, a writer of the first century B.C. left it on record that "it is vain to seek for a remedy against the lightning." Although it is true that during the few microseconds that a stroke lasts energy is being dissipated at the rate of thousands of millions of kilowatts, the study that has since been given to protection against lightning enables the destruction of plant or buildings to be avoided in many instances.

Protection of Buildings.

The fundamental principle which must be observed is that a means has to be provided by which a discharge may pass to earth without traversing a non-conducting part of the building. Reference has already been made to the shattering effects which result from the passage of the stroke current through poor conductors such as wood, bricks, or concrete. A non-conducting structure may be protected by the erection of lightning rods projecting above it and connected to earth. Their object is to intercept the discharge rather than to divert it from a direction it would otherwise follow. Generally, a lightning rod will afford protection from a direct stroke within a cone whose radius is 2 to 4 times the height of the rod.

As the stroke is of very short duration a conductor of comparatively small gauge may be sufficient to carry the current without fusing. It must be remembered, however, that because of the steep wave front of the surge very high voltages may be built up at bends or loops in the lightning conductor. These may result in the discharge leaving the conductor. Lightning conductors should therefore be run in as straight a path as possible. If practicable there should be two or more widely separated paths from each lightning rod to earth. In general the surge impedance of such paths in parallel is inversely proportional to their number.

If the lightning conductor passes within a few feet of any large metal object there will be a tendency for side flashes to jump from the conductor to the metal at its nearest point. Such objects should therefore be bonded to the conductor. Another somewhat similar danger which must be avoided is that of sparking between two imperfectly bonded metal parts due to the high voltages induced in them when a discharge passes through another part of the structure. A disastrous oil fire causing the destruction of 9 million barrels of oil was started in this way in California in 1926. Roofed in, all-steel, oil tanks are essentially self protecting, as are gasometers and other metal structures. Steel framed buildings come in an intermediate category, but may be given adequate protection at a relatively small cost by means of a sufficient number of lightning rods connected to the frame and projecting above the structure.

Protection of Power Lines.

Although not his direct concern, the protection of power transmission lines against lightning damage is a matter of considerable interest to the telephone engineer. The insulators on the highest voltage lines yet constructed will not withstand an impulse voltage of more than about $2\frac{1}{2}$ million volts. Every direct stroke to a phase conductor will therefore produce a flash-over to earth. The power current which in most cases will follow, besides causing a shut down of the system, may induce high voltages to earth in neighbouring telephone lines.

Overhead earth wires prevent direct strokes to phase conductors. In this country the Central Electricity Board use a single earth-wire connected to the tops of the steel lattice towers on the 132 kV lines, but in the U.S.S.R. and the U.S.A., where lightning storms are more severe, it has been found necessary to build some lines operating at voltages over 200 kV with two earth wires. These are conventionally placed above the phase conductors and bonded together at mid span. The efficiency, however, of any system of lightning protection by earth wires depends on the footing resistance of the towers to which the earth wires are connected. This will be appreciated if it is recollected that, when the line is struck, the current in the tower structure may be 50,000 amperes or more. If the footing resistance is only a few ohms the tower structure may rise to a potential of several hundred kilovolts above earth and so cause the insulators to flash over. In practice considerable difficulty is often experienced in mountainous country in getting a sufficiently low footing resistance. The use of a " counterpoise " earth, which consists of a length of bare cable buried either under the line or at right angles to it, is difficult under these conditions. Elsewhere a counterpoise has been used with advantage, having been found to reduce the current density at the tower base and hold down the tower potential.

Protection of the line by earth wires combined with low tower footing resistances has proved very effective in reducing the number of shutdowns due to thunderstorms. Comparison of the behaviour of unprotected and protected sections of a 220 kV system in the U.S.A. during the past two or three years suggests a reduction of the order of 25.5 to 1.8 shutdowns per 100 circuit miles per annum.

Protection of Telephone Lines.

The current B.P.O. Engineering Instructions state that earth wires to act as lightning conductors should be fitted:

(i) On every tenth pole on main lines
(ii) On all distribution poles
(iii) On all poles in exposed areas subject to lightning storms.

The 150 lb. hard-drawn copper wire used is run straight down the pole on the side opposite to that on which the arms are fixed and formed into a flat spiral at the butt of the pole. It is secured by staples.

Experiments were made at the Dollis Hill Research Station using groups of model poles and a 250,000

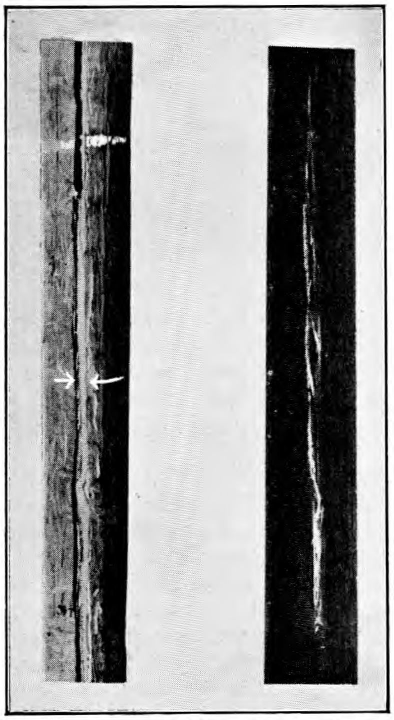


FIG. 6.—SPLINTERING OF TELEGRAPH POLE (LEFT) BY LIGHTNING AND (RIGHT) MODEL POLE SPLINTERED IN THE LABORATORY BY IMPULSE GENERATOR.

volt impulse generator giving a current surge having the characteristics, if not the magnitude, of the lightning stroke. As shown by Fig. 6, the splintering of the timber observed after a single discharge in the laboratory experiments was very similar to that which occurs on a larger scale when actual poles are struck by lightning. The shattering effect which results from the passage of a lightning discharge through timber is well known. It is usually attributed to the sudden conversion into steam of the moisture held within the pores of the material. Calculation shows that internal pressures of many tons per square inch could readily be generated in this way. Possibly a certain amount of decomposition takes place in addition due to the high current density, with the formation of gaseous products.

The presence of a pole earth wire in close proximity to line wires in which relatively high voltages may be induced by fault currents on an adjacent power system increases the likelihood of shock to linemen. In such cases the wire may be terminated a foot or so above ground level. Laboratory experiment has indicated that, if the wire is terminated higher up, shattering of the lower part of the pole may be serious. The experience of the American Telephone and Telegraph Co. has shown that care has to be taken with the bottom end of a wire terminated some distance above ground level. Experiments using an impulse generator have confirmed that, unless the wire extends well beyond the lowest staple, the discharge will tend to enter and damage the pole and it is recommended that if 1-in. staples are used the wire should be extended for 3 ins. beyond the lowest.

When an open wire line is struck by lightning, wires may be brought down and insulators shattered or punctured. If the open wires go into a cable adjacent to the point where the line is struck the cable sheath may be punctured and the conductors welded together (Fig. 7). The duct line may be cracked and small holes blown in the roadway above it. Generally, however, the damage is restricted to within a few yards of the open wire line terminal pole.

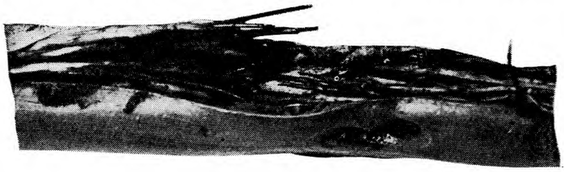


FIG. 7.—CABLE FAULT CAUSED BY LIGHTNING.

Protection of Telephone Apparatus.

At the Exchange. The presence between the open line and the exchange of a length of paper core cable of limited dielectric strength safeguards the exchange to a certain extent. It can fairly safely be assumed that, provided there are at least 200 yards of cable, the potential at the exchange will never exceed 2,500 volts. Detailed examination of fifteen cases of lightning damage occurring under such conditions in south-east England during August and September, 1934, showed that apparatus was damaged at the exchange in only two cases, and then, presumably, by direct conduction of part of the stroke current. Experiments with an impulse generator, although failing to reproduce the damage experienced in practice, had previously shown that the surge voltage, though limited by the cable, was likely to cause perforation of the insulation of wiring at the exchange and welding of relay contacts.

In order to minimise these effects the connection of spark gap protectors between lines and earth is essential. Other telephone administrations connect such spark gap protectors at the junction between the open wire line and the cable. In this country the resulting increased maintenance cost, particularly when, after a severe thunderstorm, short-circuited protectors may be located at many points within a wide area instead of confined to the exchange, is held to outweigh any advantage which may arise.

A type of protector consisting of a spark gap between two carbon electrodes is in use by almost all telephone administrations. Carbons, protector Nos. 12 and 13, which have been used by the British Post Office for a number of years, are covered on the surface with a cellulose acetate lacquer. A thicker layer of cellulose acetate, applied at both ends of the principal face of one carbon, serves to keep the two carbons separated by about 0.004 inch. The nominal operating voltage is between 500 and 750. These carbons superseded an earlier type in which two carbon electrodes were kept apart by a perforated mica slip.

Low insulation, due to accumulation of dust and moisture in the air gap, has given trouble with standard types of protector, especially under the damp conditions existing in some unattended automatic exchanges. Attempts have therefore been made to develop a protector in which the gap is made inaccessible to the ingress of dust. In this respect a spark gap protector brought into use some 6 or 7 years ago by the Telephone Companies forming the Bell System of America introduced the novel and successful design shown in the top part of Fig. 8. A plane surfaced carbon faces an unglazed and recessed porcelain block containing a small carbon insert. The latter, which is held by a low melting point glass, is set into its surrounding block by automatic machinery working to extremely fine limits of gauging.

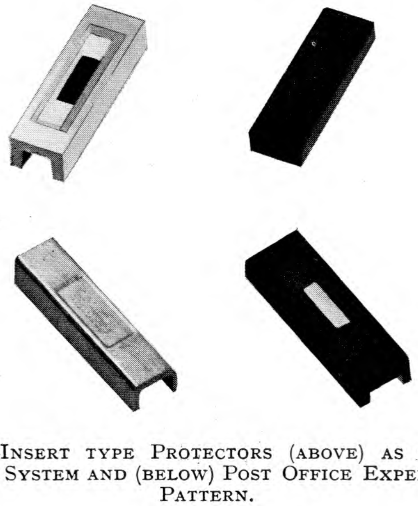


FIG. 8.—INSERT TYPE PROTECTORS (ABOVE) AS USED BY THE BELL SYSTEM AND (BELOW) POST OFFICE EXPERIMENTAL PATTERN.

The result is a protector nominally operating at between 300 and 450 volts and showing fair consistency of performance.

After a thunderstorm carbon protectors are frequently found to be short-circuited, and have to be removed and cleaned in order to restore lines to working order. As a result of consideration by the Subscribers' Apparatus and Miscellaneous Services Branch, supplies of the type of spark gap protector shown in the lower part of Fig. **8** were therefore ordered in 1935 by the B.P.O. Engineering Department and are being given experimental trial in the field. The type is somewhat similar in design to that adopted by the Bell System but employs a moulded synthetic resin block and stainless steel electrodes. Experiments carried out concurrently by the Research Branch at Dollis Hill showed that, using the same gap lengths, the number of discharges that could be passed between a pair of brass electrodes without giving rise to a permanent short-circuit very greatly exceeded those possible with most other metals or carbon. Stainless steel of the "Staybrite" type also gave a good performance. Brass was ruled out on account of its liability to atmospheric corrosion. It is, however, possible that new types of protector may be introduced in the future which will comprise two brass electrodes separated by a cellulose acetate slip containing one or more windows. The whole ensemble will be moulded into a cellulose acetate block completely enclosing the electrodes and the air gap.

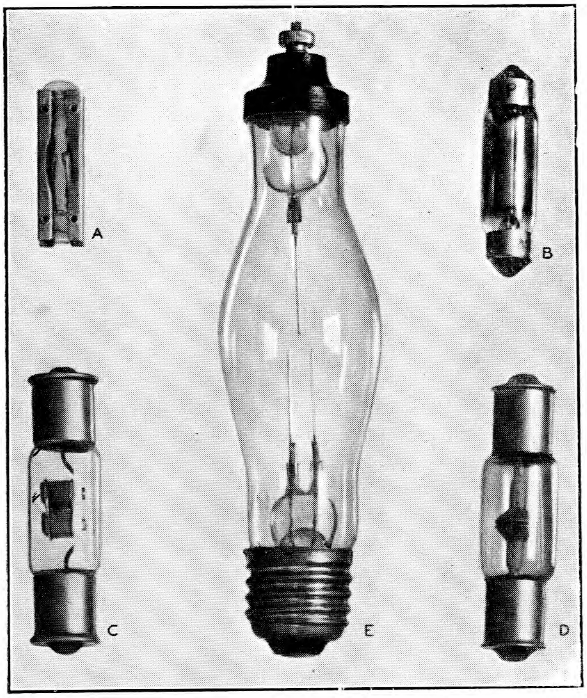


FIG. **9**.—GAS FILLED DISCHARGE TUBES.
A. AMERICAN LOW-CAPACITY TYPE.
B. CONTINENTAL LOW-CAPACITY TYPE.
C. EARLY POST OFFICE "G" TYPE.
D. LATER POST OFFICE "G" TYPE.
E. MEDIUM CAPACITY TUBE FOR TWO LINES.

Gas filled discharge tubes have been used in some countries. They have the advantage that, for a given operating voltage, the electrode spacing is much wider than with a spark gap in air. The operating voltage can therefore be controlled much more accurately and may be reduced to 110 volts. Greatly increased cost as compared with a spark gap protector and the space occupied are major disadvantages of gas filled tubes. They also compare unfavourably with the spark gap protector as regards ability to withstand a very heavy discharge. Gas filled discharge tubes used for various purposes are shown in Fig. **9**.

British practice inserts a fuse operating at 3 amperes on the line side of the protector at the exchange. Fuses are intended primarily as part of the scheme of protection against contact with power circuits. They are however, very frequently operated during thunderstorms. Replacement of a large number of fuses after a storm is troublesome, especially when such fuses are located in unattended exchanges. It is for such reasons that the C.C.I.F. envisages as the ideal fuse one which, while operating with a comparatively small current flowing through it for some seconds, will not readily operate with very much larger surge currents flowing through it instantaneously. Unfortunately, a fuse to meet such a requirement is not easy to construct. It can, however, be said that a fuse which is readily operated by discharges of atmospheric electricity through the protector may, by effecting a disconnection between the line and apparatus early in a thunderstorm, act as a safeguard from subsequent lightning strokes.

The heat coil does not come into the circuit taken by the current discharging through the protectors and does not form any part of the scheme of protection against lightning.

At the subscriber's premises. In the past subscribers served by an aerial lead-in have been supplied with spark gap protectors of the same types as those fitted in exchanges. Instructions have not called for fuses or heat-coils to be fitted unless the circuits were exposed to risk of contact with overhead power lines. They were to be added later if necessitated by subsequent power line construction. Because of the rapid spread of such construction it has, however, been the practice in many districts to provide full protection at the outset.

Heat coils are not fitted at subscriber's premises in many other countries and as a result of recent consideration they will not in future be fitted in Great Britian. The degree of protection afforded to the subscriber will in no degree be lessened by that omission. At the same time as this change is made a new fitting will be introduced containing spark gap protectors and fuse. This will be made standard for all subscriber's circuits with overhead distribution whether endangered by power circuits or not. The standard of protection against lightning will be improved thereby.

The Creepage of Underground Cables

A. C. TIMMIS, B.Sc., A.M.I.E.E.

An account is given of the experimental work performed to discover the cause of cable creepage in ducts and various theories are discussed. No complete explanation of the phenomenon is evolved, but the author demonstrates that the amount of creepage depends mainly on the magnitude of the travelling depression in the road surface caused by vehicular traffic, and that vibration has only a secondary effect.

Introduction.

ONE of the less obvious results of the rapid increase in road traffic in the last few years has been the slow movement of telephone cables, laid in ducts, under roads where there is severe vibration due to traffic. Neither armoured telephone cables laid direct in the ground nor, apparently, telephone cables laid in pipes show creepage. The cast iron pipes used before 1912 were made in 9 ft. lengths. Such a pipe line is evidently stiffer than a line of 2 ft. 6 in. ducts, and possibly there is more friction than in ducts. Power cables laid in ducts have given trouble in some places, and the circumstances indicate that temperature changes are a contributory cause. The effect is generally most serious on embankment roads laid over marshy ground, such as the causeway known as "Sarre Wall" between Canterbury and Margate, but it has also been found in unexpected places. For instance, on the Taunton-Minehead road, which is slightly undulating, with a light clay subsoil, and appears quite a typical main road, a cable of $1\frac{1}{4}$-in. diameter in 3-in. ducts was found to have crept over 2 ft. in the direction of the traffic. The movement was observed within two years of laying.

On other roads, such as the Brighton-Worthing road at Shoreham, where it consists of a causeway across water-logged gravel, the movement has been more serious. Here the traffic is exceptionally heavy, with a good proportion of heavily-laden lorries.

It was obvious that some means of anchoring the cables was required and several devices were tried. The arrangement finally adopted is shown in Fig. **1** and is known as Anti-Creepage Device No. 1. This type of anchor, applied at every joint box, i.e., roughly every 170 yards, has generally proved successful, but in one or two instances the creeping force was so great that the conductors moved inside the sheath. Fig. **2** shows a view of a manhole on a route where creepage has occurred. The joints were originally straight across the manhole.

No instance of the core slipping has yet occurred on a star quad cable, owing to the closer formation of the core. It is hoped that this trouble of core slipping has been overcome by dressing down the sheath, with a special split wooden clamp which is rotated by hand so as to compress the core about 30 per cent. Capacitance measurements show that no electrical damage is done, and it is found that the core is firmly gripped by the sheath. In a preliminary test the sheath was compressed for a length of 4 ins., the reduction of area being 34 per cent., and it was found that the force required to pull the core through the sheath was increased from 15 to 22 cwts. The sheath would not stand much more tension than this, and a reduction of area by 30 per cent. was therefore considered suitable. If an anti-creepage collar is fitted over the compressed part the lead cannot yield and so reduce the grip. Otherwise the compressed part may be covered with a plumber's wipe to make it up to the diameter of the cable.

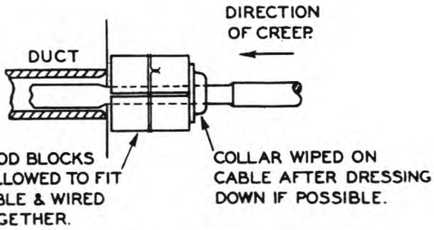


FIG. **1**.—ANTI-CREEPAGE DEVICE.

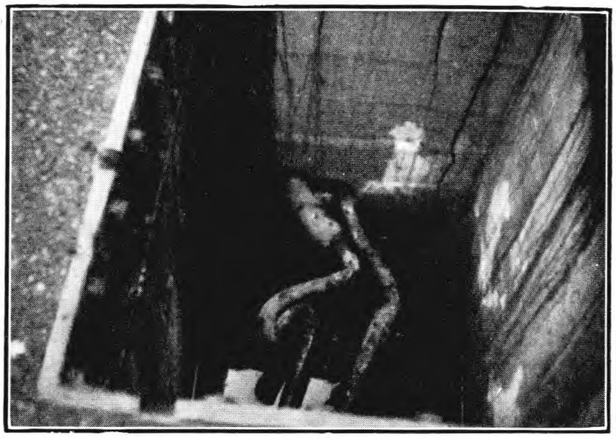


FIG. **2**.—VIEW OF MANHOLE WHERE CREEPAGE HAS OCCURRED.

This method was applied at Shoreham where the core of a multiple twin cable had crept relative to the sheath, and observations made after six months showed no further relative movement.

Investigation of the Causes of Cable Creepage.

It would obviously be useful to be able to predict, when laying a new line of ducts, whether creepage is likely to occur. The two main factors which determine the answer are (1) the weight and speed of traffic and (2) the character of road as regards surface and foundation. It is an easy matter to form a good idea of (1) by comparison with known cases where creepage has occurred, but the relation between the character of the road and creepage is still somewhat obscure. In the early stages of the investigation it seemed reasonable to hope that the rate of creep would, other things being equal, be a function of the vertical vibration at the road surface when a lorry of a certain weight and type was driven over it at a certain speed.

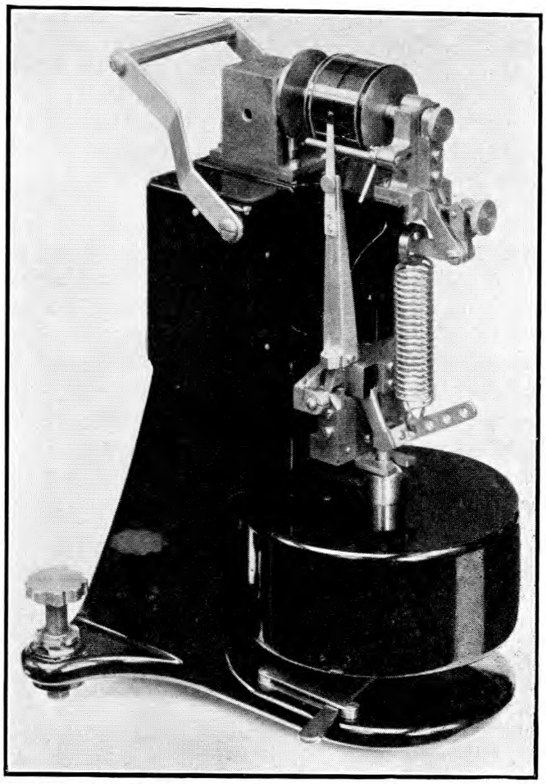


FIG. 3.—CAMBRIDGE VERTICAL VIBROGRAPH.

In order to obtain some forecasting data, therefore, vibration records were taken at places where serious creepage has occurred, such as the Sarre Wall. Two lorries were used as the generators of vibration. One lorry had pneumatic tyres, and, as might be expected, the vibration for a given weight and speed was only one quarter to one third that produced by a lorry with solid tyres.

Vibration measurements were made with a Cambridge vertical vibrograph (Fig. **3**) standing within 3 ft. of the lorry as it passed. The instrument consists of a frame carrying a clockwork drum on which a strip of celluloid is wrapped, with a heavy weight hanging on springs and connected through levers to a pointer which marks on the strip the movements of the frame relative to the weight. As the system has a natural frequency of three or four vibrations per second, the weight may be regarded as remaining still, owing to its inertia, while the frame vibrates about it. The principle is well known in seismographs. The curves traced on the celluloid by the special ball-pointed needle are magnified by projection on a screen. The frequency ranges between 10 and 20 c.p.s. and the amplitude depends on weight and speed as shown by the curves of Fig. **4**.

Somewhat similar vibration records are described in a paper by Aughtie, Bateson and Brown—" The Impact of Wheels on Roads."[1] Comparatively little is known of the transmission of vibrations through the soil, but in studying the causes of cable creepage it seems necessary to deal only with the movements which occur immediately under the roadway.

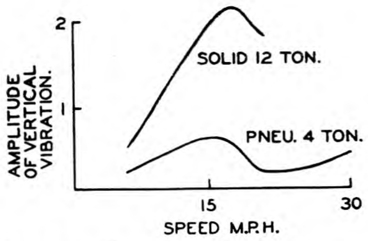


FIG. **4**.—EFFECT OF SPEED ON AMPLITUDE OF VIBRATION.

Probably the waves which travel downwards from under the wheel of a vehicle diverge at about 45 degrees from the vertical. Vibrograph tests at 12 ft. from the vehicle, and at the bottom of a concrete manhole 7 ft. deep, gave no measurable amplitude, showing that the vibrations suffer rapid attenuation.

Theories regarding Cable Creepage.

There are two possible explanations of the phenomenon of creepage. The first may be loosely called the surf-riding theory. Consider one wheel of a heavy vehicle rolling on a macadam surface above a duct line (Fig. **5**). The shape of the depression, much exaggerated in the figure, will be curved to the radius of the wheel in front, but behind it the ground, being semi-plastic, will recover gradually as shown. The duct line will be given a travelling depression of the same shape, but reduced amplitude, and the cable being flexible will fall into the depression. The movement is extremely small—of the order of 1/1,000 in.—and within the elastic limit of a cable considered as a beam. (This has been verified by testing short pieces of cable, and the load-deflection curves are shown in Fig. **6**). But, the depression being steep at A (Fig. **5**) and trailing off gradually at B, the cable will drop into it in such a way that the upward thrust of the duct will be practically without a horizontal component at A, whereas the cable will rest on the slope at B and there will be a horizontal component of the thrust tending to push the cable forward somewhat as a surf-rider advances by sliding down the face of a wave. It must be admitted that the analogy is picturesque rather than exact, but this theory has received some confirmation from a simple experiment. A line of pipes each 2 ins. long and $\frac{5}{8}$ in. diameter was laid between two layers of sorbo rubber, and a roller a few inches in diameter rolled along the line by hand. A flexible wire laid in this model duct line moves quite definitely in the direction of rolling, but a stiff rod does not ; nor does a perfectly flexible chain. This effect was studied on a larger

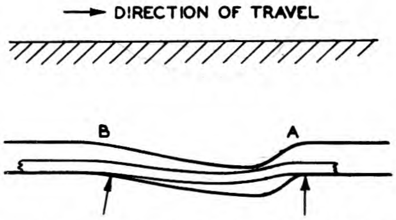


FIG. **5**.—SURF-RIDING THEORY OF CABLE CREEPAGE

---

[1] Proceedings of the I.C.E. Vol. 237 (1933/4)

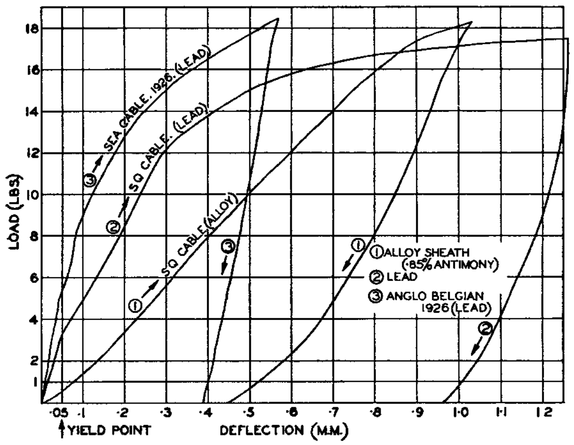


Fig. 6.—Load Deflection Curves for Short Lengths of Cable.

scale near Yeovil, where a 30-ft. length of cable and 30 ft. of steel tube, jointed by means of plugs so as to preserve the smoothness of the external surface, were laid in spare ducts. Creepage had been observed in the neighbourhood and measurements were taken in order to compare the movements of the cable and the tube. After three months the cable had crept 4 ins. but the tube had not moved. The road is practically level.

The second theory depends on vibration, and assumes that the horizontal component of the movement of any particle in the road is not sinusoidal but has a saw-tooth form, like the movement of a shaking conveyor. This type of conveyor consists essentially of a belt or tray, which is driven by an oblique connecting rod, or other suitable means, so that it makes a slow forward stroke and a quick back stroke. The material (coal or shingle for instance) is carried forward on the slow stroke but, on the sudden reversal of movement, the static friction, or "stiction," is overcome and the material slides forward till it is caught up again by the tray on the next forward stroke. So it moves forward rather more than the length of one stroke, at every cycle. It is quite apparent that the cable is not like a loose piece of coal, and that the whole duct line cannot move bodily. But each duct may easily execute a fore-and-aft vibration of small amplitude, since the joints cannot be absolutely rigid. Moreover, that part of the cable sheath in contact with the duct can move like a concertina, or the skin of a gliding snake, and so exert a very small creeping force on the whole cable as the vibration travels along under the vehicle causing it.

Lateral flexibility of the cable does not come into the question, but the longitudinal friction between sheath and core, and the elasticity of the sheath, are important factors. Friction between sheath and core was roughly measured for (1) an A.S.P.C. cable 1·1 in. diameter, and (2) the Anglo-Belgian (1926) cable (land portion). In both cables the friction increased as the core moved in the sheath, due to expansion of the spiralled quads, but the friction in the Anglo-Belgian cable was double that in the A.S.P.C. cable. The plasticity of the sheath is about the same for both. The Anglo-Belgian (1926) cable runs along the Sarre Wall, together with an A.S.P.C. cable of about the same size, and the former seems to have crept more rapidly than the latter. So far, however, there is not sufficient evidence to confirm this.

An approximate analysis of the operation of a shaking conveyor has been made in order to find a relation between vehicle speed and rate of creepage. Fig. 7 gives the displacement, velocity, and acceleration graphs of a shaking conveyor when the back stroke velocity is six times that of the forward stroke. Such a ratio is unlikely with a road vibration, but the assumption should not affect the general principles.

Let V = velocity of tray on forward stroke,
and $6V$ = velocity of tray on back stroke.

Consider a mass M on the conveyor and let the coefficient of stiction $= 0{\cdot}4$ and of (moving) friction $= 0.2$

$g = 32$ ft.·sec./sec.
d = displacement.
s = stroke.

At the end of the forward stroke the acceleration must be high enough to overcome stiction.

Stiction $= 0{\cdot}4\ Mg$ poundals.

$\therefore\ 0{\cdot}4\,Mg = M \times$ acceleration.

$\therefore$ Acceleration $= 0{\cdot}4g = 13$ ft./sec./sec.

Suppose M ceases to stick when velocity $= 0{\cdot}5\ V$ at point A on the graphs. M slides forward with this velocity and a retardation of $0{\cdot}2g = 6{\cdot}4$ ft./sec./sec., which is independent of the relative velocity of M and the tray until it becomes zero, when stiction

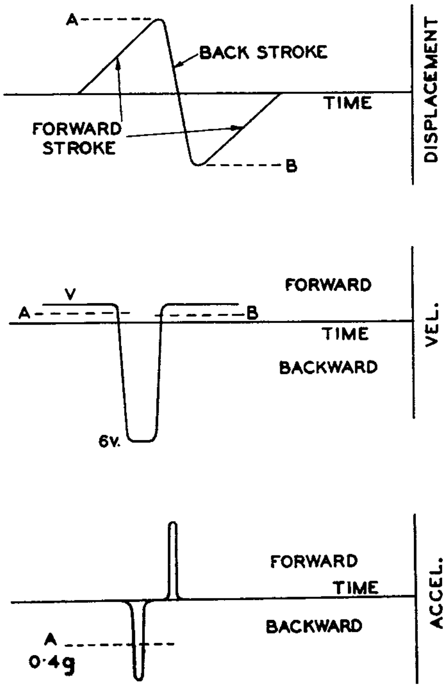


Fig. 7.—Displacement, Velocity and Acceleration Graphs of a Shaking Conveyor.

again comes into play and M is carried along by the tray.

Time of back stroke $= \frac{s}{6\,V}$ secs.

Absolute velocity of M when it begins to slide $= 0{\cdot}5\,V$ ft./sec.

and is reduced to zero in $\frac{0{\cdot}5}{6{\cdot}4}\,V$ secs.

If $\frac{s}{6\,V}$ is less than $\frac{0{\cdot}5\,V}{6{\cdot}4}$ the mass would stop and be carried back by the sliding friction until its velocity equalled that of the tray (still executing the back stroke). But the usual assumptions regarding static and sliding friction are unreliable and it is convenient to assume that $\frac{s}{6\,V}$ is equal to or greater than $\frac{0{\cdot}5\,V}{6{\cdot}4}$, so that before the velocity of M has been absorbed by the retardation the next forward stroke has begun. The tray will then catch up M at the point B (say) and carry it forward approximately x feet.

If $\frac{s}{6\,V} = \frac{0{\cdot}5\,V}{6{\cdot}4}$, then $V^2 = 2{\cdot}1s$

Average velocity of M $= {\cdot}25\,V$

$$\text{time} = \frac{s}{6\,V}$$

$$\text{hence } x = \frac{s}{6\,V} \times {\cdot}25\,V$$

$= \frac{s}{24}$ which is negligible compared with s.

It appears, therefore, that if the amplitude of vibration is constant, creepage rate is proportional to strokes per sec., i.e. to frequency. Conversely, if frequency is constant creepage rate is proportional to amplitude.

As the "shaking conveyor" theory is based on the assumption that the horizontal component of the ground vibration is not sinusoidal, but saw-toothed in shape, it may be tested by making a record of the vibration under a road surface.

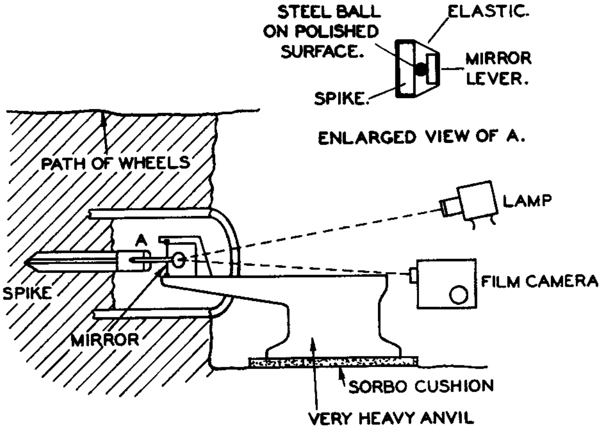


FIG. **8**.—APPARATUS FOR RECORDING THE WAVE-FORM OF THE HORIZONTAL VIBRATIONS.

For this purpose a duralumin bar of cruciform section (Fig. **8**) was driven hard into the ground so that it behaved as an integral part of the ground. Its horizontal motion was recorded by means of a suitably pivoted mirror and a film camera. The steel ball between the bar and the lever allowed the former to move vertically without deflecting the mirror. The heavy anvil, owing to its inertia, remained still when the road was vibrating with the passage of a vehicle. The lamp and camera should, strictly, be attached to the anvil, but as there is hardly any vibration a few feet back from the edges of the road, they may safely be mounted on a separate base. This device was first tested on a model road consisting of a long box of sand on which a strip of linoleum was laid to represent the metalled surface of the road. The bar was driven into the sand 6 inches down, and vehicles were represented by a heavy roller. Some doubtful indications of the expected saw-tooth wave shape were obtained, but a full-scale test was made later on the Sarre Wall, and this strongly discounts the shaking conveyor theory.

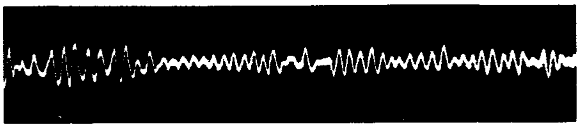


FIG. **9**.—OSCILLOGRAM OF HORIZONTAL VIBRATIONS.

The horizontal vibrations, of which an example is shown in Fig. **9**, are approximately sinusoidal and certainly do not show any indication of the saw-tooth shape. During these tests a cinematograph record of the resultant movement of the bar was taken, with the aid of a mirror supported on a gimbal arrangement. This showed Lissajous figures, indicating that the horizontal and vertical components differ in frequency. The frequency of the vertical vibrations, as already stated, ranges from about **10** to **20** c.p.s. and is more or less proportional to speed, until a critical speed is reached. Road vibration measurements made here and in America all agree on this point. The critical speed corresponds to the resonance frequency of the wheels and axles of heavy motor vehicles, which, like the wave-length of road ripples, does not vary much. In Fig. **4** the critical speed is seen to be about 16 miles per hour for solid and pneumatic-tyred lorries. On the other hand, the frequency of the horizontal vibrations is higher, and seems to depend on the road metalling and subsoil rather than on the speed of the vehicle.

A possible explanation of these effects may be that the vertical vibrations are "forced" vibrations generated by the wheels bumping over irregularities, or ripples, on the surface. For reasons not yet fully understood the wavelength of these ripples is generally between 15 and 24 ins. Hence the relation between speed and frequency. On the other hand, in the kind of ground where creepage occurs, the horizontal component of the wheel impacts is small and the attenuation of the medium less than in a vertical direction. Thus "free" vibrations having the natural frequency of the medium—generally of

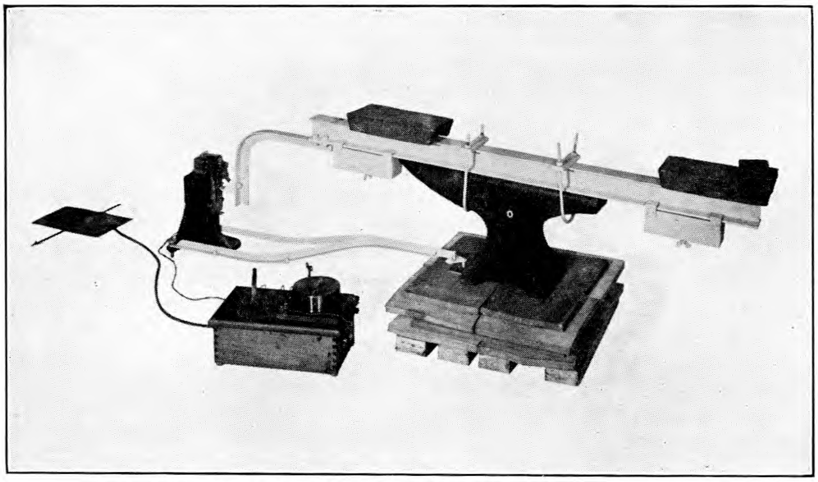


FIG. **10**.—APPARATUS USED FOR MEASURING THE DEPRESSION.

the order of 30 c.p.s.—may be set up, in addition to the forced vibrations, by the travelling depression under the wheels which is practically the same whether the surface is rough or smooth.

This somewhat crude explanation is put forward with reserve. If it is correct, then creepage is mostly due to the surf-riding effect, and vibration plays a secondary part. It would follow that vibration measurement is not a good criterion of the tendency to creepage.

A simple experiment carried out in 1936 has confirmed that vibration has only a slight influence on creepage. With the co-operation of the Ministry of Transport arrangements were made to lay a 40-yard length of special asphalt, giving an almost perfect surface, on the Ilchester-Yeovil road at a point where the subsoil is marshy clay and rapid cable creepage has been observed.

Two similar lengths of cable, each 40 yards long, were laid, one under the special surface, the other under the ordinary surface which is a good average tarmacadam with slight ripples. The difference in vibration was very obvious when a car passed, and it may safely be assumed that under the special surface there was depression only, whereas there were both depression and vibration under the ordinary surface. After three months the cable under the former had moved $4\frac{3}{4}$ ins. while under the latter it had moved $4\frac{1}{4}$ ins.; showing clearly that depression accounted for nearly all the movement.

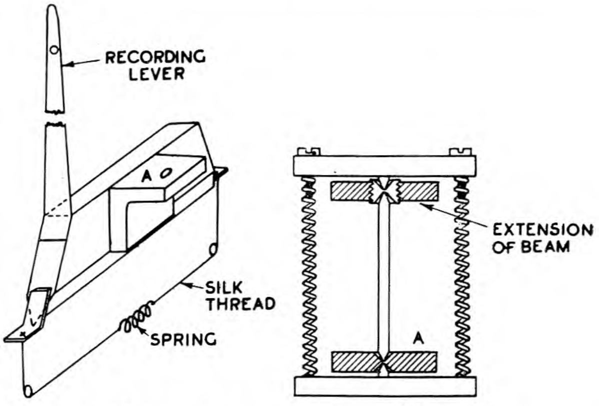
No doubt the vibration facilitates movement by reducing the static friction but it probably has no direct effect on the cable movement. There is supporting evidence for this statement in the movements of a power cable, laid by the British Electrical and Allied Industries Research Association in a Post Office duct near Chester. This cable was at first carrying no current and then carried a varying load. The periodical heating and cooling apparently reduced the static friction for the cable moved from two to ten times as fast as when it was unloaded.

The coefficient of friction between a lead covered telephone cable and earthenware ducts is roughly 0.25. The power cable mentioned is 1.75 ins. in diameter, lead covered but not armoured.

Measurement of the Depression.

The measurement of the depression is more difficult than that of the comparatively rapid vibrations. After some helpful discussions with engineers of the Road Research Laboratory (Colnbrook) a special instrument incorporating a modified form of Cambridge vibrograph was built to measure the depression, of which the frequency is one or two per sec. at ordinary speeds. Fig. **10** is a photograph of the apparatus. The anvil, standing on a mechanical filter of lead and sorbo rubber, provides a heavy mass practically unresponsive to vertical movements of the ground, which are generally small at 3 or 4 feet from the wheel track. The frame of the vibrograph is placed as near to the wheel track as practicable and the rotating drum used to record the vertical movement relative to the beam. The connection between this and the recording arm is made by means of a push-rod, kept in place by two springs, arranged not to exert any controlling force. A beam balanced at the centre like that of a seismograph was first tried, but it was found better to clamp the beam to the anvil, as shown in the photograph.

It will be seen that the frame of the vibrograph is supported on two points which rest on the road surface, and is kept vertical by a long framework of angle iron rigidly fixed to the vibrograph and provided with a point which rests on the board, just under the anvil. This point is, for all practical purposes, a stationary fulcrum about which the frame moves up and down. The movement being very small (of the order of $\frac{1}{100}$ in.) may be regarded as vertical. This arrangement was found necessary to prevent tilting of the frame towards the wheel-track. On any road surface, other than heavy concrete, a saucer-shaped depression is formed under a wheel, and the consequent tilting of the vibrograph when resting on its three points tended to reduce the recorded movements relative to the beam. Special care was taken to avoid any shake or controlling force, frictional or elastic,



(a) (b)

FIG. **11**.—METHOD OF COUPLING THE VIBROGRAPH TO THE BEAM.

in coupling the vibrograph to the beam. Details of the arrangement finally adopted are shown in Fig. **11**.

The recording lever (Fig. **11a**) is mounted on a knife edge which is kept in position by the silk thread. The points of attachment are in line with the knife edge, and the tension of the thread, therefore, exerts no controlling force. This arrangement is better than pivots as it cannot get out of adjustment.

In Fig. **11b** the push-rod coupling the recording lever to the beam is shown. The bracket A, seen in section, is drilled so that the push-rod and the point on the crossbar are nearly touching. The springs have sufficient tension to ensure firm contact at both ends of the push-rod, which thus acts as a connecting rod without any appreciable friction or controlling force.

An electrical timing device, consisting of contacts operated by the wheels of the vehicle and an electromagnet on the vibrograph, was used to measure the speed and to show the position of the wheels corresponding to any part of the record. The marks made by the pointer of the electro-magnet can be seen in Fig. **12**. The clock which gives the timing marks at $\frac{1}{10}$ sec. intervals can be seen in the foreground of Fig. **10**.

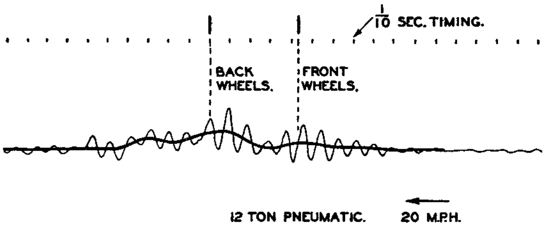


FIG **12**.—RECORD OF THE DEPRESSION AND VIBRATION CAUSED BY A 12-TON LORRY AT 20 M.P.H.

This apparatus enables very slow movements, even the steady depression due to a stationary vehicle to be recorded. It has also been used to record horizontal surface movements. Although heavy, the apparatus is easily transportable and seems to provide a useful method of measuring the liability of a road to produce cable creepage.

A typical record is shown in Fig. **12**. It was produced by a 12-ton lorry running at 20 miles per hour on a road near Watford. The subsoil is marshy with a layer of peat about 4 feet down. Incidentally, it was found during these measurements that a layer of " Aquadag " graphite paste on the celluloid gives a line which photographs easily. The film of graphite lubricates the point and is an excellent substitute for the well-known smoke film.

Creepage Force.

As part of the general study of the problem a dynamometer was made and installed near Ilchester to record the maximum creepage force on a 100-yd. length of cable, due to the ordinary traffic. The cable is held by a lever to which the dynamometer is connected through a simple non-return device which has no backlash. The cable can move in the direction of the traffic above it but cannot be pulled back by the dynamometer spring when vibration from traffic in the opposite direction reduces the static friction. When last inspected the dynamometer read 220 lbs. The creepage force was also measured on the power cable previously mentioned, near Chester, and found to be of the same order. This is rather surprising in view of the greater stiffness of the power cable. Much greater forces than this have been experienced, however. For instance, on the Sarre Wall where traffic is very heavy, a cable-sheath was broken, indicating a force of more than a ton. The unanchored length was about three quarters of a mile.

Conclusions.

To summarise the position :—Cable creepage occurs to an increasing extent in many parts of the country. It has caused serious damage and sometimes interruption to the service, but can generally be overcome by anchoring the cable at intervals of 170 yards or so. The cause of creepage is being investigated principally with a view to finding a method which will enable the effect to be predicted by measurements on the road surface. It has been proved fairly conclusively that the rapid vibration caused by wheels passing over the ripples which occur on most roads is not a criterion of liability to creepage trouble. The magnitude of the effect depends almost entirely on the travelling depression made by the wheels. A special deflection recorder has been built which measures this depression and should enable the amount of creepage to be predicted with some degree of certainty by comparison with known cases.

Many aspects of the general problem have yet to be investigated ; such as, for instance, the amount of creepage to be expected in the new asbestos-cement ducts which will shortly be laid under many roads. The coefficient of friction for lead cables is about 0.1 in these ducts, as compared with 0.25 in earthenware, and moreover the ducts are made in 10-ft. lengths. It is reasonable to assume that creepage will be less in these ducts than in the present earthenware type.

A Fast Operating Differential Echo-Suppressor

L. E. RYALL Ph.D. (Eng.) A.M.I.E.E.

A description is given of a new fast-operating terminal echo-suppressor which has an increased effective speech sensitivity as compared with older types, but no greater liability to false operation by noise. This suppressor will supersede the earlier types for new work.

THE importance of the part that echo plays in determining the minimum overall equivalent of a trunk circuit is well known. This equivalent can be reduced if the echo-suppressor sensitivity is increased. If, however, the tone sensitivity of the suppressor is increased there is a greater liability for unwanted operation to occur by steady line noise or exchange switchroom noise.

A new echo-suppressor (known as P.O. Echo-Suppressor No. 5), which has a very fast operating time, is first described, and then it is shown how the discrimination between speech and noise operation is increased by means of the short operating time and the differential nature of the echo-suppressor.

ECHO-SUPPRESSOR NO. 5

Location.

This double echo-suppressor is primarily designed as a 4-wire terminal suppressor to be located between the 4-wire termination and the 4-wire circuit proper and it is not associated with any apparatus in the latter circuit. This arrangement is most satisfactory with regard to installation and maintenance as the " go " operating levels are fixed and the " return " level is determined solely by the overall equivalent of the circuit. It is readily applicable to carrier circuits.

Provision has also been made for installing it at an intermediate position on the circuit, in which case it is introduced between the repeater output and the line in each direction. For use on 2-wire circuits it is connected between the repeater output terminals and the differential transformer or output filter.

Principles of Operation.

The apparatus consists essentially of rectifier attenuation networks N inserted in the two speech transmission paths (Fig. **1**). These attenuation networks have a low attenuation if the control current flows in one direction and a high attenuation when the direction is reversed (Fig. **2**). The signals to operate the echo-suppressor by changing the control current are derived from the output side of each rectifier network and are amplified by the auxiliary amplifier valves V_1, V_2. The change in anode current of one of these valves caused by the change in grid voltage produced by the rectified speech signal from the other valve is used to change the control current through these networks. The networks normally have a low attenuation and the control current change produces a high attenuation in the network in the " echo " path. The principles of the operation of the rectifier networks and the control current bridge are fully described in a previous article by the author.[1] The auxiliary valves V_1 and V_2 are not in the main speech paths so that the surge produced when the anode current changes is not introduced into the speech circuit. To obtain a very quick change of the valve anode currents and cause speedy operation of the echo-suppressor the inductance in the anode circuit is low.

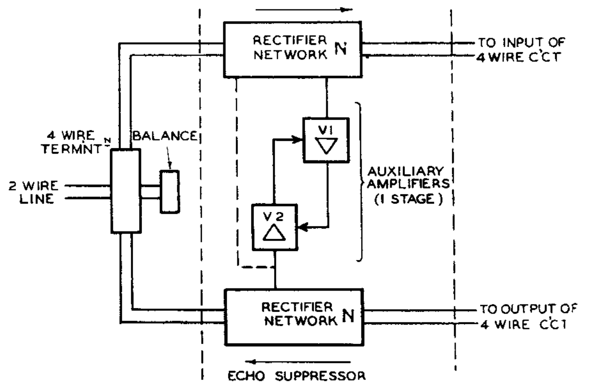


FIG. 1.—SCHEMATIC DIAGRAM OF ECHO-SUPPRESSOR NO. 5.

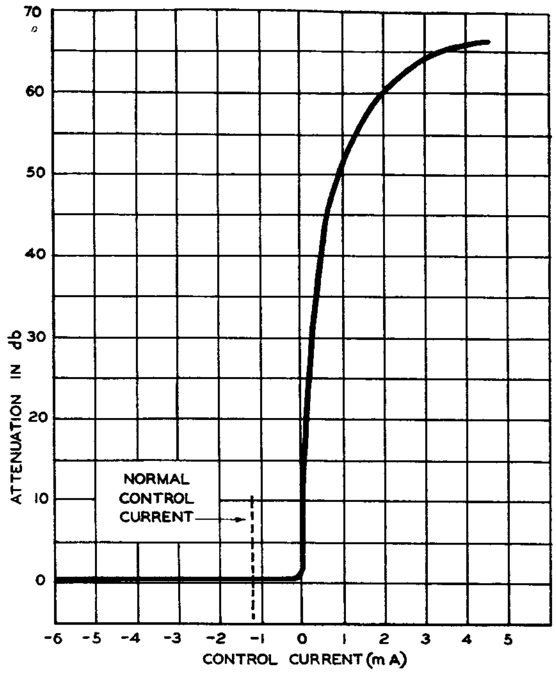


FIG. 2.—ATTENUATION—CONTROL CURRENT CHARACTERISTIC OF BALANCED NETWORK.

The circuit diagram of the P.O. Echo-Suppressor No. 5 is given in Fig. **3**.

---

[1] *P.O.E.E.J.* Vol. 28, p 27.

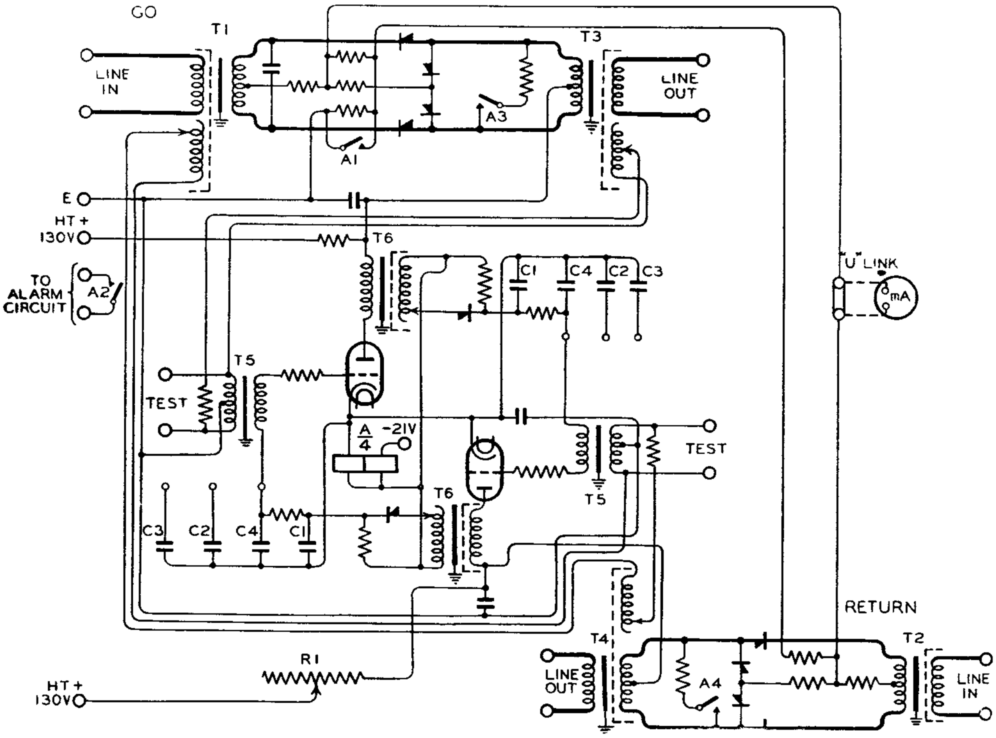


Fig. 3.—Circuit Diagram of Echo-Suppressor No. 5.

The Attenuation Network.

The loss in the transmitting condition is approximately 0·6 db.

The maximum A.C. signal power that the network will transmit without distortion is equal to one-half the power dissipated by the control current in the network resistance and is +13 db. referred to 1 mW. with normal battery supplies. The maximum total harmonic distortion is then 40 db. below the fundamental signal level, and for signals less than +6 db. referred to 1 mW. it is at least 50 db. below the fundamental signal level.

The Signal Amplifier.

The input level to the auxiliary valve is adjusted to be the same for both halves of the suppressor, by means of the taps on the transformers T3 and T4.

The sensitivity/frequency characteristic is arranged to fall off considerably below 500 cycles per sec. and is a maximum at about 900 cycles per sec. (Fig. 4). Greater selectivity can be obtained if desired by using a suitable output transformer resonated at the required frequency.

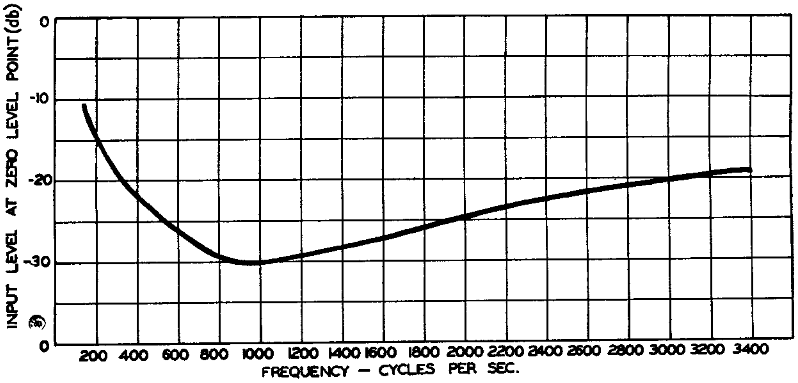


Fig. 4.—Sensitivity-Frequency Characteristic of Echo-Suppressor No. 5.

The Signal Rectifier and Hangover Circuits.

The signal to be rectified is derived from the tapped winding of the output transformer; 1 db. taps are provided so that uniform sensitivity can be obtained with all valves. The maximum A.C. impedance of the valve viewed from this winding is less than 30,000 ohms so that the condensers in the grid circuit are charged very rapidly. Single-wave rectification is used. The A.C. component in the rectified signal is reduced by a condenser C4 of 0·01 μF in series with a resistor of 25,000 ohms, so that the resultant A.C. signal produced in the output circuit of the complementary amplifier is not of sufficient amplitude to effect the reverse operation of the control current.

Three hangover times of approximately 50, 150 and 250 milliseconds are obtainable by adding condensers C2 and C3 to the condenser C1 associated with the signal rectifier. The operating and hangover times obtained are shown in Fig. 5. It will be observed that although the sensitivity is adjusted so that a signal input level of —30 db. referred to 1 mW. only just produces 6 db. echo attenuation, this attenuation is obtained in 2 milliseconds or less for signal input levels greater than —25 db. with the short hangover condition. The operating time is slightly increased under the longer hangover conditions since a correspondingly larger capacitance C1+C2+C3 has to be charged. The arrangement, however, ensures that the full hangover time is available after a very short operating signal has been applied.

Oscillograms showing the operating times under short and long hangover conditions respectively are shown in Fig. 6 and 7. The signal producing echo-attenuation is represented by C, and the signal that is suppressed is shown by oscillogram B. The space

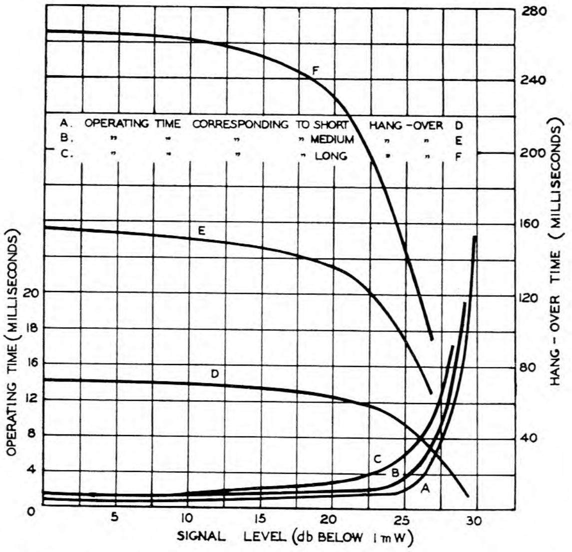


FIG. **5**.—OPERATING AND HANGOVER TIMES OF ECHO-SUPPRESSOR NO. 5.

between the vertical timing lines represents 10 milliseconds. The change in the valve anode current which produces the control current change to cause suppression is also shown.

Oscillograms showing the hangover times under "short" and "long" hangover conditions are given in Fig. **8**.

Elimination of Surge Effects due to very fast Operation.

When the echo-suppressor operates the anode current of one of the amplifier valves increases very rapidly, and this produces a surge in the output winding of the associated transformer. To prevent this surge from being rectified, half-wave rectification only is employed, and the half-wave in which the surge appears is not used. When the signal ceases the hangover time prevents the anode current from changing rapidly and no appreciable surge is produced. If there is no resistance in the grid circuit the grid potential tends to become positive, and the low grid-cathode impedance under these conditions causes a very rapid initial fall of anode current to occur, which either tends to cause reverse operation of the echo-suppressor, or results in a reduction of the hangover time. Since the addition of resistance in the grid circuit will increase the hangover time, a suitable resistance value can be chosen to maintain the hangover time approximately constant with a range of signal input levels.

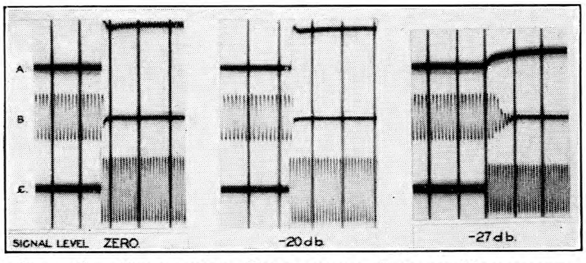


FIG. **6**.—OPERATING TIME WITH SHORT HANGOVER.

There is a complete absence of surge effect in the main transmission path, as is shown by the oscillograms.

Prevention of False Operation of Terminal Echo-Suppressor.

Referring to Fig. **1**, if a speech signal through the "return" circuit operates the suppressor, a simultaneous signal from the near end 2-wire circuit cannot pass to the auxiliary amplifier associated with the "go" circuit, but it is able to pass through the "return" circuit auxiliary amplifier. If the initial signal now ceases this latter signal may maintain the echo-suppressor operated as before, and a "lockout" condition is obtained. This condition is avoided by neutralising the effect of the unwanted signal by applying a signal of equal amplitude in opposition to it. This is derived from the input side of the "go" circuit attenuation network (shown dotted), and a reduction of at least 18 db. over the important speech frequency band is obtained.

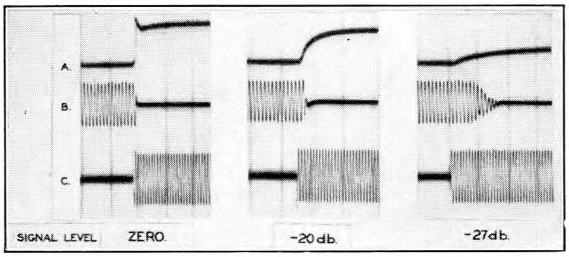


FIG. **7**.—OPERATING TIME WITH LONG HANGOVER.

Initial Adjustment and Testing Procedure.

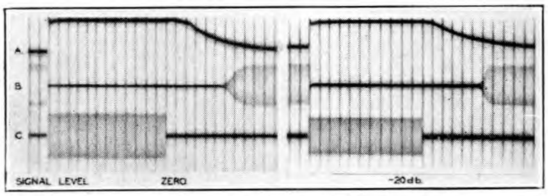
The control current bridge is first balanced by adjusting R1 (Fig. **3**). A current of 1·2 mA. then flows through each attenuation network, maintaining it in a low loss condition.

A signal 37·5 db. below 1 mW. level (800 c.p.s.) is applied to each "Test" position in turn and the corresponding output transformer is adjusted until a control current change of 1.2 mA. is produced. This ensures that the echo-suppressor sensitivity conforms to C.C.I. recommendations, i.e. 6 db. echo attenuation with a signal input of 30 db. below 1 mW. at a zero level point. This test can be made without associating the echo-suppressor with any other line apparatus.

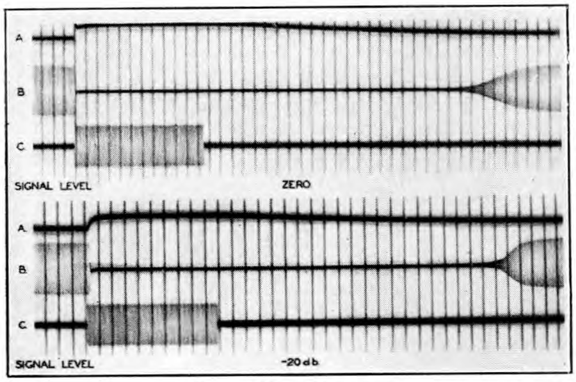
After the echo-suppressor has been associated with the 4-wire termination and the line a test is made to determine the correct polarity of the neutralising signal required to prevent false operation.

Maintenance of the Echo-Suppressor.

The balance between the control currents in the quiescent state as recorded on the milliammeter should be maintained between ± 0·25 mA. The chance of the current varying this amount during a period of a year is very small, so that a check test at three monthly intervals is adequate.



Short Hangover.



Long Hangover.

Fig. 8.—Oscillograms showing Hangover Times.

To " Cut-out " the Echo-Suppressor.

The echo-suppressor can be cut out by switching off the valve heater circuit, since the valves are not in the speech transmission path. An alarm relay A is connected in the anode circuit of the valves, and the voltage across one winding provides the cathode-grid bias voltage. The relay is normally operated, and when it releases the quiescent control current through the " go " attenuation networks is increased to 5 mA. by short-circuiting the resistance R2 by contact A1, so that large A.C. signals can be passed through the network without distortion.

The release of the relay A also closes contacts A3 and A4, thereby causing a shunt loss of approximately 3 db. to be applied to both the " go " and " return " speech circuits. This reduces the echo effects during the period the echo-suppressor is not in operation, eliminates near singing distortion and renders the circuit immune from instability.

The Operation of the Heater Circuit from A.C. Mains.

As indirectly heated valves are used, A.C. heating can be employed, the supply being derived from the mains. Such an arrangement is quite satisfactory since :—

(*a*) the valves are not in the speech transmission circuit;

(*b*) the echo-suppressor racks will be separate from the repeater racks, and the wiring will be kept separate.

Since all the terminal stations at which the echo-suppressors are located are zone or group centres, a reliable supply from " A.C. mains " is available. In the event of a failure of the " mains " supply, however, the normal echo will be reduced by the degradation of the circuit by 3 db. until the mains supply is restored. By arranging for the valves to operate on 21 V (or 24 V) the power can be obtained from the repeater station A battery during a mains failure if this is considered necessary. The A.C. power can be derived from a suitable mains transformer, and in view of the small cost it is probably most satisfactory to associate a transformer, with its fuses and switch, on each rack. No close regulation of the heater voltage is required, satisfactory operation being obtained with supply voltages between 19 and 23.

Layout of the Echo-Suppressor Panel.

The echo-suppressor is mounted on one side of a 7-in. panel (19 in. wide). Hence an echo-suppressor occupies the same space as a repeater or twice the space of a 4-wire termination, so that the layout of the racks in the repeater station is simplified. A satisfactory form of symmetrical panel layout is shown in Fig. **9**. Wherever possible, resistors have been mounted in the metal cases of the associated transformers. The rectifier and hangover circuit components have been assembled in transformer cases (apparatus assembly No. AA2 and AA3) together with the variable bridge resistance (AA1).

The Discrimination between Speech and Noise Operation of an Echo-Suppressor.

The discrimination is increased :—

(*a*) by improving the sensitivity to speech as compared with the sensitivity to noise ;

and

(*b*) by reducing the possibility of the noise in one direction affecting the transmission of weak speech in the reverse direction.

These two effects will be considered separately.

Effective Speech Sensitivity.

Operating Time. For a given tone-sensitivity and with a given sensitivity/frequency characteristic, the effective speech-sensitivity is a function of the operating time, particularly for low input levels. With weak speech signals the echo-suppressor is operated only by the peaks of the signals, and these peaks occur for a few milliseconds only, so that,

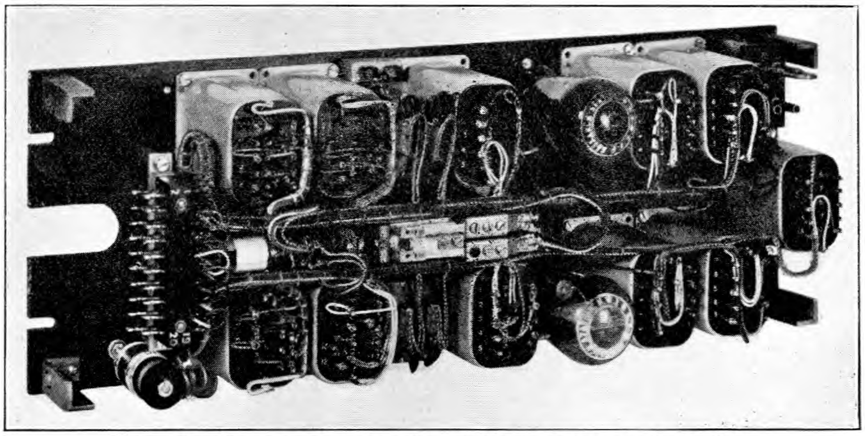


Fig. 9.—Echo-Suppressor No. 5 (Experimental Model).

unless the operating time with signal input levels just above the non-operating level is small, no operation of the echo-suppressor takes place. The ideal condition is obtained when the operating time is zero or less than, say, 3 milliseconds for all signals which are large enough to cause operation of the echo-suppressor. If a signal is too small to operate in this time, no operation is obtained, even when the signal is applied continuously. It is doubtful whether this condition can be obtained in practice, but the new B.P.O. Echo-Suppressor No. 5 approaches very nearly to this condition.

Hangover Time. The hangover time obtained with these short operating times should be as long as other considerations allow, so that the echo-suppressor remains operated during the weaker syllables.

Comparative Speech-Sensitivity Tests. Three different types of echo-suppressors were tested. The relative sensitivity/frequency characteristics were made equal before the test.

The echo-suppressors were :

(*a*) E.S. No. 2 (grid biassing or valve type) ;

(*b*) E.S. No. 3 (rectifier type with differential bridge) ;

(*c*) The new Echo-Suppressor No. 5 described above.

The operating times are shown in Fig. **10**.

The echo-suppressors were adjusted to have the same speech sensitivity and their "tone" sensitivities were then compared. It was found that, compared with the No. 5 type, the No. 3 was 7 db. more sensitive and the No. 2 was 13 db. more sensitive to tone operation.

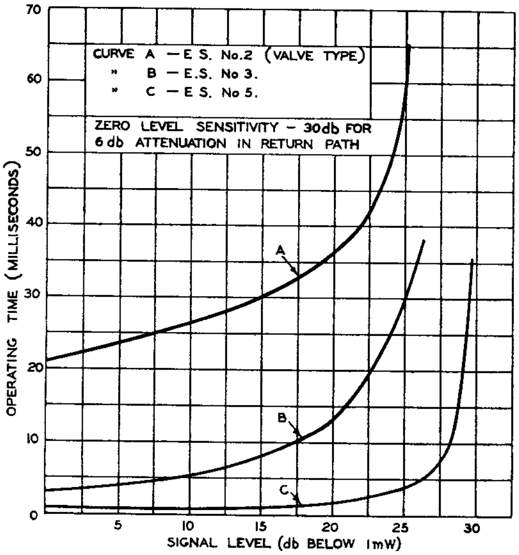


FIG. **10**.—OPERATING TIMES OF ECHO-SUPPRESSORS.

Reduction of False Operation by Noise.

The amount of noise that can be tolerated is that amount which will not cause mutilation or distortion of weak speech in the reverse direction. With no differential action the weak speech does not prevent partial operation by the noise, unless the speech is sufficiently loud to cause operation itself, when the noise is cut off. The differential action, however, ensures that the speech opposes the action of the noise, even if the speech itself is not loud enough to cause any suppression whatsoever of the noise signals. Thus a slightly higher level of the noise can be tolerated, since its effect is reduced as soon as speech occurs in the reverse direction.

This has been confirmed by tests in which switchroom noise picked up by an operator's transmitter was used to cause partial operation of the echo-suppressor. With both halves of the echo-suppressor in operation, so that the differential action was present, the noise could be 3 db. louder before it affected the transmission of the speech than when the echo-suppressor was not acting differentially.

Comparative Sensitivity to Noise Operation.

The differential action of echo-suppressors types Nos. 3 and 5 reduces their liability to false operation by noise as compared with that of type No. 2 which is non-differential. This offsets the greater sensitivity of these former types. The faster operating times produce an increased sensitivity to switchroom noise of 2 and 3 db. respectively for the No. 3 and No. 5 types as compared with the No. 2 type. Thus when made equally sensitive to false operation by switchroom noise the No. 3 echo-suppressor is 1 db. more " tone " sensitive than the No. 2 and No. 5 types, which are equally " tone " sensitive.

Conclusions.

The differential nature of the design, together with the very fast operating time of this new echo-suppressor will enable improved operation of trunk circuits to be obtained. At the same time the apparatus is simple, and by combining both halves of the echo-suppressor together and locating them at one end of the circuit, the first cost, maintenance and installation charges are small. The arrangement is very suitable for operation on zero loss carrier telephone circuits.

The Problems Associated with Impulsing in Non-Director Areas

H. WILLIAMS, A.C.G.I., A.M.I.E.E., and S. RUDEFORTH

The nature of the problem of impulsing over several junctions in tandem is examined and the results of a series of tests made to determine the permissible limits of junction resistance for long line and pick-up conditions are given. The cause of these limitations is also discussed.

Introduction.

THE function of a telephone system is to provide an efficient speech channel between any two subscribers speedily, accurately and cheaply. With this in mind the British Post Office is pressing forward with the automatisation of all the local exchanges in the country and is considering the application of automatic methods of working to the trunk system. It is, therefore, of paramount importance at the present time that existing methods of effecting connections automatically between subscribers should be reviewed and that their limitations should be examined.

As is well known, a subscriber connected to an automatic exchange indicates his requirements by rotating the dial connected to his instrument. This makes a series of disconnections (impulses) in the line circuit and causes the line relay at the exchange to become de-energised a similar number of times. This release of the line relay is made to control the stepping of selectors which connect the subscriber through to the required number.

So long as the call is to another subscriber on the same exchange the problem of operating the various selectors is a comparatively simple one, as each selector in turn can be impulsed directly from the subscriber's dial. The line relay in a group selector is then disconnected from the pair of wires, the selector being held over a third or private wire from the final selector. When, however, the call is to another exchange it would be necessary to provide 3-wire junctions. To avoid this a relay set is provided at the outgoing end of each junction to hold the preceding switches and to provide a number of other functions. These entail connecting relays across the speaking pair and dividing the local side from the junction by means of condensers in the line circuit. As it is impossible to pass direct current impulses directly through such a circuit, arrangements have to be made for the impulses received on the local side to be repeated over the junction to the subsequent selectors. In a multi-office area, or where a number of U.A.X.'s are connected together with inter-dialling facilities, several junctions may have to be joined in tandem in order to effect the required connection. Fig. **1** shows a connection via three exchanges in tandem to a final selector in a fourth. This is the maximum condition considered in the present article. At each junction a relay set (repeater) has to be introduced to repeat the impulses, and at each of these repetitions distortion of the pulse is inevitably introduced. This, added to the distortion produced by the reactance of the line, presents a very definite limit to the number and length of junctions over which automatic selectors can be operated satisfactorily.

The present article, which will be continued in subsequent issues of the JOURNAL, describes tests which have been undertaken to determine the limits over which satisfactory impulsing can take place and examines the factors which cause the limitations. Impulsing via non-ballast repeaters associated with pre-2,000 type selectors is dealt with in the present article, and subsequent articles will treat the problem when repeaters with ballast feeds associated with pre-2,000 and 2,000 type selectors are employed. All relays concerned are the Post Office 3,000 type.

GENERAL CONSIDERATIONS.

Tolerances.

It will be appreciated that to provide satisfactory manufacturing and maintenance conditions a margin of adjustment must be allowed on all apparatus. Thus the present standards allow battery voltage fluctua-

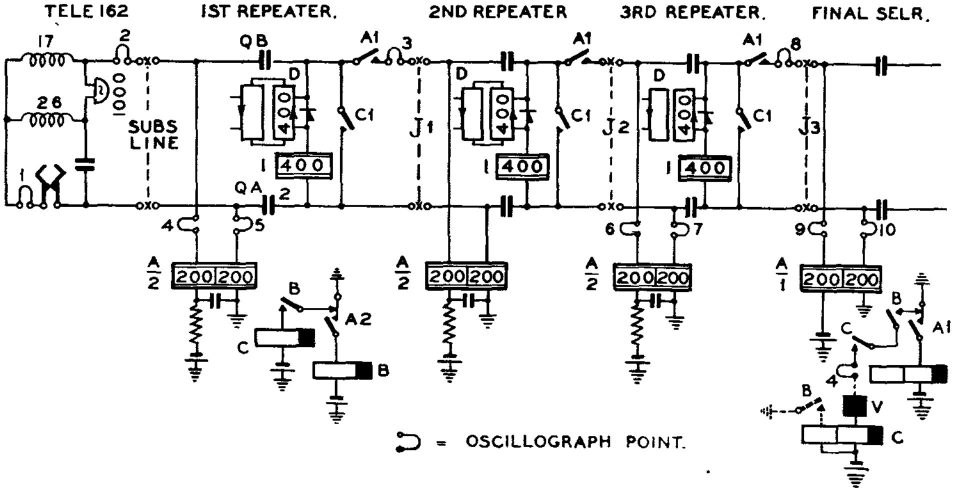


FIG. 1.—IMPULSING CONDITIONS OVER THREE JUNCTIONS IN TANDEM.

tions from 46 to 52 volts; the subscriber's dial is allowed to vary from 7 to 12 impulses per second as regards speed, with a variation in the time the contacts are made during each impulse of from 28 to 37 per cent. of the impulse period; relay contact pressures, selector mechanism adjustments, etc., have like tolerances. The tests described were made not only on apparatus in all conditions of adjustment within the permissible limits, but also on 100 repeaters and 50 selectors in nominal adjustments.

The Circuit Conditions.

In automatic equipment it is necessary, in addition to actual impulsing, to detect two conditions, replacement of the receiver and the end of each train of impulses. For these purposes two relays are provided in each selector, usually referred to as " B " and " C" respectively. Typical circuit conditions are shown for the final selector in Fig. **1**. It will be seen that during impulsing the circuits of relays B and C are intermittently broken by the A relay contact. The release of any of these relays during impulsing will result in failure. To guard against this the relays are provided with " slugs " which cause them to be slow to release. When the A relay is responding to impulses, however, the current in the B and C relays is pulsating, the flux gradually decreases and, if the pulses are insufficiently long, failure results. This is one failure point of the apparatus. It will be seen from Fig. **1** that when the pulses are long in the B relay they are short in the C relay and vice versa. Two failure points result, therefore, in practice, referred to for reasons given later as " short line " and " long line " failure.

There can also be failure of the actual operating magnet of the selector, and here again the failure may be due either to failure to step or failure to release.

In addition to these actual failures to impulse correctly, certain circuit functions take place between trains of impulses, and these may cause premature or extra steps in the selector. These and similar troubles have been classified as " pick-up " troubles, and are often of greater importance than actual impulsing.

A full list of conditions which tend to cause failure of the impulsing train will be given, but before passing to them it will be of interest to consider the design of the impulsing relay and the steps that have been taken to render it as efficient as possible.

" A " Relay.

A typical A relay, as used in a repeater, is shown in the centre of Fig. **2**. On the left of the armature is a " make-before-break " (K) contact which operates the B and C relays. One reason for using this type of contact is to avoid the transit time which would occur in moving the spring from one side to the other if an ordinary " changeover " were used. An important point to note is that all three springs are in contact for a short time while the contact is being operated or released. This relay also carries a make-contact (A1 in Fig. **1**) which repeats the impulses forward. Beneath the coil and wrapped round the soft iron core are thin sleeves of nickel iron. The purpose of these is to increase the impedance of the relay so that very little loss to speech occurs when the relay is bridged across the line. An alternating flux as caused by speech currents is found to penetrate only a small distance into the core, and by making this portion of high permeability magnetic material a high impedance is obtained without increasing the D.C. resistance. It will be seen from Table 2 that the impedance is also similarly independent of the direct current in the coil.

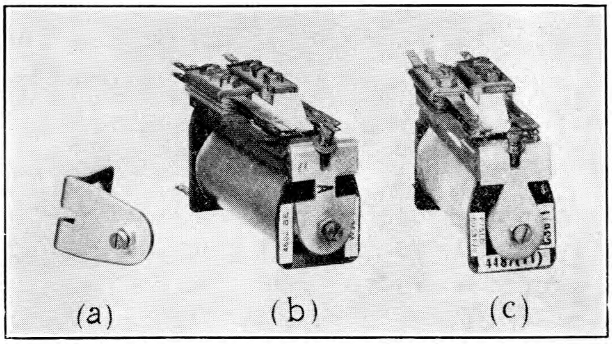


FIG. **2**.—(*a*) ORDINARY ARMATURE; (*b*) ISTHMUS ARMATURE; (*c*) V ISTHMUS ARMATURE.

The Isthmus Armature. An important feature of the relay is the design of the armature. Reference to Fig. **2** will show that the armature of a relay is not always of simple shape. The relay to the left, for instance, carries an armature which has been shaped to form a parallel neck or " isthmus." Ideally, of course, the impulses from the dial should pass on their way through the train undistorted, and it is probable that this could be done, to all practical purposes, if it were not necessary to speak over the connection. The nature of the system is such, however, that repetition using the circuit as shown in Fig. **1** is necessary. In order to pass each impulse

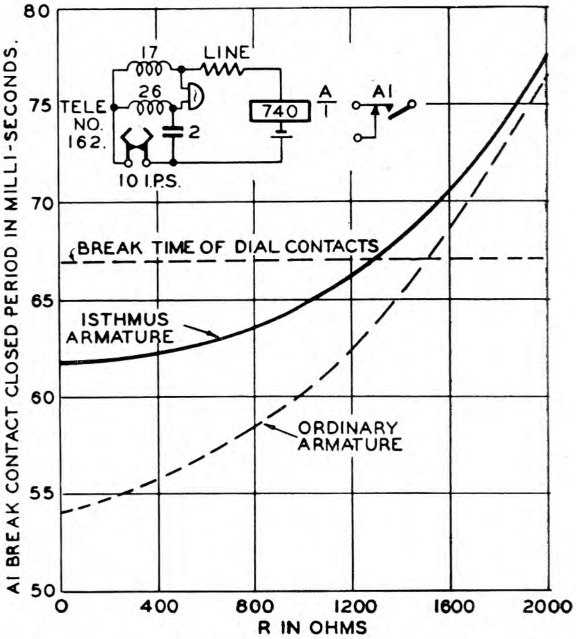


FIG. **3**.—EFFECT OF ISTHMUS ARMATURE ON THE BREAK CONTACT CLOSED PERIOD.

on undistorted the relay must take the same time to release as to operate. Using a plain armature it is not found possible to do this even approximately, but by fitting an isthmus armature a reasonable result is obtained by virtue of the fact that less flux passes through the armature and it releases more quickly. This fact and various other interesting points are shown in Fig. 3 taken on a relay 740 ohms, 5,400 turns. It has been found in practice that the isthmus should be of different size for each set of impulsing conditions, hence the shape of armature on the relay on the right in Fig. 2 which has been chosen for " ballast " conditions.

Magnetic Interference. The use of the isthmus armature is not, however, without disadvantages. It permits a large leakage flux due to its imperfect magnetic circuit, and relays with this type of armature are, therefore, susceptible to magnetic interference from neighbouring relays, especially from the adjacent B and C relays. This interference or " cross-fire " increases the operate and release currents of the repeater and selector A relays. With a repeater, for example, if the B and C relays are permanently fluxed, the operate and release currents of the A relay are increased by as much as 38 per cent. and 22 per cent. respectively over the values obtained when the B and C relays are de-energised. Since, in actual impulsing conditions, the B and C relay fluxes are pulsating this effect is somewhat reduced. The operation of the A relays is also affected by relays more remote than the B and C relays and the total magnetic cross-fire is sufficient to reduce the permissible junction resistances for a system as shown in Fig. 1 to an impracticably low order. It has been found necessary, therefore, to screen the impulsing relay of both repeaters and selectors from magnetic cross-fire by fitting over each a mild steel, channel type shield, 19 mils. thick. Shields are now fitted on isthmus armature impulsing relays as a matter of principle. The shield itself reduces the operate and release currents of the A relays ; it also affects their impedances without, however, impairing the transmission efficiency over long junctions. Some figures showing the effect of the shield on 200+200 ohm A relays having three nickel-iron sleeves are given in Tables 1 and 2.

TABLE 1.

Effect of " A " relay shield on operate and release currents (straight line relationships)

Operate Current mA		Release Current mA	
Without shield	With shield	Without shield	With shield
13·5	12·5	3·53	3·5
20·6	18·0	6·6	6·5

It is now proposed to deal with the general conditions under the following headings :

(I) Long-line impulsing conditions (as distinct from " pick-up " conditions and troubles).
(II) " Pick-up " conditions and troubles.
(III) Short-line impulsing.
(IV) Summary of agreed impulse limits.

I. LONG-LINE IMPULSING CONDITIONS.

With long junctions, the distant selector may fail to step to the correct position owing to failure of

(*a*) the B relays to hold during the trains of impulses ; and
(*b*) the selector to step correctly because of insufficient time for the release of the magnets —particularly the vertical magnet.

"B" Relays

It has been found that if a number of B relays be each adjusted to have a specific static release lag then some of them will hold and some will not hold on impulses of a particular make time. In order, therefore, to ensure satisfactory impulsing, the manufacturers in the first place make an impulsing test to ascertain whether the B relays will hold after saturation on 46 volts on impulses of 17 milli-seconds make time at a dial speed of 12 I.P.S.

Incidentally, the percentage make ratio of a contact necessary just to hold a B relay is practically

TABLE 2.

D.C. in Relay Winding mA	Effect of " A " relay shield on impedance (measured at 800 c.p.s., 1 volt P.D.)					
	Without shield			With shield		
	Effective Resistance in ohms	Inductance in henries	Impedance in ohms	Effective Resistance in ohms	Inductance in henries	Impedance in ohms
0	5,555	3·425	18,000/73° 12′	6,770	3·861	20,420/70° 37′
20	4,795	3·325	17,300/73° 56′	5,951	3·656	19,225/71° 59′
50	4,090	3·140	16,350/75° 6′	4,820	3·340	17,500/73° 48′
80	3,340	2·815	14,700/76° 36′	3,250	2·600	13,600/75° 36′

independent of impulse speed over the range 7-12 I.P.S. at least.

Selector Magnet Release Times. From a large number of tests it has been ascertained that the average selector requires 7 milli-seconds magnet release time and that only in a very few instances does the magnet release time approach the 17 milli-seconds limit for the B relays. In general, therefore, with apparatus in extreme adjustments and working over long junctions, B relay failure will occur before selector failure.

Furthermore, if the M.C.C.P. (make-contact closed period) of any impulsing (A) relay in the repeater train falls below 17 milli-seconds at 12 I.P.S., adversely adjusted B relays will fail to hold during impulsing.

The following is a list of factors which have been found to be the most onerous for " long line " conditions :

(*a*) High dial speed—upper limit = 12 I.P.S.

(*b*) Low dial make ratio—lower limit = 28 per cent. make.

(*c*) Low voltage at the repeater and selectors, i.e., 46 volts.

(*d*) " Low " value of capacitance in the subscriber's telephone and transmission bridge condensers.

(*e*) " Heavily " adjusted A relays.

(*f*) Large A relay make-contact clearances.

(*g*) Long subscriber's line and junctions.

Considering these factors separately :

(*a*) With the type of relay considered, increasing the speed of impulsing is found to reduce the percentage make of the make-contacts, other conditions remaining constant.

(*b*) is self-evident.

(*c*) and (*g*) By virtue of the reduced line current a low voltage or long line causes an increase in the operate lag and a diminution in the release lag of an A relay.

(*d*) It will be shown later that the effect on the M.C.C.P. of an A relay by connecting a condenser across the lines depends on the value of the condenser and on the inductance of the relay and hence on the nature of the oscillation occurring when the relay circuit is disconnected. Moreover, the effect on the M.C.C.P. of the relay contacts due to the condensers is different if a resistance is interposed between the relay and shunting condenser.

(*e*) By a " heavily " adjusted relay is meant one in which the spring tensions, armature travel and residual gap are the maximum permissible, so that the operate and release lags of the relay are respectively increased and reduced.

(*f*) For a given current in the A relay the larger the make-contact clearance, the shorter will be the time available for holding in the B relay. It will be seen later that the make-contact clearance of impulsing relays has a pronounced effect on the permissible junction limits.

Another important factor causing a variable M.C.C.P. is contact bounce.

The reduction in the M.C.C.P. of impulsing relays due to the above factors is offset to some extent on long junctions by the capacitance and lower insulation resistance of the junctions.

Effect of Condensers on Impulsing.

The factors which affect the operate and release lags of a relay divorced from condensers are well known and need not be enumerated here. The effect of a condenser on an impulsing relay with or without a series resistance is perhaps not so well known, and the following explanations may therefore be of interest :

Fig. **4** (*a*), (*b*), (*c*) and (*d*) shows four ways in which an impulsing relay may be worked. Consider first Fig. **4** (*a*), which depicts a relay being impulsed via a non-inductive resistance, R. When R = O the release lag of the relay may be high and the operate lag low so that the break-contact closed period (B.C.C.P.) may be appreciably less than that of the dial impulsing contacts. As R is increased the operate lag increases and the release lag diminishes, owing to the decreased flux in the relay ; the B.C.C.P. therefore continually rises with increasing values of R. The distortion will become zero when the operate and release lags are equal, and as R is increased still further the release lag will become less than the operate lag so that a gain in B.C.C.P. results.

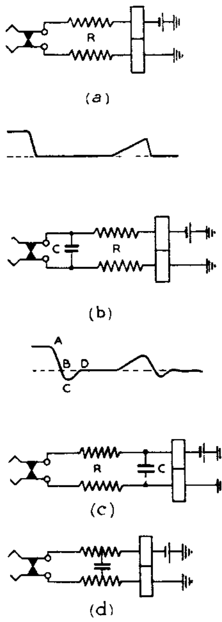


Fig. 4.—Four Ways of Connecting the Impulsing Relay.

Under the conditions of Fig. **4** (*a*) the relay flux is greater on the first break of the dial (especially when R is of low value) than for the subsequent breaks because for the latter the current and flux do not reach their maximum values. Hence on the first break of the dial contacts the relay release lag is longer and hence the B.C.C.P. shorter than for the breaks of subsequent impulses. With higher values of series resistance this difference between the first and other impulses becomes less because the current for the subsequent impulses reaches a value approximating to the maximum value. Curves A1 and A2 (first and second B.C.C.P.'s respectively) in Fig. **5** show these effects for a selector A relay in mean mechanical adjustments. The nearest approach to the conditions of Fig. **4** (*a*) in the circuits dealt with in this article is that of a selector relay impulsing from a repeater ; even so, since one winding of the selector relay is connected to the earth leg of the loop, the repeater bridge condensers affect its operation.

In Fig. **4** (*b*) a condenser is shown connected across the impulse springs. This condition represents approximately the subscriber's instrument condenser and dial contacts impulsing a repeater A relay or a selector relay. With the repeater A relay, however, the bridge condensers are also connected across the loop, via the C1 contact when that is closed.

Under the conditions of Fig. **4** (*b*), when the dial contacts open, the condenser becomes charged and,

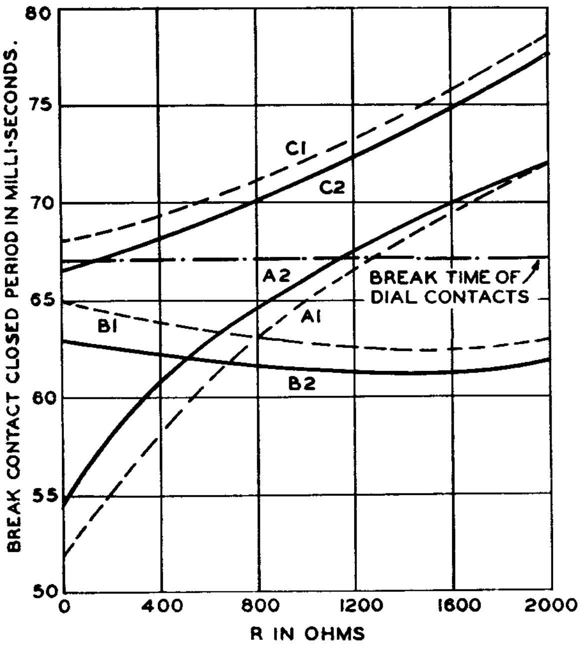


Fig. 5.—Effect of Varying Line Resistance.

owing to the inductance of the relay and the capacitance C, the charging current is in the form of a damped oscillation such as A, B, C, D. The nature of this oscillation depends, of course, on the values of R, L, and C, and the release lag of the relay will depend on the rate of decrease of the condenser charging current occurring when the dial contacts open—represented by AB. Further, the release lag will be affected by the amount of reversed current represented by BCD. If L and C are large the frequency of the oscillation is reduced, the rate of delay of the current is reduced and, since this results in an increased relay release lag, the relay B.C.C.P. is decreased. Again, if R is increased, the oscillation is more damped so that the slope AB is decreased and the reversed current BCD is reduced; the relay release lag is then still further increased with a corresponding diminution in B.C.C.P. The opposite effects are produced if R, L and C are reduced.

With no condenser as in Fig. **4** (*a*), it has been seen that increase of line resistance increases the B.C.C.P. of the impulsing relay and that with a given line resistance the effect of a condenser across the dial contacts is to decrease the B.C.C.P. by virtue of an increase in release lag of the relay. The effect of the line resistance on the release lag is, therefore, compensated by the action of the condenser so that much less overall distortion results with increasing line resistance until the latter is so great that the reduced flux in the relay causing a quicker release and an increase in B.C.C.P. becomes of greater importance. This action of the condenser will readily be seen by comparing curves A2 and B2 of Fig. **5**. Curve B2 was obtained by impulsing a selector A relay from a Telephone 162, curve A2 being obtained under the conditions of Fig. **4** (*a*). The D.C. inductance of the A relay rises from about 8 henries with maximum current to about 19 henries with 25 mA with increased line resistance, and this also causes a decrease in the frequency of the oscillation occurring on the break of the dial contacts; the release lag, therefore, tends to increase. The operate lag of the relay increases with increasing line resistance because of increasing relay inductance and decreasing flux; this tends to increase the B.C.C.P., but the effect is generally offset by the factors tending to reduce the B.C.C.P. until the line resistance is high.

Under certain conditions of Fig. **4** (*b*) the first B.C.C.P. of a train of impulses is greater than the remaining B.C.C.P.'s, as shown by curves B1 and B2 in Fig. **5**. This difference between the first and other impulses—becoming less with higher line resistance—is due to the fact that the relay flux, being higher for the first break, results in a decrease in inductance of the relay compared with that for the remaining impulses, so that the rate of the decay of the oscillatory current set up when the dial contacts open is greater for the first break; hence the A relay release lag is less and the B.C.C.P. longer.

The foregoing is an attempt to explain, among other phenomena, how the first B.C.C.P. may actually be longer than the remainder of a train of impulses. It will be appreciated, however, that the results depend greatly on the relay characteristics as well as on its adjustments.

In Fig. **4** (*c*) the condenser is now connected across the lines adjacent to the relay. The condenser connected in this way is similar to the bridge condensers of a repeater when the C1 contact is closed. Under these conditions the operate lag of the relay increases with increased line resistance, firstly, because of the decreased flux and higher inductance, and secondly, because the current cannot rise in the relay until the condenser commences to discharge. The effect of the condenser on the release lag is little affected by the line resistance until the latter is great enough to cause a decrease in lag by virtue of a decreasing flux in the relay. The net result of the foregoing is that the B.C.C.P. tends to build up with increasing line resistance although the rate of increase of B.C.C.P. would be greater with no condenser. Curves C1 and C2 (for first and subsequent impulses respectively) of Fig. **5** were obtained from a $200+200$ ohms repeater A relay with, however, a 2 μF condenser across the relay as in Fig. **4** (*c*). It will be seen that in this case the first B.C.C.P. is again longer than for the remaining breaks, this difference tending to be greater with a low series resistance, R, for reasons already explained.

Fig. **4** (*d*) represents approximately an actual pair of lines, the effect of the capacitance being somewhat intermediate to conditions (*b*) and (*c*).

In spite of the above effects it will be shown in a subsequent article that the first B.C.C.P. of each impulsing relay, with the exception of that of the first repeater, is actually shorter than the remaining B.C.C.P.'s. This effect is due to the inclusion of the D and I (signalling) relays in the loop, these being short-circuited after the first impulse has been dialled owing to the operation of the C relay.

Effect of varying Capacitance connected across a repeater A relay is shown in Fig. **6**, the diagram illustrating the conditions with a zero subscriber's

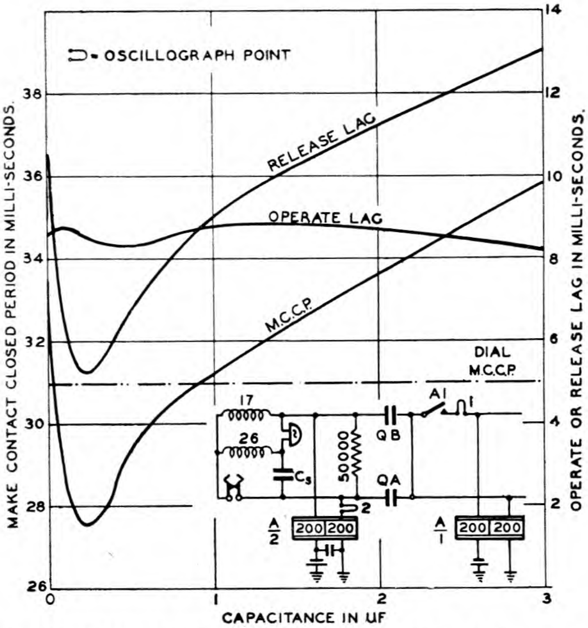


Fig. 6.—Effect of Varying Capacitance across the Impulsing Relay.

line. The total capacitance across the loop, represented by (QA in series with QB) + Cs was varied and the M.C.C.P. of the repeater A relay repetition contact A1 measured. It will be seen that when the total capacitance is low the M.C.C.P. is less, and the B.C.C.P. therefore higher, than for high values as well as for no capacitance. The reason for the shape of the curve will be understood from the foregoing. Fig. 7 shows how the waveform of the A relay coil current changed for different values of total capacitance. The numbers 1 and 2 indicate the position of the oscillograph vibrators shown in Fig. 6. The surges, shown by " S " in Fig. 7 occur, due to the inclusion of the bridge condensers, when the A1 contact opens.

The important fact about the conditions described in the foregoing paragraph is that capacitance between the lines does not always cause an increase in M.C.C.P. or a decrease in B.C.C.P. compared with that of the dial impulsing contacts and that the result depends upon the value of the capacitance, for a given relay inductance, and hence on the nature of the oscillation which occurs when the dial contacts break.

Determination of Long Line Impulsing Conditions.

By " Long line " conditions are meant those conditions which reduce the M.C.C.P. of the impulsing relays.

Tests with Shop-product apparatus. The subscriber's line and junctions were simulated by variable non-inductive resistors in each leg of the loop. For shop-product repeaters and selectors in nominal adjustments the permissible junction resistances for 1, 2 and 3 tandem junctions were determined, using a Telephone 162 and a subscriber's line of 500 ohms, the foregoing adverse factors (*a*), (*b*) and (*c*) being applied.

The extent of the magnetic interference on non-shielded A relays from neighbouring relays was not at first realised and some tests were carried out without A relay shields. Table 3 gives some of the limiting junction resistances obtained when no shields were fitted over the A relays, and also shows the considerable improvement in those limits when the shields were fitted.

Table 3.

Number of Junctions in tandem	Permissible junction limits in ohms			Cause of failure if stated junction limits exceeded
	J1	J2	J3	
Using Non-shielded " A " Relays				
1	1,120	—	—	Extra impulse to selector at end of vertical train of impulses.
2	560	560	—	Premature rotary step to selector at end of vertical train of impulses.
3	280	280	280 or zero	3rd repeater B relay failure.
Using Shielded " A " Relays				
1	2,560	—	—	False vertical step on initial pick-up.
2	1,360	1,360	—	Premature rotary step at end of vertical train of impulses.
3	700 680	640 680	640 680 or zero	3rd repeater B relay failure.

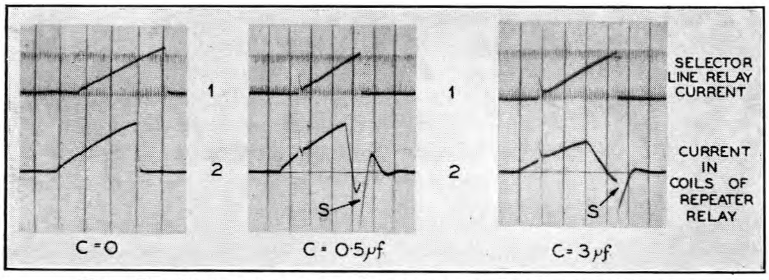


Fig. 7.—Oscillogram of Current in Impulsing Relay.

Table 4 summarises the lowest values of junction resistances over which satisfactory impulsing (and "pick-up") was possible, using Contractors' apparatus in " as received " adjustments with shielded A relays. The repeaters (and their order along a two- or three-junction route) were selected entirely at random, 20 repeaters and 10 final selectors from each of the five contractors being tested.

TABLE 4.

Number of Junctions in Tandem	Limiting Junction Resistances in Ohms		
	Minimum	Maximum	Average
1	1,800	3,460	2,580
2	860	1,800	1,230
3	560	1,700	870

Note : Equal junction resistances were used.

The minimum values of junction resistance given in Table 4 resulted from actual impulsing failure, i.e., failure of the B relays to hold during impulsing or failure of the selector to step correctly due to high vertical magnet release time. Out of 50 selectors tested, however, the latter caused a low limiting value of junction resistance once only. Tests were made on 1, 2 and 3 tandem junction routes, in each instance with 50 different combinations of repeaters and selectors. For the single-junction route, the junction was limited by impulse distortion only three times out of 50, the corresponding figures for the 2 and 3 junction routes being respectively 25 and 41. The remaining causes of failure when the limiting junction resistances were exceeded arose from various forms of " pick-up " troubles, which are dealt with later.

Impulsing with all factors adverse. The impulsing limits, expressed in terms of permissible junction resistances, for the shop-product repeaters and selectors were found after applying adverse battery voltage, subscriber's line resistance, dial speed and dial-make ratio. It will now be seen what happens to the limits when, in addition, the B relays are adversely adjusted so that they just meet the 17 milliseconds impulsing test and when all A relays are " heavy." By a " heavy " A relay is meant one which, having been adjusted to the maximum mechanical tolerances, has the residual gap changed until the relay is just actuated with the maximum allowable operate current, the armature travel being kept at 27 mils. The A relays were adjusted in this way in order to preclude the worst possible adjustments but also to reduce variations in results between relays having the same mechanical adjustments.

" A " Relay contact clearances. The minimum make or break contact clearances of the repeater and selector impulsing relays considered in this article have now been fixed at 10 mils. Depending upon the value of the armature travel, the make-contact clearances of the K spring-set of an average non-ballast repeater impulsing relay having an 18 mils. back spring can vary from about 10 to 22 mils., the corresponding figure for the selector A relay having 14 mil. springs with a stiff 14 mil. back spring, being about 10 to 20 mils. The contact clearance of the make-contact, A1, of the repeater A relay can be as high as 29 mils., but for most relays the buffer lift is less than 2 mils. if the contact clearance exceeds about 25 mils. for an armature travel of 27 mils.

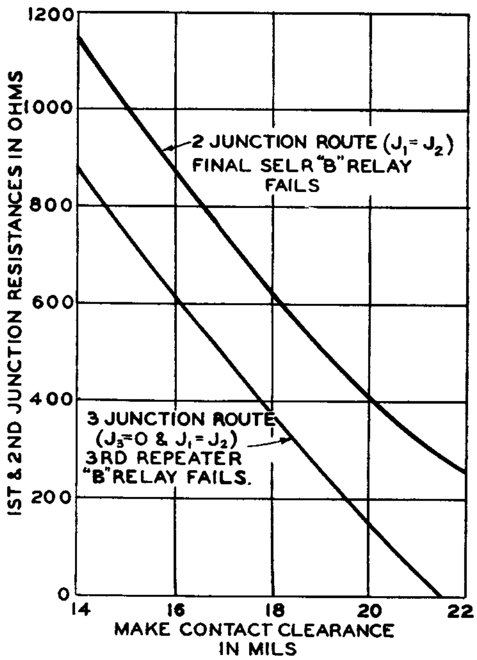


FIG. 8.—EFFECT OF VARYING MAKE-CONTACT CLEARANCE.

The considerable importance of contact clearance is illustrated in Fig. 8, which shows the effect of changing the clearances of the repeater A relay repetition contact A1 only, for two and three-junction routes on a particular set up of repeaters and selector. It is seen that when all factors are simultaneously adverse, including make-contact clearances of the order of 22 mils., it is not possible to impulse over three repeaters in tandem even with zero junctions, and that the permissible junction resistances with two repeaters in tandem are still of an impracticably low order. Nevertheless, with relaxed make-contact clearances of about 16-17 mils. reasonable junction limits can be met even when all other factors are adverse.

Since the tests on the contractors' shop-products had shown that in the majority of cases three equal junctions of 800 ohms or more could be met and that only in three exceptional cases were the junctions limited to 560-640 ohms each, it appeared that three equal junctions of about 500 ohms would be a reasonably safe limit. It was found that by adjusting the repeater impulsing relays to mean mechanical adjustments with adverse make-contact clearances of 23 mils, and with the selector A relay " heavy " and having a make-contact clearance of 21 mils., the requirement of three equal junctions of 500 ohms could be met ; and, with two-tandem junctions, the individual resistances could be 800 ohms, all other factors—dial speed and ratio, voltage, subscriber's line and B relay adjustments—being simultaneously adverse. Again, when all impulsing relays were in " heavy " adjustment but with make-contact clearances of 15-16 mils., it was found possible to meet junction resistances of 640 ohms per junction when three repeaters were in tandem and 1,080 ohms for the individual junctions using two repeaters in tandem.

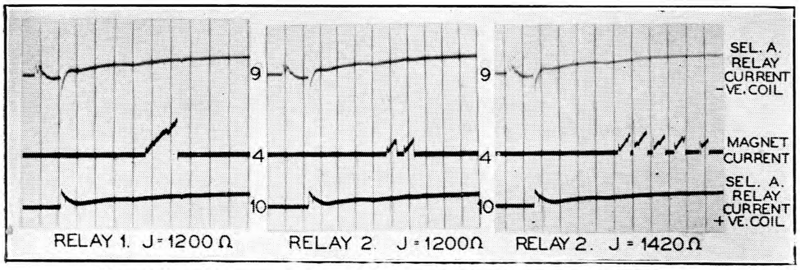


FIG. **10**.—OSCILLOGRAM ILLUSTRATING "PICK-UP" TROUBLE.

limiting junction resistances for just no false step to the selector on initial pick-up. Oscillograms of the vertical magnet current of a selector—i.e. the current in the A relay break contacts—for these two relays during the process of initial pick-up showed that two or more separate pulses of current were delivered to the magnet with the relay giving the highest permissible junction resistance, whereas, for the other relay, only one large pulse was evident. These effects are shown in Fig. **10** which refers to relays having "flexible" back springs, i.e. those which lift from the buffer block.

It would appear that when an A relay operates so slowly that the momentum of the moving parts is low there is a tendency for the armature to drop back again when the upper spring load is taken by the armature; when the latter is again relieved of this load the lever spring once more comes into contact with the upper spring and the condition is repeated. The extent of the effects described will depend on the contact clearance and the position of the armature relative to the pole-face on the instant of closure of the lever and upper spring contacts. If the make contact clearance is small the armature will be some distance away from the pole-face when it meets with the upper spring load, so that a longer bunching time is to be expected. Moreover, assuming a particular armature travel and make contact clearance, it is reasonable to suppose that the bunching time of the contacts will be greater for relays with flexible back springs than those with stiff back springs, so that the permissible junction resistances as determined by initial pick-up should be greater for the latter.

Limiting Junction Resistance for no Premature Step to a Selector on Initial Pick-up. Without A relay shields and using "flexible" back springs the permissible junction resistance between a repeater and selector was, even on shop-product apparatus, in some cases as low as 1,120-1,280 ohms. Putting a shield on the selector A relay raised this value to 1,920-2,560 ohms. With all factors adverse, using shielded A relays having stiff back springs, the maximum junction resistance was 1,500 ohms. This value of 1,500 ohms has been increased by connecting a rectifier across the D relay. Although the rectifier does not, of course, constitute a perfect short-circuit on the 400 ohms winding of the D relay, the permissible repeater-to-selector junction resistance is raised thereby from 1,500 ohms to 1,800 ohms. If the 400 ohms D relay winding could be completely short-circuited during initial pick-up the junction limit would be increased to 1,920 ohms as far as initial pick-up is concerned.

The curves connecting bunching time of a selector A relay contacts with junction resistance are shown in Fig. **11**. The conditions were: a subscriber's Telephone 162, a line of 500 ohms, followed by a repeater, a junction and a selector. The bunching time of the A relay contacts of the selector was measured, for various values of junction resistance, each time the telephone receiver was taken off the switch-hook. The curves which, on account of their peculiar shape indicate some connection with the way in which the armature load builds up during its stroke, show the effect of the selector A relay make-contact clearance and of the D relay rectifier. The minimum duration of a pulse through the selector A relay necessary to cause operation of the B and C relays of the selector and step the vertical magnet was about 66 milli-seconds, the magnet itself requiring approximately 19 milli-seconds of this time. Referring to Fig. **11** it will be seen that the bunching time was 66 milli-seconds and the selector made a premature step for an A relay make-contact clearance of 10-11 mils. when the junction resistance exceeded about 1,610 ohms. For a larger make-contact clearance of 16 mils. the false step did not occur until the junction was raised to 1,910 ohms; this figure became 2,300 ohms when a rectifier was connected across the D relay.

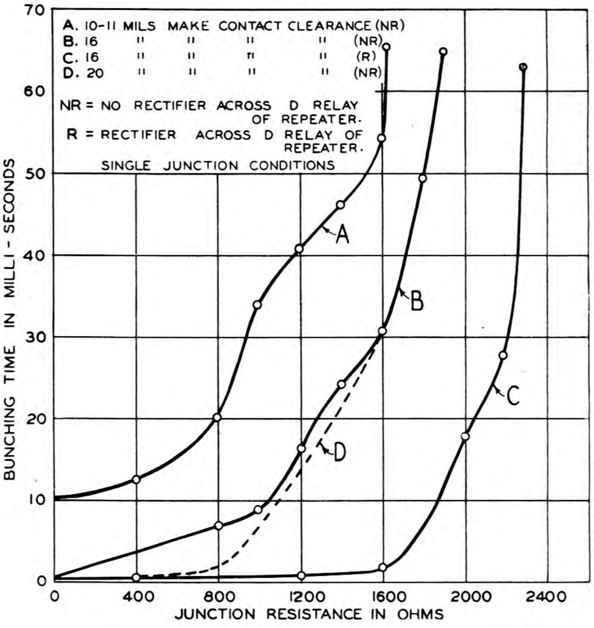


FIG. **11**.—BUNCHING TIME OF MAKE-BEFORE-BREAK CONTACT, IMPULSING RELAY.

If the inter-repeater junction resistance be too great the repeater A relay contacts may be bunched long enough to operate momentarily the C as well as the B relays of the repeater. As will be seen later, when the repeater C relays release incident on full operation of the A relays the selector may make a false step owing to momentary release of the selector A relay.

(*To be continued.*)

It will be shown in a subsequent article that *small* make-contact clearances considerably affect permissible dial speeds under " short line, low insulation " conditions. It is, therefore, of great importance in practice to avoid extremes of contact clearance. Because of the tolerance allowed on the armature travel of 3,000 type relays and the flexing of the springs with varying tension, no simple rule for contact gauging can be devised. Some work is being done, however, to ascertain whether it is possible to formulate a table for contact gauging allowing for armature travel.

Considering the permissible single-junction resistance: it was found possible to impulse (i.e. excluding " pick-up " effects) over 1,700 ohms with all factors adverse, and with A relay make-contact clearance of 23 mils., and 21 mils. for the repeaters and selector respectively. When both the repeater and selector A relay make-contact clearances were reduced to 15-16 mils., the permissible junction resistance for actual impulsing became approximately 2,500 ohms.

" Spread " diagrams. By plotting the M.C.C.P. of the impulsing relays for each stage along the route a spread diagram is obtained which shows the amount of impulse distortion introduced by the subscriber's apparatus, repeaters and selector. Fig. 9 shows such a diagram for A relays in heavy adjustment having make-contact clearances of 15-16 mils. and with all other factors adverse for long line impulsing. It will be observed that there is an increase in M.C.C.P. from the dial to the first repeater; this is due to the greater capacitance across the first repeater A relay of approximately 3 μF compared with 1 μF for the other repeater A relays. Moreover, the subscriber's line is of lower resistance than the junctions for the example under consideration. In the particular examples of spread diagram shown in Fig. 9 the impulse distortion for the two-junction route from the first to the second junction, say, is greater than that for the three-junction route because of the higher junction resistance of 1,080 ohms used for the two-junction route.

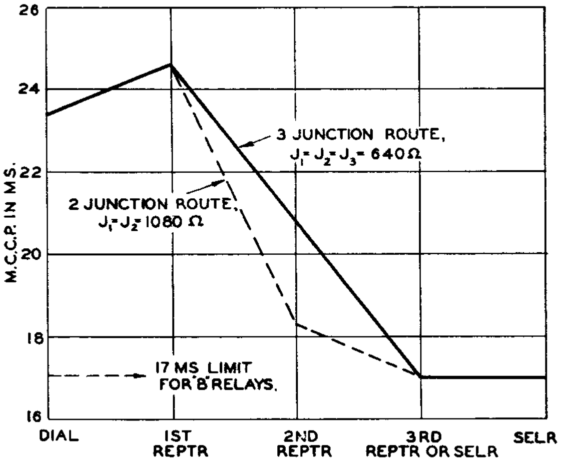


FIG. 9 —SPREAD DIAGRAM.

Effect of dial speed and battery voltage. Consider two repeaters and junctions in tandem having the conditions and relay adjustments under which Fig. 9 was obtained; changing the dial speed from 12 to 10 I.P.S. when the voltage was 46 volts increased the maximum resistance of each junction by about 150 ohms. At a dial speed of 12 I.P.S., however, a change of voltage from 46 to 50 volts increased the permissible resistance of each junction by approximately 500 ohms.

II. " PICK-UP " TROUBLES.

When the line is initially looped the A relays at each repeater and at the distant selector, together with certain other relays, operate in sequence, and the apparatus is prepared for the train of impulses which follows; this is called the " initial pick-up." At the end of a train of impulses, the A relays are held operated or are again " picked up " ; this will be called " subsequent pick-up," although it is sometimes referred to as " end-of-train " or " drop-back " pick-up.

Certain troubles may arise during pick-up which may take the form of false impulses being given to the selector, or the repeater C relays may permanently hold in at the end of a train of impulses. Such troubles arising from pick-up are collectively called " pick-up troubles."

Initial Pick-up.

On looping the lines, the repeater and selector A relays must, of course, fully operate. Moreover, they must operate quickly, especially the selector A relay. If the junction between a repeater and selector be too long, even if the relay fully operates, the long line, together with the inductances of the repeater D and I relays and the selector relay causes the latter to operate slowly. In consequence the make-before-break (K) contacts of the selector A relay are bunched together for an appreciable time. If the bunching time be great enough, the selector B and C relays being operated, a pulse is given to the vertical magnet of the selector of sufficient length, under certain conditions, to cause a false or premature vertical step before actual dialling commences.

Factors Tending to Cause Initial Pick-up Troubles.

The following are the main factors tending to cause initial pick-up troubles :—

(*a*) 46 volts at both repeaters and selector.
(*b*) High resistance junctions.
(*c*) " Lightly " adjusted selector.
(*d*) Small make-contact clearance of selector A relay.
(*e*) Heavily adjusted A relays.
(*f*) " Fast " operating selector B and C relays.
(*g*) Large D and I and A relay D.C. inductances.

In addition to the above factors some selectors operate more easily on the first impulse owing to the assistance given by the off-normal springs.

It is clear that factors (*a*), (*b*), (*e*) and (*g*) will, if applied simultaneously, cause slow operation of the A relays on initial pick-up, and that (*c*) and (*f*) will facilitate false stepping of the selector from a transient pulse during the bunching of the selector A relay contacts. The influence of factor (*d*), however, is not so clear, and this is, therefore, dealt with in more detail. It was observed that two selector A relays having almost identical adjustments in regard to operate and release lags and currents gave different

The Production of Portland Cement

Geo. F. TANNER, M.I.E.E.

The author describes the method of production of Portland Cement at Bevan's Works, Northfleet, which is the largest cement factory in Europe.

Introduction.

IN all the great engineering achievements of to-day Portland Cement plays a most important rôle and such enormous quantities are now being produced that it is felt that a few words describing its evolution will be of interest.

After listening to a number of technical papers on concrete and reinforced concrete at the International Congress of the International Association for testing materials, held at the Institution of Civil Engineers, the author was one of a party invited to inspect one of the works of the Associated Portland Cement Manufacturers, Ltd., at Northfleet, Kent, and during this visit notes relating to the production of this valuable commodity were compiled.

Bevan's Works, Northfleet.

Whether it be viewed from a vessel passing down the river Thames, or from the crest of the hill at the back of the works, Bevan's Works presents a striking appearance. The view is an impressive one of bold outlines suggesting the energy of a great productive industry. The four gigantic stacks emitting a faint trail of white smoke and steam, long rows of roofs, the expansive deep-water jetty with the many high-speed electric cranes loading into ocean liners, and, dominating all, the massive pile of storage silos, present to the outside world but a slight suggestion of the ceaseless activity within the largest factory in Europe for the manufacture of Portland Cement. The industry was cradled here nearly a century ago, and to-day some of the original chamber kilns of Aspdin—son of the Englishman who invented and patented Portland cement—still stand in contrast to the huge modern factory, (Fig. 1).

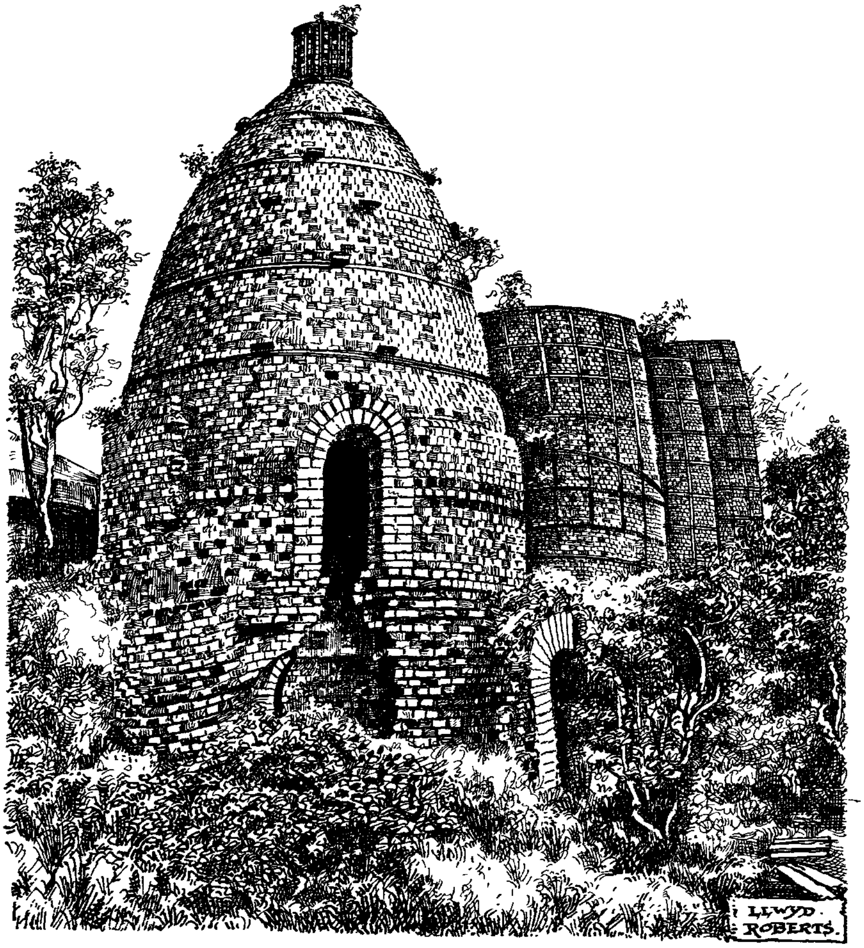


FIG. 1.—ASPDIN'S KILNS AT NORTHFLEET.

The natural advantages of the district are at once obvious ; unlimited raw material of the finest quality, ideal material for the foundations of such enormous plant, and deep-water facilities which enable 15,000-ton ocean liners to come alongside at all states of the tide. It is not surprising then, that this great industrial centre sends millions of tons of cement to all parts of the world. Few people would realise that the repaving of Broadway, New York, or, again, the construction of oil wells in Persia would mean employment and prosperity to Northfleet, yet such is the case.

Subsidiary to the actual cement manufacture, the industry embraces extensive plant for the manufacture of casks, steel drums, sacks, and paper bags. The manufacture of cement is, indeed, to-day one of England's major industries. Tens of thousands are employed directly in production, packing and distribution and many more are employed indirectly in the transport of the product some 35 million ton miles per annum. In addition, there is the mining and transportation of over 2 million tons of British coal each year and the provision of expensive mechanical and electrical plant required at each works.

MANUFACTURE

For convenience the work may be divided into five stages :

(1) Winning of raw materials (chalk and clay),

(2) Breaking down and intimately mixing the materials,

(3) Burning this mixture (called slurry) into hard clinker at a very high temperature,

(4) Grinding clinker to a fine powder,

FIG. 2.—ELECTRICALLY-OPERATED CHALK NAVVY AT WORK.

(5) Storage, packing and despatch.

These operations, as carried out at the Northfleet Works, will be described in the order given.

Quarry and Washmill.

The clay is dug by steam navvy from a deposit of London clay two miles away, and is immediately tipped into washmills and reduced to a thin slurry with about 60 per cent. of water. The fluid clay is then pumped to storage tanks at the main washmill, which is situated in the chalk quarry half way to the works. The chalk is dug by an electrically-operated navvy weighing 70 tons (Fig. **2**), which scoops $3\frac{1}{2}$ cu. yards of chalk at a bite and drops it in 10-ton railway wagons, trains of which are hauled by steam locomotives a short distance to a combined electric hoist and tippler (Fig. **3**) which picks up the wagons bodily and tips their contents into the first of a series of washmills.

The necessary proportion of clay slurry is delivered into the same mill from the storage tanks adjoining, the two materials are then mechanically mixed while the chalk is being reduced to a very fine state of sub-division by revolving harrows in the washmill. The resulting mixture of chalk and clay slurry contains about 40 per cent. of water and leaves the first washmill when it is fine enough to pass through the surrounding screens, and passes through three other mills in succession, each of which has finer screens than its predecessor. The resulting slurry is of such fineness that 96 per cent. will pass through a sieve of 28,900 holes per square inch. The slurry then passes to storage tanks where its composition is checked and adjusted.

Slurry Storage.

The slurry is then pumped a mile through two pipe lines to the final series of storage tanks at the works. These six tanks are located at the upper end of four rotary kilns and the slurry gravitates from these tanks to the boots of four bucket elevators which deliver it at sufficient height for gravity feed to the rotary kilns.

Burning the Mixture.

Unit Coal Mills.—The raw coal for burning in the kilns is fed to the plant units by continuous measuring apparatus through a ball-mill and air separator. The fine coal is drawn off and delivered directly to the burner pipe, the heavier pieces of coal being returned from the separator to the ball-mill for grinding. The air for the conveyance and elutriation of the coal is furnished by fans which draw hot air from the kilns; this also performs the duty of drying the coal previous to grinding. The pulverised coal from the mills is discharged into the air current and conveyed, by the coal-firing fan, to the kiln burner pipe (Fig. **4**). The length and shape of the burner flame is controlled by the air velocity.

Kilns.—The kilns (Fig. **5**) have a loaded weight of about 800 tons. Three are 250 ft. long with separate clinker coolers; the fourth is 294 ft. long and embodies a combined cooling arrangement consisting of a series of small tubes arranged around the periphery of the

FIG. 3.—RAW MATERIAL ARRIVING AT THE WASHMILL.

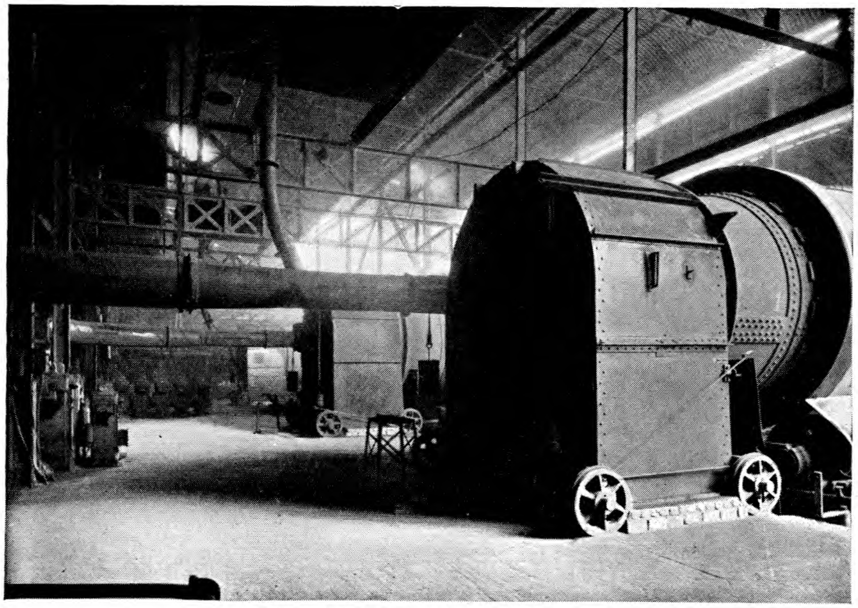


FIG. **4**.—FIRING END OF KILNS.

firing end of the kiln. All kilns have enlarged burning zones and they are driven directly through gearing from the motor to the girth ring.

In these rotary kilns the slurry is subjected to heat. Firstly, the water is evaporated and the burden rendered dry and friable. This dry material is then continuously heated to a temperature of 2,800° F. The intensity of this heat will be realised by reference to Fig. **6**. The whole of the carbonic anhydride in the chalk is expelled, thus converting the chalk into lime. The last reaction in the burning zone of the kilns is when the lime, together with the particles of clay with which it is mixed, enters into chemical combination forming tricalcium and dicalcium silicates and aluminates which are the main constituents of cement clinker.

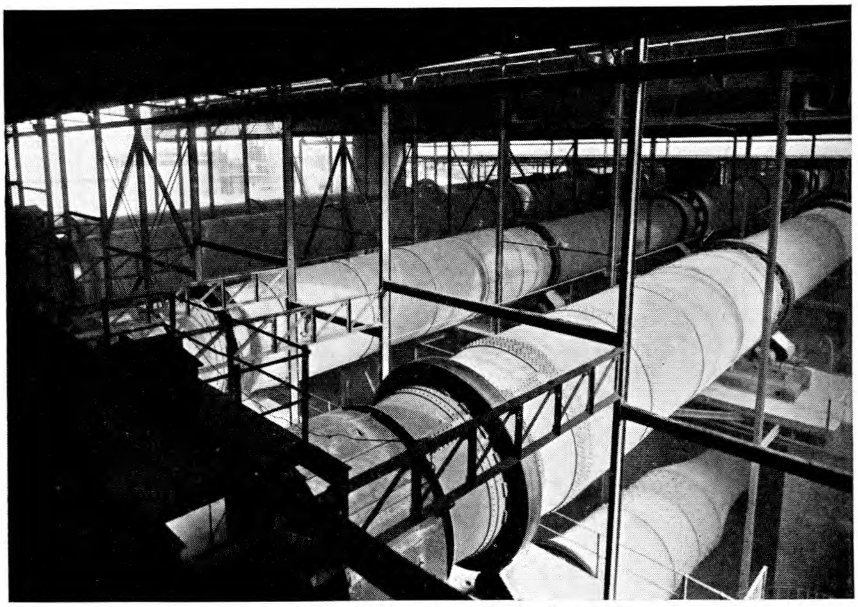


FIG. **5**.—THE KILNS.

Scientific control of the kiln is obtained by the continuous sampling of the exit gases, careful regulation of fuel, and also the requisite supply of air necessary for combustion. The kilns are lined with refractory fire bricks and have induced draught supplied by large exit gas fans. Here again, the speed of these fans, coupled with suitable dampers, is under the control of operators. The rotary kiln was an English invention and is interesting as it is probably the heaviest piece of moving plant in any of our basic industries.

The cooled clinker from the kilns is transported by band conveyors and bucket elevators to large reinforced concrete storage hoppers.

Grinding the Clinker to a Fine Powder.

One of the clinker stores is shown in Fig. **7**. It is **173** ft. by 81 ft. and is **47** ft. deep and has a capacity of **20,000** tons of clinker which is delivered by gravity to the grinding mills immediately beneath. These mills consist of a long steel tube 36 ft. long by 7 ft. diameter divided into compartments.

The first compartment into which clinker is delivered is charged with steel balls of from 4 ins. to 2½ ins. diameter. The coarse grit from this compartment passes through a slotted diaphragm into another with smaller balls, and so on, to a final compartment where it is reduced to an impalpable powder. There are seven of these mills driven by slow-speed synchronous motors of 750 H.P. The powder is then delivered to a pumping installation which delivers it by means of compressed air to a battery of twelve storage silos, the lift being **102** ft. The pump itself is a simple apparatus comprising an iron barrel inside which a motor-driven screw rotates ; the cement is admitted to one end of the barrel and the screw conveys it forward. The pitch of the screw being diminishing, the cement fills the barrel as a piston towards the end of the screw.

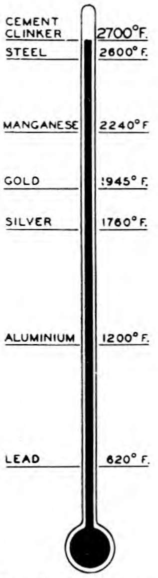


FIG **6**.—CLINKERING POINT OF PORTLAND CEMENT COMPARED WITH THE MELTING POINTS OF OTHER MATERIALS

At the end of the barrel is a ring (with an annular space between the cylinder walls) which is provided with numerous air ports drilled at an angle of 45° towards the direction of flow. Compressed air is applied at this point, and so maintains the velocity of the current of air and cement towards the open end. The transmission of the cement is continuous except for periodic gusts.

STORAGE, PACKING AND DESPATCH

Storage Silos

The twelve cement storage silos are built of reinforced concrete and are capable of holding 22,000 tons of cement (Fig. **8**).

Each silo is 32 ft. in diameter and 84 ft. high. Considerable space is, however, taken up by the tunnel and cement extracting mechanism at the base. Some are plain circular tanks above the tunnel, others are sub-divided into bins, with a wall and staircase up the centre. The latter are necessary when cement to a special specification is required, and holes are arranged at each landing of the staircase so that test samples may be withdrawn from any bin.

It should perhaps be remarked that the output from this particular works is mainly exported and cement is supplied to many differing foreign specifications. Both ordinary Portland and Ferrocrete rapid-hardening cement are produced here.

Portland cement, as produced in this country, has to conform to the requirements of British Standard Specification No. 12, which are somewhat exigent; nevertheless, these requirements are more than met. To ensure such uniformly high quality, however, it is necessary to apply tests at each stage of production. Samples of slurry are taken half-hourly and tested for fineness and correctness of chemical composition. Cups on rotating belts pick up samples of the cement while it is in transit from the grinding mills to the silos, and these are also tested at half-hourly intervals for fineness, setting time and soundness. In addition to routine tests, each works has its own laboratory where check tests are carried out night and day.

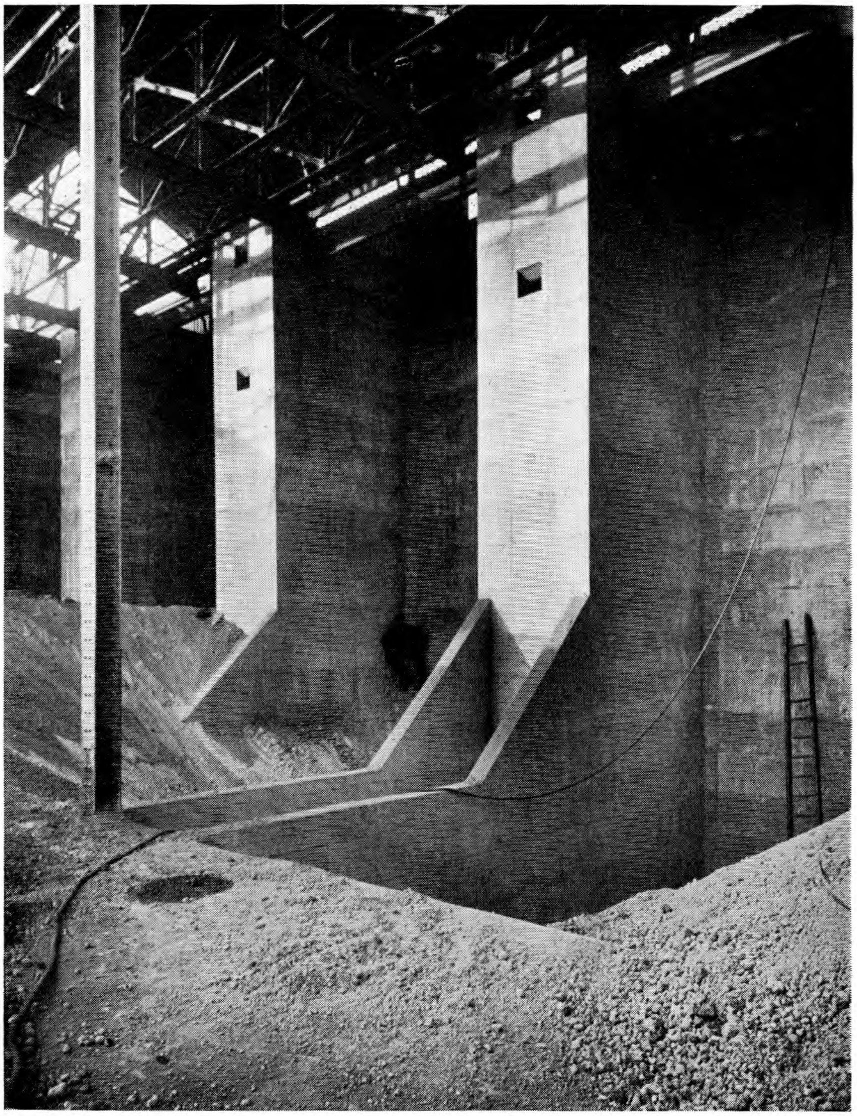


FIG. **7**.—CLINKER STORE.

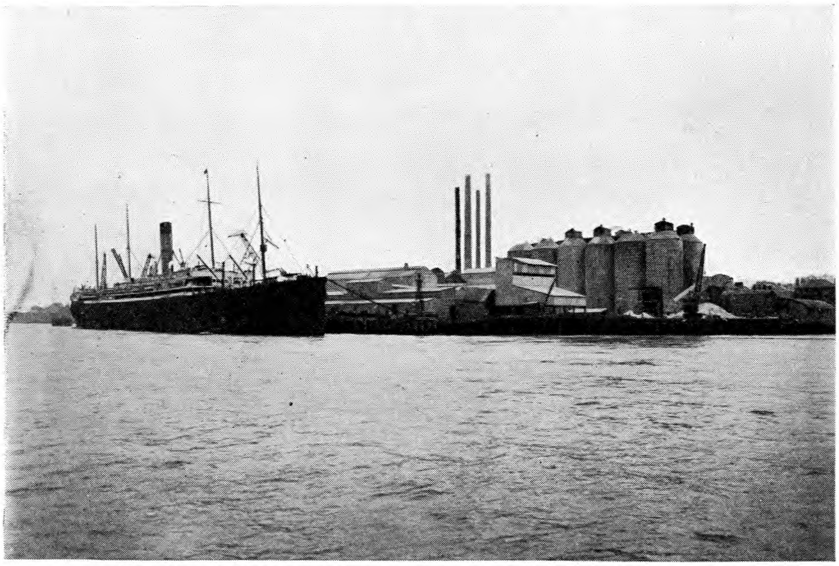


FIG. 8.—A GENERAL VIEW WITH LARGE STEAMER ALONGSIDE.

Fig. **9**.—Loading Cement in Paper Bags.

Filling and Despatch.

The deep-water reinforced concrete jetty is some **600** ft. in length and is capable of berthing steamers up to **15,000** tons at any state of tide ; it stands away from the plant, thus affording ample accommodation. It is equipped with five high-speed heavy-duty electric luffing cranes, which travel along the jetty as required.

Several independent systems are provided for extracting the cement from the silos and conveying it to the various packing plants. The delivery end of one of the conveyors from the packing plant is shown in Fig. **9**. The sacks are stacked on a turntable in slings, as shown, where they can be picked up by the crane and delivered to the craft alongside.

Some **10,000** tons have to be despatched weekly (occasionally **12,000** tons) and, when the delays due to rain, fog and other accidents incidental to shipping are considered, the necessity for elaborate plant and careful organisation will be apparent. (Fig. **10**).

Electric Power.

The power for motive purposes is derived from the national grid system at a pressure of **33,000** V, **3** phase A.C. It is stepped down to **3,000** V at the main receiving station. All motors over **100** H.P. are on the **3,000** V circuit but smaller units are fed from a **500** V distribution system. Precautions are taken in the switching on and off of the larger units to preserve an even load factor, as there are some four hundred motors in the works, ranging up to **750** H.P. each.

Subsidiary Products.

If kept quite dry Portland cement will keep indefinitely, but as cement rapidly absorbs moisture and becomes lumpy or even solid (in which condition it is useless), it is very necessary to provide efficient containers for transport purposes. This has entailed the installation of plant for making casks, drums and paper bags and many ingenious machines are employed.

Cooperage.—The cooperage at Northfleet is capable of producing **20,000** casks weekly. Thousands of standards of timber are held in stock to mature and the stave yards cover many acres of ground. Starting at the drying ovens, the dried timber is shaped in the jointing machines and passed to others which tongue and groove the staves on their sides. The ends of the staves are then notched and bevelled to form the recess which encloses the wooden ends. The finished staves

Fig. **10**.—One of the Conveyors from the Sack Packers.

pass along to the hydraulic bells, a type of vertical press in which the barrel is formed within the steel hoops. The casks are filled with cement and shaken mechanically on jarring machinery and passed forward to the packing plant.

Steel drum plant.—Flat steel sheets are here formed into thousands of drums of various capacities and types, an endless belt traversing the entire sequence of operations. In the initial stages the flat sheets are cut to shape and the edges which are to form the longitudinal seam, turned over. The two edges are hooked together and pressed in the seaming machine, additional security being imparted by spot-welding at intervals down the seam. A little later come the corrugating rolls which add so much strength to the cylinder. Finally, the previously pressed and stamped bottoms are seamed, spray painted and inspected. Another conveyor delivers the finished drums to the packing plant where, after filling, the drum is shaken tight by mechanical jarring plant and the top seamed into position.

Paper bag factory.—Near the works is the factory where the paper bags used in the associated companies' branches are manufactured. Nearly two million multi-walled bags of various types and sizes are produced weekly. It is a good example of mass production methods. Female labour is not employed; the lads come straight from school and after a period many are drafted to the heavier occupations in the cement factory, thus bridging the awkward gap between school-leaving and adolescence.

The raw material is mainly kraft paper which is manufactured locally and arrives at the works in rolls 40 inches in diameter, weighing 15 cwt. The first stage in manufacture is undertaken by three large tubing machines, the various plies of paper being drawn at great speed into a " web " and passed through the different operations. Early in its passage the outside ply is printed in one or more colours with its appropriate brand, trade and shipping marks. This is done with rubber dies mounted upon rotating drums using aniline waterproof ink. Next the paste " tracks " are put along the inside edges of the sheets which form the tube; this operation is regulated by a small beam of light and a selenium cell which (by means of a relay) gives warning of any " wander " of the seams. After printing and pasting, the web is drawn through a forming table where the various plies take the shape of a long continuous multi-walled tube and at the end of this table the tube is cut into regular lengths. These machines produce 10,000 tubes hourly.

The next stage in the process is the formation of a valve at the end of the tube (it is by means of this valve that the bag is subsequently filled with cement as both ends are otherwise closed) which is effected by hand-folding over a former. After valving, the tubes are next sewn across both ends, a reinforcing strip of crepe paper being folded over the ends to give the closure additional strength. The sewing machines are electrically driven and hand fed; an ingenious automatic rotary knife cuts off the crepe strip and cottons, and allows the finished bag to fall into a cradle.

A certain amount of last-minute printing such as shipping instructions and the like is printed after the bags are finished—often in foreign languages and curious characters. The bags are inspected, counted and pressed into bundles of one hundred prior to delivery by rail, road, or sea, to the many branches of the company.

The writer desires to acknowledge the courtesy of The Cement Marketing Company, Ltd., Portland House, Tothill Street, London, S.W.1, in affording the necessary facilities and information for compiling and illustrating this article.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM. TELEPHONES AND WIRE MILAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30th JUNE, 1937.

Number of Telephones	Overhead Wire Mileages.				Engineering District	Underground Wire Mileages			
	Telegraphs	Trunk	Exchange*	Spare		Telegraphs	Trunk	Exchange†	Spare
1,065,803	378	1,319	57,335	7,538	London	33,329	267,970	4,187,267	61,098
130,628	1,690	2,664	64,319	11,159	S. Eastern	6,309	110,974	417,233	58,110
153,405	2,357	13,284	122,610	9,279	S. Western	19,396	109,148	342,958	76,820
110,489	3,173	13,749	109,051	18,722	Eastern	14,102	121,088	241,099	57,160
127,075	3,473	14,704	81,640	24,149	N. Midland	8,754	184,948	293,254	107,432
143,574	1,896	8,533	95,665	17,697	S. Midland	10,719	155,372	431,876	65,060
75,786	1,212	7,521	70,301	11,396	S. Wales	5,532	72,704	173,462	44,496
189,539	2,259	11,469	103,032	22,037	N. Wales	2,988	190,254	550,565	108,160
227,049	995	1,572	38,262	9,050	S. Lancs.	9,870	117,336	819,426	53,536
95,396	947	2,205	39,355	18,555	N. Western	5,788	113,898	296,894	46,020
37,295	2,893	8,030	21,725	1,346	N. Ireland	1,320	7,312	96,750	17,342
268,319	5,044	17,328	109,948	26,187	N.E. Region	16,133	209,946	780,496	139,816
248,099	6,424	27,924	121,537	23,158	Scot. Reg.	8,538	187,186	530,715	81,708
2,872,457	32,741	130,302	1,034,780	200,273	Totals	142,778	1,848,136	9,161,995	916,758
2,807,359	33,309	266,855	877,137	194,179	Totals as at 31 Mar., 1937	168,723	2,027,529	8,658,029	1,032,860

* Includes low gauge spare wires, i.e., 40 lb.

† Includes all spare wires in local underground cables.

The London—Birmingham Coaxial Cable System

A. H. MUMFORD, B.Sc. (Eng.), A.M.I.E.E.

Part. I.—Description of the System

Previous articles in this Journal have described the principles of carrier working, and the factors determining the design of a coaxial cable. In the present article the author describes the London—Birmingham coaxial cable system in greater detail. This article will be followed by others giving details of the cable, repeaters and terminal equipment.

Introduction.

THE recent advent of high definition television has presented communication engineering organisations with the problem of providing land lines capable of transmitting television programmes to different parts of the country. The problem consists essentially in developing a transmission system capable of handling a band of frequencies ranging up to 2 megacycles per second or more, with negligible attenuation and distortion. Once the necessity for such a system arises it becomes immediately apparent that, in view of recent achievements of communication engineering research, the system might well be applied to multi-channel carrier telephone working; whether or not such an application is desirable becomes a matter which must be settled finally by various economic considerations.

The practicability of constructing such a system had been studied by the Bell Telephone Laboratories of the American Telephone and Telegraph Company for some years when, in 1934, Espenschied and Strieby[1] described their wideband system, in which the " go " and " return " lines each comprised a single concentric or coaxial pair. Stated briefly, the system utilised the range of frequencies from 60 kc.p.s. to 1,020 kc.p.s. for the transmission of 240 circuits, channels being evenly spaced throughout this range at intervals of 4 kc.p.s. The coaxial lines had an internal diameter of approximately ½ inch, amplification by means of repeaters of the negative feed-back type being provided at intervals of 10 miles. The influence of radio technique on the design is seen particularly in the channel filters in which the piezo-electric coupling between the electrical and mechanical oscillations of quartz crystal plates was used to provide the equivalent of inductive reactances with much lower losses than could be obtained by the use of inductance coils. The equivalent circuit of a vibrating crystal plate involves capacitors as well as inductors and the manner in which these are associated made it necessary to develop a special technique of filter design. More recently a description of the experimental system installed between New York and Philadelphia has appeared.[2]

The mathematics of the transmission of alternating currents over a concentric system of conductors was fully worked out by Russell in 1909 but it is only in the last few years that this arrangement of conductors has come into prominence as a high frequency transmission line, although concentric lines have been in use for a number of years as feeders for short wave radio aerial systems. For reasonable cost in transport and installation as underground lines, it is necessary that such cables shall be flexible enough to permit of being wound on to drums like present type telephone cables. Flexibility has been attained in certain designs by forming the outer conductor of specially shaped overlapping ribbons of copper laid up together in a spiral to form a tube, the inner wire being positioned with respect to the outer conductor by means of a cotton rope.

A similar construction can be used for a shielded pair line which can be regarded as having two conductors instead of a single central wire, the outer tubular conductor of the coaxial line now performing only the functions of an electrostatic and electromagnetic screen. The advantage of the shielded pair line at low frequencies is unquestionable but larger overall dimensions for an equal attenuation, as compared with a co-axial line, are necessary.

The freedom of a coaxial line from crosstalk and the effects of external disturbances at high frequencies is due to the screening effect of the outer conductor but at the lower frequencies, say below 100 kc.p.s., its efficiency as a screen falls off rapidly and at voice frequencies the unbalanced nature of the circuit renders it unsuitable for the transmission of telephone currents. This is not of importance where a wideband system is required for the transmission of a large number of telephone conversations, but it renders this type of line unsuitable for the transmission of television signal currents unless these are first modulated to bring them into an appropriate range of frequencies.

At the present time the maximum gain for which it is practicable to design a negative feedback repeater is dependent upon the highest frequency to be transmitted and upon the ratio of the highest to the lowest frequency to be transmitted. Broadly an increase in either of these factors involves a decrease in the other, if the maximum gain for which it is practicable to design is not to be reduced. Since this necessitates the incoming signals being modulated to bring them into an appropriate range of high frequencies, the lower attenuation of the coaxial line becomes an attractive proposition and hence this type of cable has been adopted in this country for transmission over relatively long distances.

It was realised about 1934 that the transmission of television programmes over land lines for simultaneous transmissions from television broadcasting stations would be required in this country before many years had elapsed. This alone might have been deemed sufficient justification for proceeding but the inherent possibilities of cheapening the cost of long distance

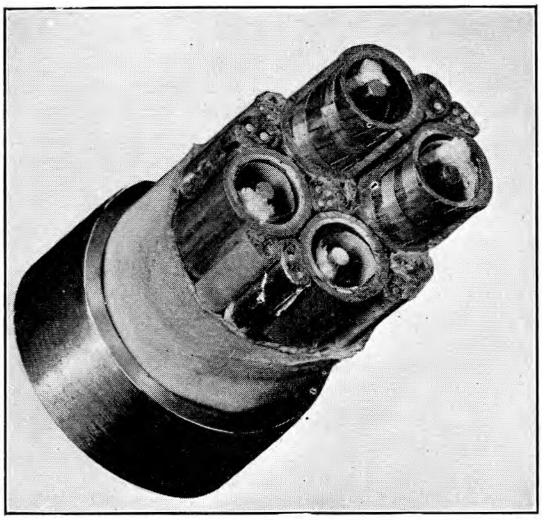
---

[1] L. Espenchied and M. E. Strieby: " Systems for Wide-band Transmission over Coaxial Lines." *Electrical Engineering*, 1934. Vol. 53, p. 1371.

[2] M. E. Strieby: " A Million-Cycle Telephone System." *Electrical Engineering*, 1937. Vol. 56. p. 1.

circuits with such a system was an important consideration. It was decided, therefore, to conduct an experiment with a view to determining the technical and economic advantages associated with the use of multi-channel carrier telephony over an extended frequency range collaterally with the provision of television circuits between London and Birmingham. The greater urgency for short distance television circuits and the urgent necessity for the provision of telephone circuits between London and Birmingham and beyond has led to the concentration of effort chiefly on the telephone aspect of the project.

Previous articles in the Journal have dealt with the principles of wide-band carrier telephony[3] and the factors determining the design of the cable itself[4]. The present article describes the London-Birmingham experiment in greater detail and will be followed by other articles detailing the equipment supplied and giving test results.



THE SYSTEM.

The London-Birmingham cable includes four coaxial pairs, two of which were included for television transmission and the other two for telephony. For telephony one pair is used for each direction of transmission, the same frequency band being employed in each cable. Each pair is designed to have an attenuation not exceeding 6·4 db. per mile at a frequency of 2·1 Mc.p.s. The centre conductor consists of a solid copper wire, 0·125 in. diameter, and the outer conductor of twelve specially shaped interlocking copper tapes, giving a radial thickness of 30 mils to the self-supporting tube so formed; the inner diameter of the outer conductor is 0·45 in. The inner conductor is positioned in the centre of the tube by means of cotopa cords. The outer conductor is bound by thin brass tapes and a thin lead sheath extruded directly on to the brass binding. The inclusion of a lead sheath over each of the coaxial cores increases the ease of handling the cores in the subsequent manufacturing operations and during installation. It also has advantages in the event of penetration of the outer sheath by moisture. Experience has shown that this type of coaxial pair with its self supporting outer conductor of many segments can be wound on drums of normal size and then laid without any distortion reacting upon its transmission qualities. The centre space and the interstices between the four coaxial cores are occupied by fourteen 25-lb. conductor star quads and four 40-lb. conductor screened pairs. The make-up of the cable is illustrated in Fig. **1**.

The installation of the cable between London and Birmingham—a total route length of 125 miles—has been completed. The attenuation-frequency and crosstalk-frequency characteristics of a typical repeater section are given in Figs. **2** and **3**. It will be seen that the maximum gain required is of the order of 50 db. and that the component of attenuation due to dielectric loss amounts to about 20 per cent. of the total loss. In later designs even this low figure has been considerably reduced. The extension of the cable towards Manchester is now in progress.

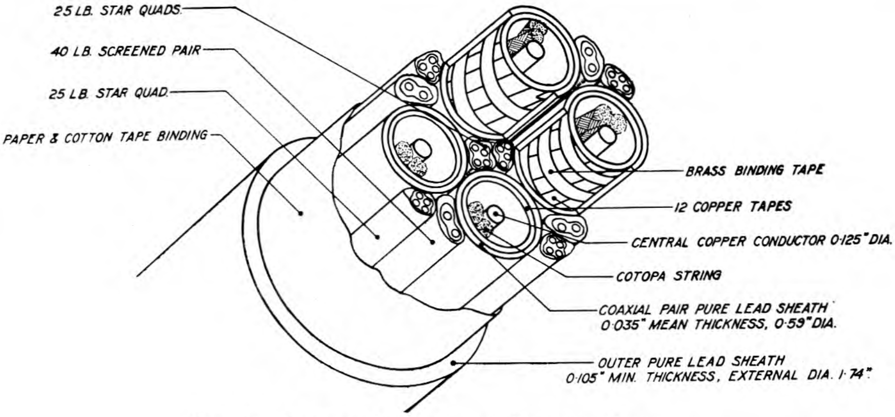


FIG. **1**.—LONDON-BIRMINGHAM COAXIAL CABLE.

Selection of Frequency Band.

When this experiment was begun early in 1935, 1·4 Mc.p.s. was the highest frequency that had been used successfully in the modulation of a television transmitter. The width of the frequency band to be provided for the transmission of television signals was, therefore, fixed tentatively at a value slightly above 1·4 Mc.p.s., namely 1·6 Mc.p.s.; the possibility that it might be desirable to extend this band at some future date has not been overlooked.

The width of the frequency band having been fixed it remained to locate the band in the frequency

---

[3] *P.O.E.E.J.*, Vol. 29, p. 329.
[4] *P.O.E.E.J.*, Vol. 30, p. 138.

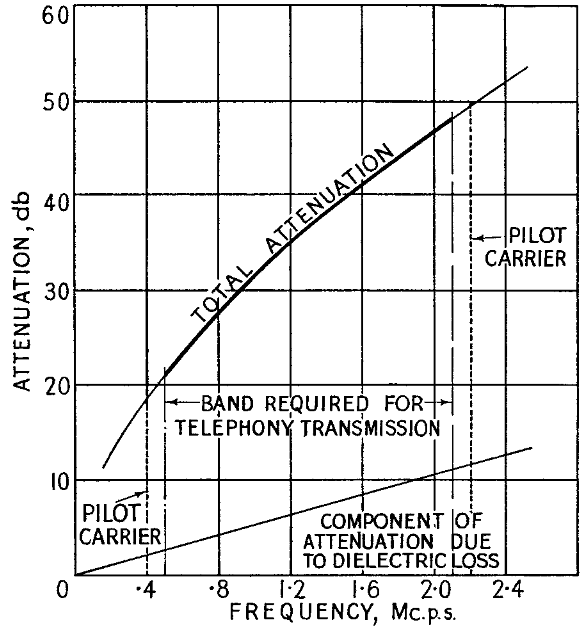


FIG. 2.—ATTENUATION/FREQUENCY CHARACTERISTIC FOR TYPICAL REPEATER SECTION, 7·5 MILES.

spectrum. Consideration of cable attenuation obviously made it desirable to utilise the lowest possible frequencies ; on the other hand the difficulty of designing suitable euqipment increases rapidly as the ratio of the upper frequency limit of the band to the lower limit increases. Preliminary experiments indicated that, initially, it would be inadvisable to use a frequency ratio much in excess of 4. The 1·6 Mc.p.s. band was therefore located between the limits of 0·5 and 2·1 Mc.p.s.

Frequency Separation between Channels.

It was decided to proceed with the design of telephone terminal equipment on the basis of providing circuits spaced at 5 kc.p.s. intervals and to reduce the the spacing to 4 kc.p.s. if this were found to be expedient when the performance of the first part of the installation had been ascertained. The scheme chosen enables the reduced spacing to be adopted with only minor changes in detail. Since the effective transmission band extends from 0.5 to 2.1 Mc.p.s. it is hoped that some ·320 to 400 channels will be provided on each coaxial pair.

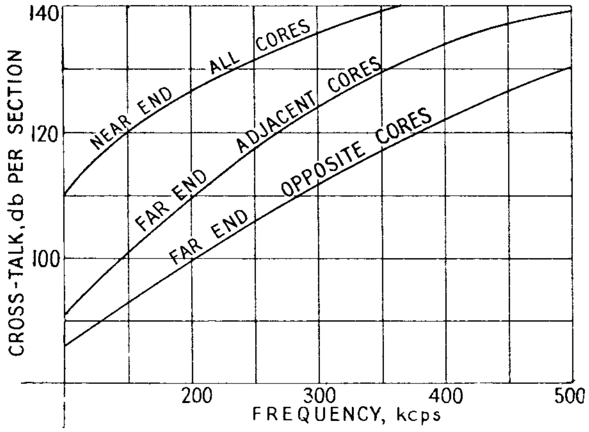


FIG. 3.—CROSSTALK/FREQUENCY CURVES FOR TYPICAL REPEATER SECTION (6·1 MILES).

The frequency band for each audio frequency circuit over which transmission was to be substantially uniform was fixed tentatively at 2,700 c.p.s., although it was felt that at least 3,000 c.p.s. was desirable in view of future developments. It is anticipated that even with the closer spacing of 4 kc.p.s. uniform transmission up to some 3,200 c.p.s. will be effected. See Fig. 4.

The Modulation Process.

Since it is impracticable to modulate directly up to the frequencies actually to be transmitted over the cable, the modulation process must be carried out in several stages. In the present system three stages of modulation have been adopted. Fig. 5 and Table I illustrate the frequency spectra appropriate to the modulation process when 5 kc.p.s. spacing is employed together with the changes involved in an alteration of the spacing to 4 kc.p.s. The adoption of the reduced frequency spacing of 4 kc.p.s. would increase the number of channels in each group from 8 to 10, the band occupied by a group and the arrangement of groups and super-groups remaining unchanged.

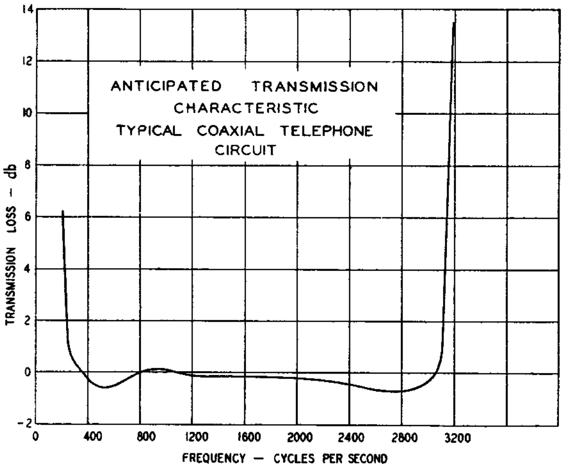


FIG 4—ANTICIPATED CHARACTERISTIC OF TYPICAL TELEPHONE CIRCUIT

The first stage of modulation, using 5 kc.p.s. spacing locates the speech bands between 60 and 100 kc.p.s., eight channels completely filling the band. The groups of eight channels so formed are used to modulate carrier frequencies in group modulators which locate these groups between 300 and 500 kc.p.s. Five groups completely fill the band and form a " super-group " comprising 40 channels. These super-groups are translated to the appropriate portions of the frequency band which the amplifiers have been designed to handle, by means of a final stage of modulation, eight super-groups occupying the whole of the band.

An inverse process is followed in demodulation. Fig. 6, which is self-explanatory, shows diagrammatically the method by which any desired channel is selected from a multitude of incoming channels.

TABLE I

FREQUENCY ALLOCATIONS

Frequency spacing of channels	5 kc.p.s.			4 kc.p.s.		
Channel No.	Channel Frequency Band kc.p.s.	Channel Carrier Frequency kc.p.s.	Channels occupying frequency band kc.p.s.	Channel Frequency Band kc.p.s.	Channel Carrier Frequency kc.p.s.	Channels occupying frequency band kc.p.s.
1	60-65	65	60-100	60-64	64	60-100
2	65-70	70		64-68	68	
3	70-75	75		68-72	72	
4	75-80	80		72-76	76	
5	80-85	85		76-80	80	
6	85-90	90		80-84	84	
7	90-95	95		84-88	88	
8	95-100	100		88-92	92	
9	—	—	—	92-96	96	
10	—	—	—	96-100	100	
Channel carrier frequency multiple of	5 kc.p.s.			4 kc.p.s.		

Group No.	Group Frequency Band kc.p.s.	Group Carrier Frequency kc.p.s.	Groups occupying frequency band kc.p.s.
1	300-340	400	300-500
2	340-380	440	
3	380-420	480	
4	420-460	520	
5	460-500	560	
Group carrier frequency multiple of	40 kc.p.s.		

Super-Group No.	Super-Group Frequency Band kc.p.s.	Super-Group Carrier frequency kc.p.s.	Super-Group occupying frequency band kc.p.s.
1	500-700	1,000	500-2,100
2	700-900	1,200	
3	900-1,100	1,400	
4	1,100-1,300	1,600	
5	1,300-1,500	1,800	
6	1,500-1,700	2,000	
7	1,700-1,900	2,200	
8	1,900-2,100	2,400	
Super Group carrier frequency multiple of	200 kc.p.s.		

No. of telephone channels available	320	400
Brief description of system	8/5/8 (5 kc.p.s.)	10/5/8 (4 kc.p.s.)

The discrimination required for the selection of a single sideband from the products resulting from any modulation step is far higher in the lower frequency than higher frequency stages. Thus crystal filters have been adopted in the initial modulation and final demodulation stage in order that the high selectivity and uniformity of response in the pass band characteristic of this type of filter, may be utilised. Subsequent stages use filters of the more normal type employing inductors and capacitors only.

Fig. 7 is a block schematic to illustrate the assembly of channels, groups and supergroups at a terminal station. For simplicity, only one super-group is shown in complete detail, the additional equipment for further super-groups being indicated to a limited extent.

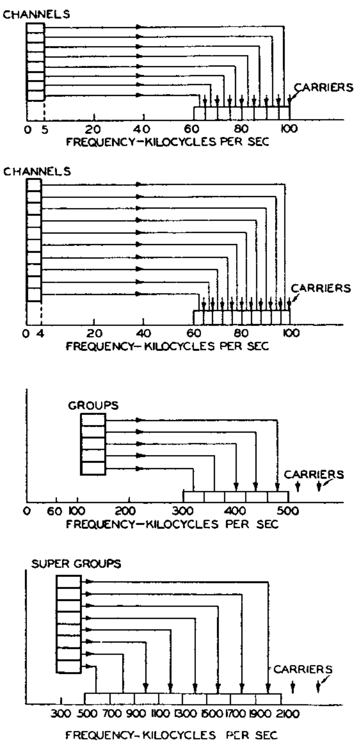
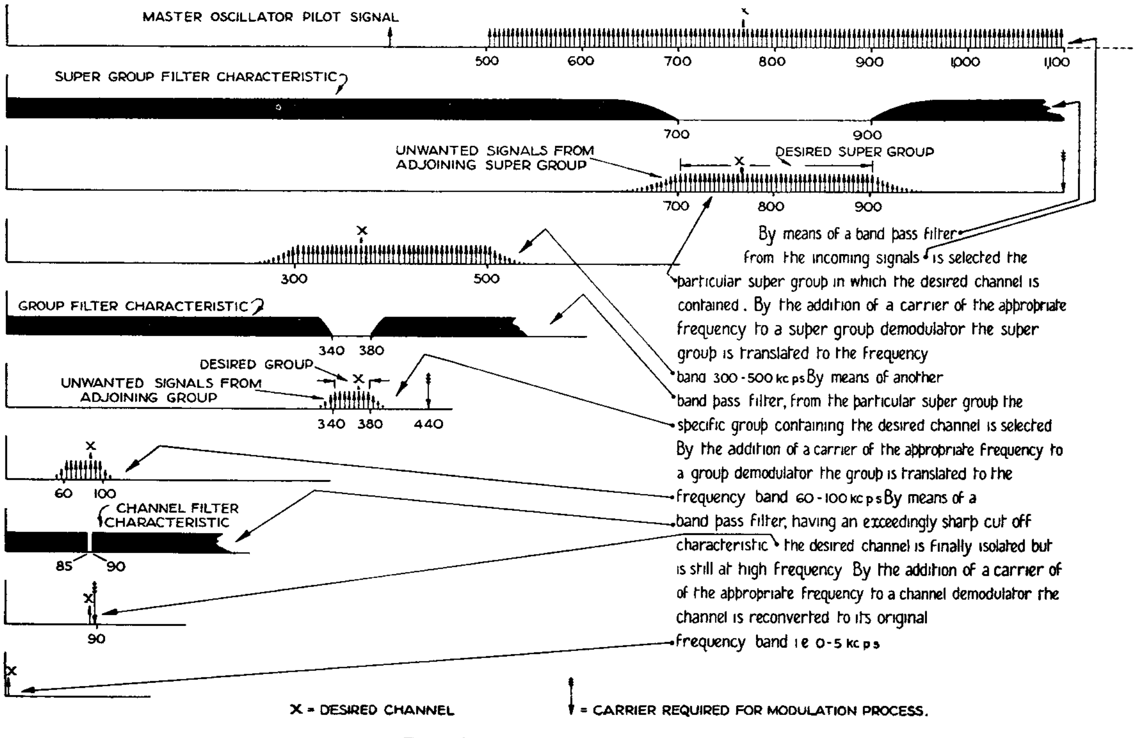


Fig. 5.—Frequency Allocation of System.

Stability of Carrier Supply.

The application of carrier telephony to such high frequencies as those involved in the system being described, demands an extremely high degree of frequency stability and accuracy of synchronisation of the carrier suppliers at each end of the system. The frequency of the carrier reintroduced in the receiving demodulator may be permitted to differ from that suppressed at the transmitting end of the circuit by as much as 20 c.p.s. without reducing the intelligibility of the demodulated speech materially although not without some loss of naturalness. On the other hand, the requirements for voice frequency telegraphs and for music, which might well be transmitted by merging two or more adjacent channels to provide a sufficiently wide frequency band, are very much more stringent, and make it necessary to reduce the frequency difference to the order of one c.p.s. This implies a difference of less than one part in two million between the corresponding carrier frequencies generated at each end of the system.

In view of these stringent requirements the carrier generating equipment has been designed in such a way that all frequencies required at the two ends of the system are derived from a common source by processes of frequency division and multiplication. The master control consists of a crystal controlled oscillator of high frequency stability which is located at one of the terminal stations, the necessary link to the other terminal being provided by means of a pilot frequency transmitted over the line. The frequency of the master oscillator and the pilot have a common value of 400 kc.p.s., a multiple of both 4 and 5 kc.p.s. so that the carrier supplies for 4 or 5 kc.p.s.



By means of a band pass filter from the incoming signals is selected the particular super group in which the desired channel is contained. By the addition of a carrier of the appropriate frequency to a super group demodulator the super group is translated to the frequency band 300-500 kc p s By means of another band pass filter, from the particular super group the specific group containing the desired channel is selected By the addition of a carrier of the appropriate frequency to a group demodulator the group is translated to the frequency band 60-100 kc p s By means of a band pass filter, having an exceedingly sharp cut off characteristic the desired channel is finally isolated but is still at high frequency By the addition of a carrier of of the appropriate frequency to a channel demodulator the channel is reconverted to its original frequency band i e 0-5 kc p s

Fig. 6.—Demodulation Process.

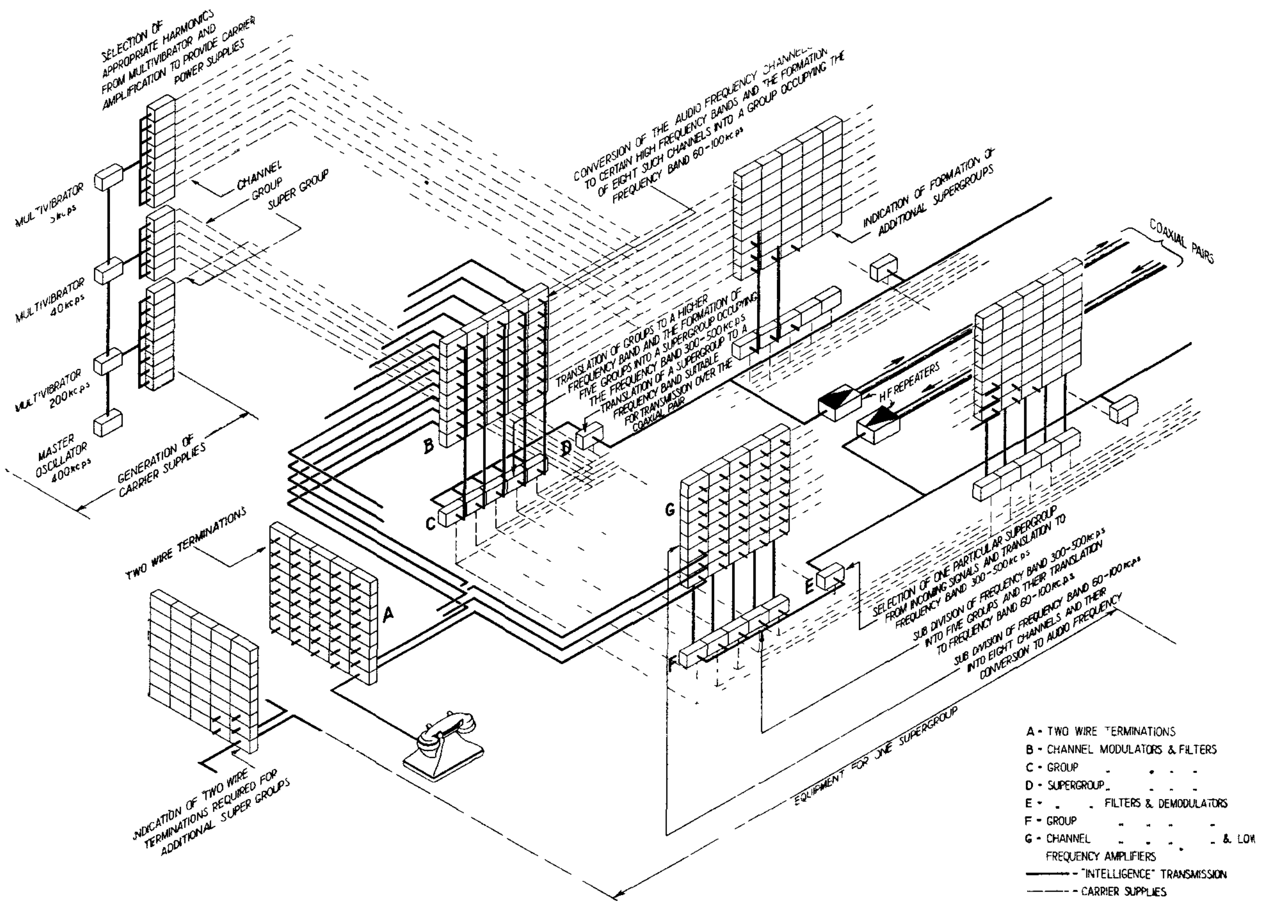


FIG. 7.—SCHEMATIC DIAGRAM OF TERMINAL EQUIPMENT REQUIRED FOR COAXIAL SYSTEM, NEGLECTING POWER EQUIPMENT.

spacing may be derived from the master oscillator without alteration in frequency.

The production equipment at each terminal employs three synchronised multi-vibrators, operating on the fundamental frequencies of 200, 40 and 5 kc.p.s. respectively, from which the three harmonic series corresponding to the super-group, group and channel carriers may be formed. See Table I.

Spacing of Repeater Stations.

The shielding afforded by the outer conductor of the coaxial pair at frequencies above 500 kc.p.s., the lowest frequency used for telephone transmission, is of such a high order that crosstalk and interference from outside sources or between coaxial pairs is negligible. Thus, in this system crosstalk and external disturbance do not limit the level to which the speech currents may be allowed to drop as they do in the normal trunk cable system. Since crosstalk and interference are negligible in the present system thermal agitation noise developed in the cable and valve noise become the factors limiting the drop in speech level that can be tolerated. The thermal agitation noise is strictly amenable to calculation and is a fundamental limitation constituting a constant irreducible noise level at the input of each repeater. In considering the overall noise level for a complete system it must be remembered that the noise introduced in the various repeater sections is additive; the signal-to-noise ratio at the end of a long circuit will therefore be less than it is at the end of the first repeater section.

It is obviously desirable to ensure in the design of the repeater that the intermodulation interference caused by the output signal level—the minimum value of which is fixed by the fundamental limitation detailed above—is appreciably lower than the total resistance and valve noise. It was estimated that the minimum level to which the signals could be permitted to fall, while giving the normal grade of service on circuits up to 400 miles in length, was 60 db. below the corresponding level at entry to the circuit. Making due allowance for future developments of television technique which might require the transmission of a wider band than 1.6 Mc.p.s., and such increased requirements are already being actively discussed, it was decided to limit the attenuation of repeater sections at 2.1 Mc.p.s. to 50 db.

The design of cable adopted has resulted in a permissible maximum repeater spacing of 7.9 miles, the actual lengths varying from 6 to 7.9 miles. The route layout is shown in Fig. 8.

Power Supply to Repeater Stations.

The coaxial tube forms a useful means of transmitting a 50 c.p.s. power supply, and in the present scheme power is fed over the coaxial conductors from selected repeater stations. In general, these

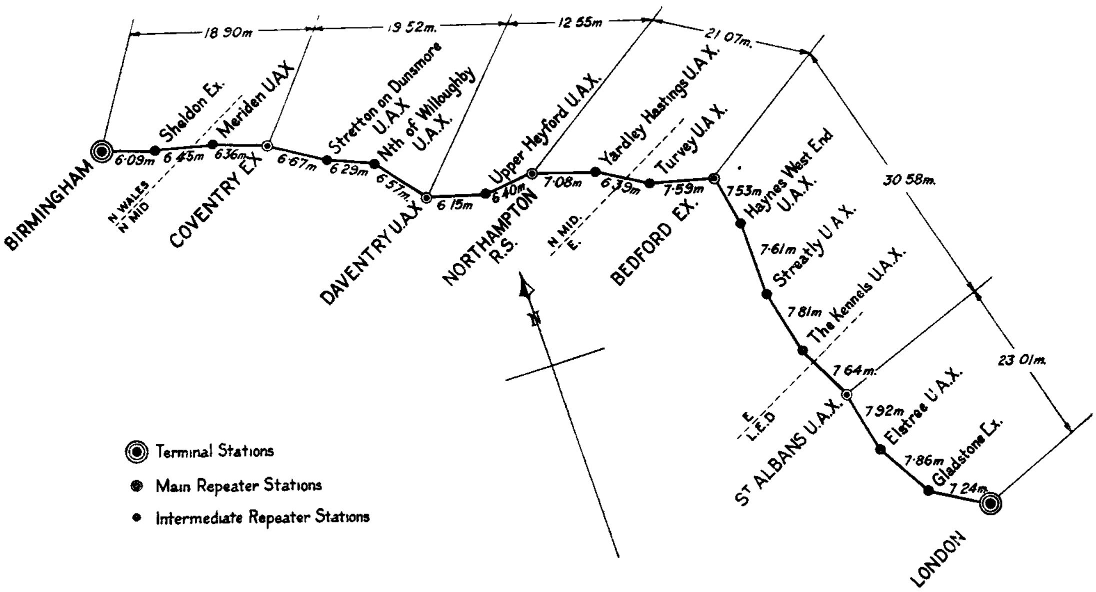


FIG. 8 —LONDON-BIRMINGHAM COAXIAL CABLE ROUTE.

main stations feed one repeater station on either side, the main power feeding points and the intermediate stations which receive power along the coaxial tubes being shown in Fig. 8. It has been possible by this means to reduce the number of supply sources to seven with a consequent reduction in the possible number of power supply failures due to external causes, the reliability of the power supply to the repeater stations being of fundamental importance. Automatic standby power equipment available for immediate operation is being tried at the main repeater station at Northampton. If found necessary similar standby equipment will be provided at the other main stations. The transmitting voltage on this scheme has been reduced to as low a value as is consistent with maintaining the regulation within reasonable limits. A voltage of 350 has been adopted, and with this the factor of safety against breakdown of the cable, which was tested to 2,000 volts in the factory, should be adequate. The power

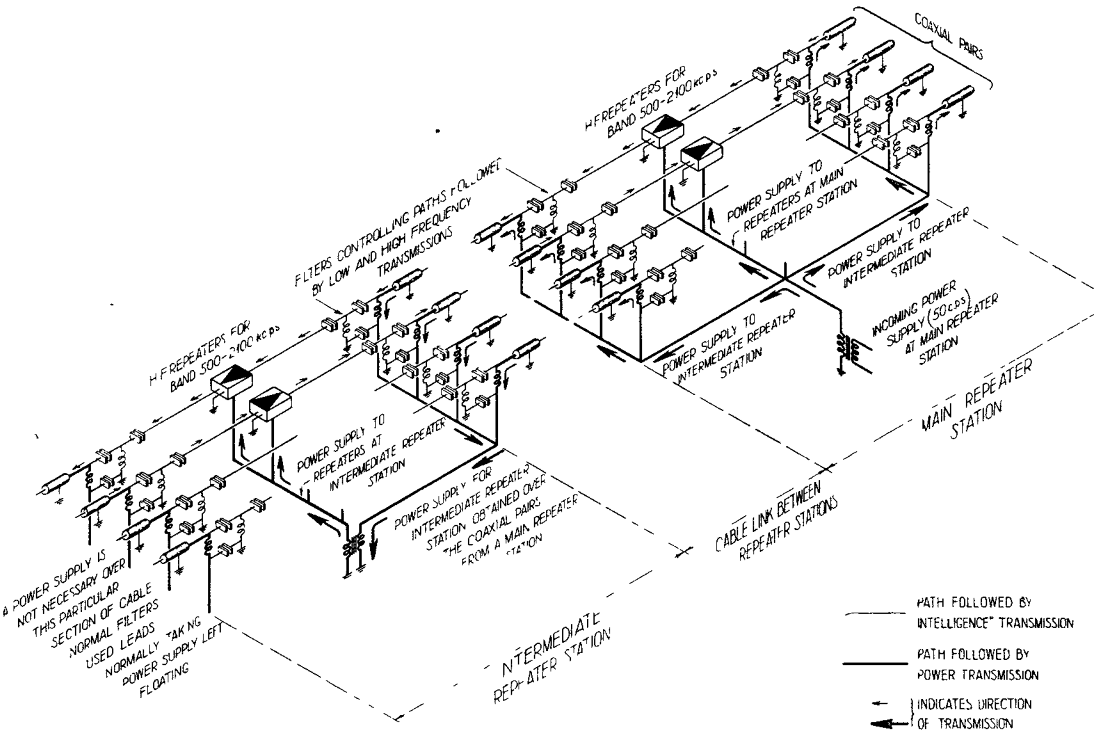


FIG. 9.—SCHEMATIC DIAGRAM ILLUSTRATING SIMULTANEOUS POWER AND INTELLIGENCE TRANSMISSION OVER THE COAXIAL PAIRS.

supply at every main repeater station is stepped up to 350 volts, and all power equipment is designed to operate from 280-350 volts.

For the purpose of power transmission the four coaxial tubes are connected, electrically in parallel, at power supply frequencies by means of low-pass filters teed together. The high frequency signals are bypassed by means of high-pass filters. The arrangements necessary at a typical main and intermediate repeater station are shown in the block schematic Fig. **9**. The high-pass filter has to attenuate the 350 volt 50 cycle voltage so that the power frequency voltage on the grid of the first valve in the repeater produces negligible intermodulation with the H.F. signal channels. The half section, low-pass filter is necessary to prevent crosstalk at high frequencies via any impedance in the power supply and the connections between two coaxial tubes carrying signals at a level difference of up to 60 db., i.e., a crosstalk attenuation of at least 130 db. is required. In addition the low-pass filter has to carry a power current of 2 amperes without undue heating.

Unnecessary transmission of power for lighting, inspection, etc., over the coaxial cables is avoided by having a local power supply brought in to all the intermediate stations.

The High Frequency Repeater.

The possibility of transmitting hundreds of channels through a single output valve operated at a comparatively low anode voltage is perhaps one of the most surprising developments connected with the advent of wide-band systems of telephony. The effective amplitude of speech currents of a single conversation varies widely from moment to moment, and if a few conversations only are handled together in an amplifier it is necessary to provide for instantaneous peak values in an appreciable proportion of conversations coinciding at frequent intervals. When, however, the number of conversations is greatly increased the proportion of these in which simultaneous peak values will occur sufficiently frequently to have a practical bearing on design will be very greatly reduced. In an amplifier handling hundreds of conversations the power will not be greatly in excess of the average power handled by the repeater when all circuits are busy.

The use of negative feed-back repeaters theoretically permits harmonic production to be reduced to any desired value, provided there is sufficient inherent gain to allow of the consequent reduction in gain by feed-back. The realisation of a constant high stage gain over the frequency band concerned requires a valve having a very high value of the parameter (mutual conductance)/(input + output capacitance). It might be stated here that the application of negative feed-back to a high gain amplifier working at these frequencies presents a very definite problem as in order to obtain even a relatively low stage gain the phase shift through the couplings is considerable. Small interwiring capacitances and lead inductance, which can be neglected at lower frequencies, are of paramount importance. The gain of the repeater at 2.2 Mc.p.s. must be 53 db. to provide for the longest repeater section. This does not allow for any additional losses such as that due to internal cabling, or basic loss of the equaliser.

Provision of Spare Repeater Equipment.

For each direction of transmission between London and Birmingham nineteen 4-stage repeaters have to be traversed. For the complete system, therefore, a total of 152 valves are employed on the cable, the failure of any one of which would affect all the circuits. As most of the repeaters are installed in unattended repeater stations, steps have been taken to secure immediate continuity of service in the event of the failure of a valve or other component in the repeater. A spare repeater is provided for each main repeater, the spare being automatically switched in if the main repeater fails.

Equalisation of Attenuation-frequency Characteristic of the Cable.

As mentioned in an earlier section, the level to which the high frequency signals can be allowed to fall is set by resistance and valve noise. If the frequencies corresponding to all the channels are transmitted to line at the same level, only the channel highest in frequency could fall to the prescribed limit since the attenuation of the line would be progressively less for other channels. If the output level of each channel is such that after traversing a repeater section the levels of all channels have fallen to the same point, that is by pre-equalisation, the average power handled by the repeater can be materially reduced without passing the restriction set by noise. For this reason, pre-equalisation has been adopted in the present system.

Compensation of Variation of Cable Attenuation due to Temperature Changes.

Although the cable is laid in buried ducts throughout the route, an appreciable annual temperature cycle is present. Measurements made on cables along the same route indicated that this cycle would be somewhat as shown in Fig. **10** ; recorded temperature

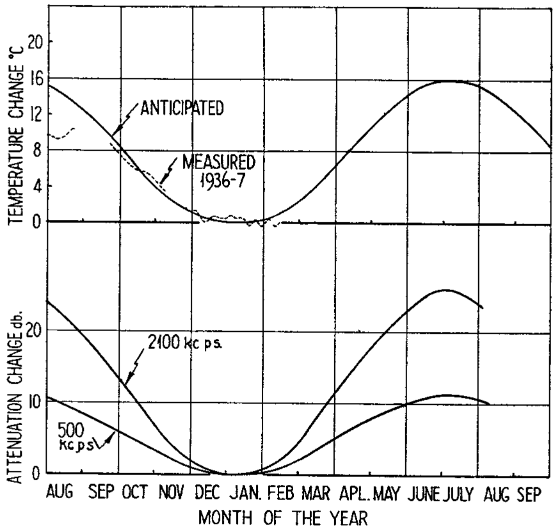


FIG. **10**—RELATIONSHIP BETWEEN TEMPERATURE OF CABLE AND THE TIME OF YEAR, SHOWING ALSO THE CORRESPONDING CHANGE IN ATTENUATION.

measurements made on a typical repeater section during the past few months are superimposed on the diagram. The possible maximum temperature variation limits assumed for design purposes are :—Daily 1°C, Weekly 4°C, Monthly 8°C and Yearly 20°C. The total attenuation of the cable between London and Birmingham at 2.1 Mc.p.s. is approximately 800 db., a value which will be subject to an annual variation of about 30 db. due to these temperature changes. At 0.4 Mc.p.s. the corresponding loss is approximately 340 db, subject to a variation of about 12 db. The difference between the values of loss at the two edges of the band amounts therefore to some 460 db., and in this figure also the annual variations are considerable.

The extremely high cable losses necessitate correspondingly high values of repeater gain and equalisation. The latter quantities have to be balanced against the cable loss with the utmost precision since, for satisfactory operation, it is desirable that the overall transmission loss of cable, repeaters and equalisers, shall be maintained within +2 db. of zero.

Maintenance Control.

Certain of the stations have been termed main repeater stations, and at such stations it is anticipated that staff will always be available to give attention to the cable and equipment under fault conditions. The remaining stations have been termed intermediate repeater stations and their control and maintenance is effected from the main stations. The main control of the system is vested in London and Birmingham and by giving appropriate signals these stations can get in touch, over separate L.F. speaker circuits, with the staff at the main stations and give maintenance instructions for that station and its particular satellites.

The occurrence and location of various failures at both main and intermediate repeater stations is immediately made known at the terminal stations by means of a fault indicating system.

A "Town-Type" Cable Drum Trailer

Cable drum bogies and trailers of conventional design generally suffer from the lack of a ready means of getting the drum from and into the travelling position. The normal method is to use a hand winch mounted on the trailer to haul the drum up or lower it down a long tailboard used as a ramp. This method is cumbersome and the tailboard occupies a considerable length when down, causing congestion in busy thoroughfares.

For suburban and country work, a type of trailer which utilises the movement of the towing lorry to load or unload a drum of cable has been designed and brought into experimental use.[1] The total length of vehicle and trailer during loading and unloading operations is too great for the trailer to be used in the busier streets and an entirely new and different type known as the " town type " trailer has been designed for this class of work.

The " town type " trailer owes something to the cable bogey developed and used in the old Northern District for the Newcastle exchange transfer work, which had as its main features solid rubber tyres, and short track and wheelbase and consequently extremely good manœuvrability. The limitations imposed by subsequent Road Traffic Acts on vehicles intended to be towed at speed has, however, necessitated the addition of springs and pneumatic tyres to bogies of this type with the consequent raising of the centre of gravity and the general loss of " handiness " and manœuvrability. To compensate for this and keep the centre of gravity as low as possible torsion bars have been employed instead of ordinary leaf springs, one end of the torsion bar being rigidly secured to the chassis and the other end carrying an arm on which the road wheel is mounted. Thus any vertical movement of a wheel, e.g., when encountering a bump or pot hole in a road, alters the degree of twist initially put into the torsion bar. The degree of twist in the torsion rod restores to normal when the wheel has passed over the obstruction or depression and thus the rod acts as a spring. The movement of one wheel is not, however, transmitted to the other wheel as each has its own torsion rod and thus independent wheel springing is obtained. The rods are, of course, of suitable spring material, silico-mangenese being normally employed.

It will be apparent that, if during the course of fitting an initial twist is put in the torsion rods and held by a suitable locking device, subsequent removal of the locking device will allow the bars to untwist, and the wheels at the ends of arms on the bars to move relative to the chassis, or, if the wheels are resting on the ground as they are in practice, the chassis to lower relative to the wheels. This in principle is what happens when a drum of cable is lowered to ground level, the chassis sinking till the cable drum spindle is clear of its supporting hooks on the chassis frame.

To raise a drum of cable from ground level, a hydraulic system pumped by hand applies pressure to arms on the torsion rods, so restoring to the latter the degree of twist required to raise the chassis above the wheels, the chassis lifting the ends of the cable drum spindle as it rises. This same hydraulic system takes the load when the locking device is removed to lower the drum, so allowing the latter to sink gradually to the ground.

The trailer is designed for direct cabling as well as cable drum transport and is capable of handling drums up to 8 ft. in diameter and 4 tons in weight.

It is hoped to publish a more detailed description together with experiences of its use at a later date.

---

[1] *P.O.E.E.J.*, Vol. 29, p. 213.

London's Television Twin Cable Links

JOHN COLLARD, Ph.D., M.I.E.E.,
of Electric & Musical Industries, Ltd.

The author gives a general description of the twin cable and equipment installed to link Alexandra Palace to a number of important points in London, in order to provide a television service from these places. A feature of the equipment is the method of equalising simultaneously for both attenuation and phase distortion.

Introduction.

THE inauguration of London's Television Broadcast Service and the resulting need for including in the programmes items taking place at some distance from the transmitting station have brought into prominence the question of providing a system of links capable of carrying the television signals. The problem is a difficult one because, for the successful transmission of the present high-definition 405-line system, a frequency band from zero up to at least 2 megacycles per second is required. Moreover, not only must the circuit be substantially free from amplitude distortion over this wide band, but there must also be very little phase distortion. Freedom from the effects of non-linear distortion and extraneous interference are further requirements which must be met.

One possible method of providing such a circuit is to use a mobile ultra-short wave transmitter with a receiver at Alexandra Palace. Such a radio link has advantages under certain conditions and has actually been used. For places in the centre of London, however, such as Westminster Abbey, Buckingham Palace, the Houses of Parliament, the Cenotaph and the theatres, it is not always convenient or practicable to find space for the radio transmitter van and the transmitting aerial. Furthermore, transmission over the radio link is apt to be spoilt by local interference at the receiving end. It was therefore decided that a television cable network should be installed to link a number of points of interest in the central London area with Alexandra Palace. This has the advantage of requiring at the transmitting end merely a mobile scanning van and provides the greater reliability of service inherent in a cable network.

The signals are transmitted directly over the cable without change of frequency and, in order to avoid the effects of low frequency interference, a balanced type of cable was developed in which two conductors are carried within a single sheath, the signals being applied between the two conductors. Although interference voltages may be induced in the cable, they are of approximately equal magnitude in the two conductors with the result that there is no appreciable interference between the conductors.

The cable was arranged to be tapped at various places so that the mobile scanning van with its associated television cameras could be connected to the cable.

Television Signals.

A brief description of the nature of television signals will help in the understanding of the problem of their transmission. In the television camera the scanning beam traverses the picture formed on the signal plate by an ordinary photographic lens. The beam produces a varying current proportional to the density of the light and shade in the picture along the line it follows. At the end of the line the beam is quickly returned to the other edge of the picture and proceeds to traverse the next line but one. This continues until the bottom of the picture is reached. The beam then returns to the beginning again and proceeds to traverse the intermediate lines which were omitted the first time. Having once more reached the bottom of the picture the whole process is repeated. At the receiving end the cathode ray which traces out the picture must be caused to move and return in step with the scanning beam. At the end of each line, therefore, a synchronising signal is sent to the receiving end and this occurs approximately 10,000 times per second.[1] At the end of the complete picture or frame a different signal is sent, this occurring at the rate of 50 times per second. An approximate idea of the signals to be transmitted will be obtained from Fig. 1 which shows the synchronising signals in the form of square-topped pulses running from the zero line AB to the line EF and lasting for about 10 microseconds. The synchronising signal is followed by a short signal on the line AB corresponding to full black and lasting about 5 microseconds, and then the line signal begins. This varies between full black, line AB, and full white, line CD, according to the picture, and at the end of the line signal the next synchronising signal is sent. The frame signal consists of a series of square pulses of the same sign as the line-synchronising pulse. (This is not shown in the figure.) If in the picture there is a sudden change from full black to full white, the corresponding line signal must rise almost instantly from the line AB to the line CD as shown in the second line signal of Fig. 1.

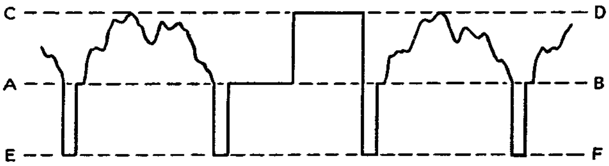


FIG. 1.—TYPICAL TELEVISION SIGNALS.

In order to get the sharp square-topped synchronising signals and the sudden changes in line signals, it is theoretically necessary to transmit all frequencies up to infinity. In actual practice, however, it is found sufficient to transmit up to 2 or, preferably, 2½ megacycles per second. Since the area of the signals is not equal on the two sides of the zero line, it follows that there is a large D.C. component present. If this is removed by passing the signals through some device such as a transformer, the signals will set themselves so that there is no D.C. component, that is to say, so that the areas of the signals are equal

---

[1] Methods of scanning and the nature of television signals are described in detail in *P.O.E.E.J.*, Vol. 30, p. 37.

on the two sides of the zero line. This means in general that the zero line will move over towards CD. Hence the effective height of the synchronising signals below the zero line is increased, which tends to cause overloading at points in the circuit where high level signals exist. In addition, the height of the picture signals above the zero line is reduced so that the general brightness of the picture is wrong. Hence it is necessary either to transmit the complete range of components down to and including direct current or to do what is more usual, and that is to suppress the direct current and low frequencies at the sending end and to re-establish them at the receiving end. This re-establishment is carried out by choosing as reference value some part of the signal, such as the peak of the synchronising signal or the short black signal which occurs before each set of line signals, the correct level of which at the receiving end is known. Then if this arrives at the receiving end at some other level due to the loss of D.C. or, what comes to the same thing, to a loss of the low frequencies, a D.C. signal can be superimposed of the correct value to bring the reference signals back to their proper level. This will automatically restore the picture signals to their correct level with respect to the zero line, and if it is done once every line, i.e. once every 1/10,000 of a second, it will have the effect of re-establishing the D.C. component and any A.C. component whose frequency is so small compared with 10,000 c.p.s. that its effect can be assumed constant over the space of a line signal.

In actual practice the circuit has been arranged to transmit signals with negligible loss from 2 megacycles per second down to 100 c.p.s., and below that frequency the signals are gradually attenuated but are re-established at the receiving end.

Cable.

Since the cable has to transmit frequencies of the order of two megacycles per second, it is essential that, as in coaxial cables, the conductors should be substantially air insulated. The means by which this is attained is shown in Fig. **2**. The two conductors are of 100-lb. copper and each is contained within a paper tube. In order to hold the conductor central within its tube, a double crinkle is formed on the conductor at regular intervals. The conductor therefore approaches the paper tube only at the tops of crinkled portions so that over the greater part of its length the paper is in a relatively weak field. That this construction has been successful in producing a low-loss cable is shown by Fig. **3**, which gives an attenuation-frequency curve for the cable.

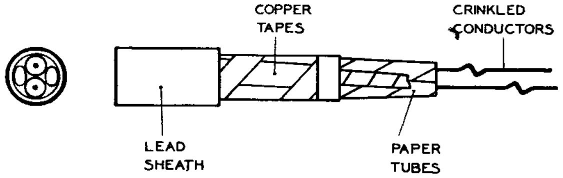


FIG. **2**.—TWIN TELEVISION CABLE.

Two of these conductors, each in its own paper tube, are twisted together; the whole is made up into circular form with paper worming and is covered with a layer of copper tapes and a lead sheath. This construction, while producing a circuit with substantially air insulation, is nevertheless strong mechanically. The fact that the electrical characteristics of the cable were identical before and after laying shows the satisfactory nature of the construction, particularly as it was not possible to provide ducts free of other cables and the route, with many bends, was a difficult one.

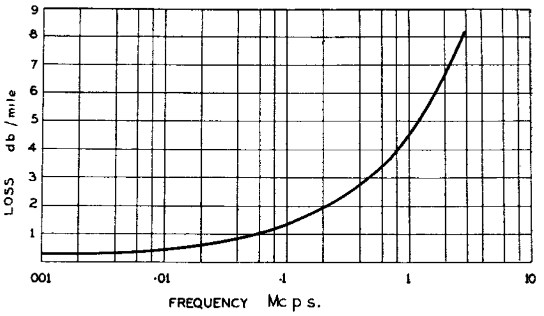


FIG. **3**.—ATTENUATION-FREQUENCY CURVE OF THE CABLE.

Equalisation.

In order to reproduce the steep-fronted square-topped signals required in television, it is found necessary to transmit frequencies up to about 2 megacycles per second with negligible loss. In telephony, provided the various frequency components arrive at the receiving end with little amplitude distortion, the amount of phase distortion is, within relatively wide limits, comparatively unimportant. In television this is not so, since in order to obtain the square pulses it is just as essential that the components should have their correct phase relations as it is that they should have their correct amplitudes. In television, therefore, there is the additional requirement, not usually necessary in other branches of communication work, that phase distortion must also be small so that a time delay independent of frequency is obtained.

Before considering the type of equaliser used, it is necessary to discuss the question of the limits to which the circuit should be equalised. These limits depend on a number of factors; for instance, this cable link up to Alexandra Palace forms only one part of the overall circuit from television camera to television receiver. At one end there are the modulator and radio transmitter followed by the television receiver. At the other end of the cable link there is the equipment of the mobile scanning van. Furthermore, it is possible that the cable link may be extended either by short lengths of relatively small and inefficient feeder cables so as to tap points of interest just out of reach of the main cable, or by long lengths of high grade circuit comprising numerous repeater sections. All these elements of the circuit will introduce distortion of their own, so that the permissible limits for the particular cable link in question must be kept sufficiently small so that, when joined to the other parts of the circuit, the overall distortion remains within the permissible limits. A further consideration to be taken into account is that, as improvements take place in the television technique, less overall distortion will be tolerated. A part of the circuit such as the cable link which is expected to give satisfactory service over a number of years must, therefore, be designed to closer limits than are actually necessary at the start.

Taking all these questions into consideration, it was finally decided that the transmission equivalent of the overall cable link from the input at the mobile scanning van to the input of the radio transmitter at Alexandra Palace should be designed to be flat within ± 0·5 db. from zero to 2 megacycles per second. In order to keep the phase relations right it would be necessary that the angle θ through which each component is rotated in passing over the cable link should be directly proportional to frequency. If, therefore, θ be plotted as a function of frequency a straight line through the origin is obtained. Any deviation from this straight line indicates phase distortion, and the permissible limits for this have been taken as ± 3·5 degrees. Actually at the top end of the frequency range rather more distortion than this can be tolerated, rising to about ± 30 degrees at 2 megacycles per second.

It must now be considered how such exact equalisation of amplitude and phase is possible over a frequency range extending from zero up to 2 megacycles per second. D.C. re-establishment is capable of putting right any distortion in the D.C. component and will also operate on any frequency which is sufficiently low so that its amplitude remains substantially unchanged for the duration of a line, i.e. for about 100 microseconds. In practice it is found that D.C. re-establishment as normally carried out will cater for frequencies up to about 50 c.p.s.

For the higher frequencies the propagation constant of the cable may be written

$$P = \alpha + j\beta = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} + j\omega\sqrt{LC}$$

where

$$\alpha = \text{attenuation constant} = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}}$$

and β = phase constant $= \omega\sqrt{LC}$

It will be seen that if the primary constants R, L, G and C remain invariant with frequency, then the attenuation constant is independent of frequency and the phase constant is directly proportional to frequency. Under these conditions there would be no distortion either of amplitude or phase. Unfortunately, R, L, G and C do not remain constant at the high frequencies, so that both amplitude and phase distortion exist.

Considering first the changes of R and L in a very small length of the cable: if the cable is properly terminated at each end this short length may be assumed to be working into and out of an impedance Z_0 equal to the characteristic impedance of the cable. As the frequency rises the resistance of this short length of cable will rise while the inductance falls, both effects being due to the skin effect in the conductors which causes the current to distribute itself non-uniformly over the cross-section. These variations can be simulated by constructing a circuit which consists of an inductance L_0 in series with a resistance R_0, both being in series with a number of elements each consisting of a resistance R shunted by an inductance L (Fig. **4**). At low frequencies the impedance ωL of each of the elements would be small compared with the resistance R, so that the effects of the various R's in the elements may be neglected. The circuit would therefore have a total inductance equal to $L_0 + \Sigma L$ and a total resistance of R_0. At very high frequencies the ωL terms are large compared with the R terms, so that the effect of the various ωL terms may be neglected. The circuit now has a total resistance $R_0 + \Sigma R$ and a total inductance L_0. Thus the resistance has risen and the inductance has fallen. At intermediate frequencies the inductance and resistance will lie between these limiting values and by adjusting the values of the resistances and inductances of the individual elements, it is possible to make the effective resistance and inductance of the total circuit vary with frequency in exactly the same way as in the small length of cable. The effect of R_0 and L_0 may be neglected since, being constant, they do not produce any distortion of attenuation and phase. Thus only the various resistance-inductance elements need be considered, since, as the length of cable considered is very small, it is permissible to treat each resistance-inductance element as though it existed alone. Let the impedance of one of these elements be A (Fig. **5**) and note that it operates between impedances Z_0, constituted by the rest of the cable and its terminations. One of these impedances Z_0 contains the signal E.M.F. E so that the current passed on to the other impedance is $\frac{E}{A + 2Z_0}$. If A is made zero, the current passed on is $\frac{E}{2Z_0}$. Hence the effect of A is to change the current in the ratio

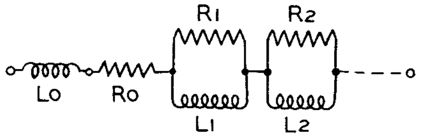


Fig. 4.—Equivalent Circuit of Cable.

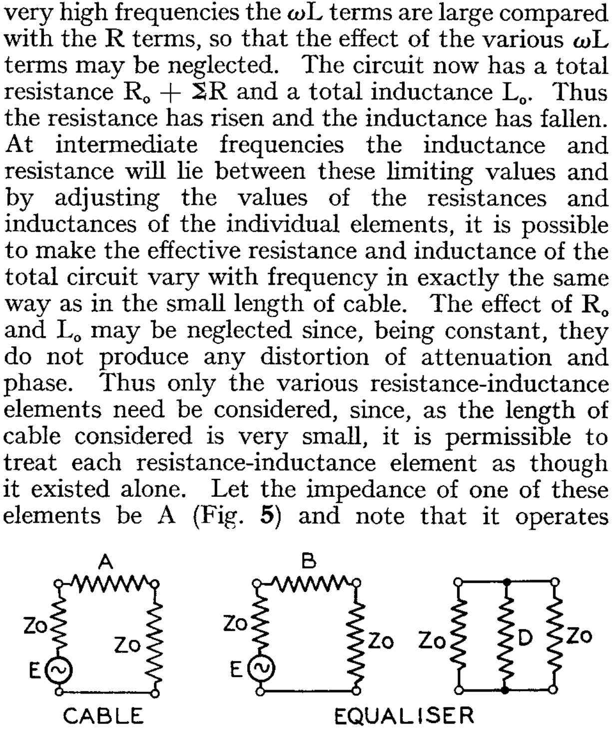


Fig. 5.—Conditions for Correct Equalisation.

$$k_1 = \frac{A + 2Z_0}{2Z_0} = 1 + \frac{A}{2Z_0}.$$

Suppose now an equaliser be constructed with impedance Z_0 and inserted in the middle of it is a series impedance B, the function of which is to eliminate the distortion due to the element A of the cable. The effect of the element B of the equaliser acting between the impedances Z_0 is as before

$$k_2 = 1 + \frac{B}{2Z_0}$$

If the effect of B is to eliminate the effect of A $k_1 k_2$ must be equal to a constant.

$$\text{Hence} \left(1 + \frac{A}{2Z_o}\right) \left(1 + \frac{B}{2Z_o}\right) = \text{constant.}$$

Multiplying out and neglecting the term $\frac{AB}{4Z_o^2}$ as being very small,

$$\frac{A}{2Z_o} + \frac{B}{2Z_o} = \text{constant.}$$

Hence $A + B = \text{constant}$, so that the requirement for correct equalisation is that the impedance A plus the impedance B is a constant at all frequencies. But it is well known that if an element consisting of an inductance L shunted by a resistance R_1 is placed in series with a condenser C shunted by a resistance R_2, then provided $R_1R_2 = \frac{L}{C} = R^2$, the resultant impedance will be constant and equal to R at all frequencies. This indicates that the nature of the equaliser element B must be a condenser shunted by a resistance (Fig. 6).

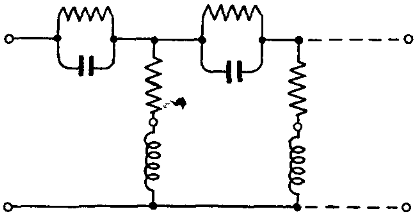


Fig. 6.—Type of Equaliser Required.

In a similar way it can be shown that the effect of the series element A of the cable can be eliminated by using a shunt element D in the equaliser where D consists of an inductance L in series with a resistance R. The condition for correct equalisation in this case can be shown to be $BD = Z_o^2$, or, if B consists of C shunted by R_1 and D consists of L in series with R_2,

$$R_1R_2 = \frac{L}{C} = Z_o^2$$

So far only one resistance-inductance element of a short length of cable has been considered, but it will be clear that each element A of the length of the cable can be similarly treated and also each short length of the total cable. By building up an equaliser as described above, therefore, it is possible to equalise the effect of the total resistance and inductance changes of the cable. In working out the relations for the equaliser complex current ratios were involved, and it follows therefore that, provided the requirements so obtained are satisfied, the equaliser will take care simultaneously of the effects of both the amplitude and phase distortion. This is a very important feature of this type of equaliser because previous methods have required the separate equalisation of amplitude and phase. Moreover, previous equalisers for attenuation usually affected the phase and vice-versa, so that some form of successive approximations was necessary. In the present equaliser, however, not only are phase and attenuation simultaneously equalised, but it is possible to design an equaliser direct from the cable measurements and make it up knowing that there will be no interaction effects to be taken into account.

So far only the equalisation of the effects of resistance and inductance has been considered, but it can also be shown that the effects of changes in the capacitance and leakance of the cable can equally well be taken into account. In fact, the practical design method developed for this form of equaliser merely makes use of the overall attenuation curve of the cable without knowing how much of the change is due to one cause or the other. Furthermore, since both phase and amplitude are simultaneously corrected by this type of equaliser, there is no need to measure the phase distortion of the cable. This is a distinct advantage, since the accurate measurement of attenuation is considerably easier than that of phase.

The proof given above deals with very small sections of equaliser so that a very large number of these would be required to equalise a repeater section of cable. In practice, however, it has been found possible to use relatively large sections of equaliser without departing from the requirement of the simultaneous equalisation of phase and amplitude distortion.

The final design of equaliser consists of a number of sections, each one of "L" type, having a series arm consisting of a condenser shunted by a resistance and a shunt arm consisting of an inductance in series with a resistance. At low frequencies the condenser and inductance cease to be effective and the section then reduces to a plain resistance attenuator. For simplicity of design and manufacture, these sections, with one or two exceptions, have been given a low frequency loss of 3 db. The condensers and inductances are given the values satisfying the relations worked out above and having time constants spaced throughout the frequency range. The impedance of this type of equaliser is a function of frequency so that the correct termination has to be applied to the end of it.

As will be seen from the attenuation curve of the cable, the low frequencies arrive at the receiving end with very little attenuation, whereas the high frequencies are considerably attenuated. If an amplifier is connected directly to the cable so as to amplify the high frequency components, the high level low frequency components are liable to overload the amplifier. Some of the sections of the equaliser are, therefore, connected between the cable and the amplifier. If all the equaliser sections were put between the cable and the amplifier, there would be a danger of attenuating the high frequencies below the noise level of the amplifier. Those sections are therefore selected which attenuate the low frequencies without having much effect on the high. Having passed through this part of the equaliser, the signals can then be amplified. It is not economical to carry out all the amplification at once as this would mean very large valves in the later stages. The amplifier and equaliser are therefore divided up into a number of stages and alternate stages of equaliser and amplifier are used.

The first equaliser must obviously be balanced, since it is connected to the balanced cable. It was more convenient, however, to make unbalanced equalisers and amplifiers so that the following construction was adopted. In order to protect the equipment against any high voltages induced in the cable by short-circuits on neighbouring power cables, an insulating transformer was required. Since it was not practicable to design a transformer to operate satisfactorily over the whole range from zero up to 2 megacycles per second, the transformer was arranged to carry the low frequencies only. Such a transformer at high frequencies can be represented as a series inductance L and resistance R. If a condenser C in series with a resistance R be connected between the two windings of the transformer and $L\,C = R^2$, where L is the leakage inductance of the transformer, the whole device will behave at all frequencies as though it were a constant resistance R. At low frequencies the signals pass through the transformer which, therefore, holds back any voltages induced in the cable. At high frequencies the signals pass through the shunting condenser-resistance circuit and, since there are no induced voltages at the higher frequencies, the fact that the transformer device does not form an insulating barrier at these frequencies is immaterial. Since the transformer and its shunting condenser-resistance network appear like a pure resistance at all frequencies, the device does not produce distortion but will produce a constant loss. However, even this loss has been avoided by realising that the constant resistance of the transformer device could be used as the series resistance of one of the equaliser sections.

Since it is not possible to keep the twin cable very carefully balanced at the very high frequencies unless it is cut into inconveniently short lengths for cross-splicing, there is a possibility that some of the signals may become transferred to the phantom circuit, i.e. the circuit consisting of the two conductors in parallel with earth return. The part of the signals so transferred would be transmitted down the phantom circuit to the receiving end where, since the transformer is not an effective barrier at these frequencies, it might cause interference with the signals received over the side circuit. To prevent this a coil is used having two windings, one in each side of the circuit. This is wound so that to currents in the phantom circuit a high impedance is presented, whereas to the ordinary signal currents the coil is non-inductive. Owing to the fact that the coil will have some leakage inductance, there will be a small resultant inductance in the metallic circuit, and this if left might be enough to cause distortion at the very high frequencies. This effect is avoided by designing the windings of the phantom coil so that the leakage inductance and the distributed capacitance between the two windings make the coil look like a short section of line with the same characteristic impedance as that of the equaliser in which the coil is to be placed.

The first equaliser consists of a few balanced sections connected directly to the cable, followed by the insulating transformer and phantom coil, and thereafter the equaliser is made unbalanced.

The repeater section to which the mobile equipment is connected has a length depending on the tapping point in use, so that the equaliser for this section must be adjustable to suit various lengths of cable. This is done by providing equalisers for 4, 2, 1, ½ and ¼ miles of cable. By connecting up various combinations of these equalisers any length can be equalised from zero to 8 miles in steps of ¼ mile.

Amplifiers.

The television signals as normally produced are unbalanced, that is to say, one side of the circuit is earthed. The cable requires balanced signals and therefore a special amplifier called a Transmitting Unit has been developed which takes the signals from the scanning equipment and converts them into balanced signals for sending over the cable. At Broadcasting House is provided equalising and amplifying equipment. As already explained, the amplification is split up into a number of stages and four are actually used. Identical amplifiers (E.M.I. type CA) are used for these four stages as, apart from reasons of economy, this has the advantage that a single spare amplifier may be used in place of one of the other four if a fault occurs.

These four amplifiers are each preceded by an equaliser and at the output of the last equaliser the signals have been completely equalised up to 2 megacycles per second. At the output of the fourth amplifier is connected a further amplifier (E.M.I. type CB), the function of which is to take the equalised signals and raise them to the correct level to supply a transmitting unit similar to that used in the van. This second transmitting unit is connected to the cable from Broadcasting House to Alexandra Palace.

This equipment is all operated from the 230 V 50 c.p.s. mains. The heaters use 13 V A.C. and direct current for the screens and anodes is supplied from small mercury rectifying valves. Since it is essential, with the rather high gains employed, that the D.C. voltages for the valves should be maintained at steady values, special voltage stabilising panels are provided which can be adjusted so that the effect of mains hum and voltage variation are balanced out.

The amplifiers are provided with meters and keys so that the feeds to all valves may be determined, and in addition a signal monitor is provided for looking at the signals at various places along the chain of equalisers and amplifiers. This monitor consists of a hard cathode ray tube with a variable time base and an adjustable gain amplifier. The signal monitor is used to determine whether signals are passing and whether any distortion is occurring. It can also be used for measuring the voltages at various points in the circuit when setting up the levels of the various amplifiers.

At Alexandra Palace the early stages of the equipment are similar to those at Broadcasting House. At the output of the fifth (E.M.I. type CB) amplifier there is a difference, however, since this is connected to a receiving amplifier. This amplifier performs two important functions. The signals from this equipment are to be handed on to the modulator of the radio transmitter, and since during a given programme this modulator may be switched to local scanning

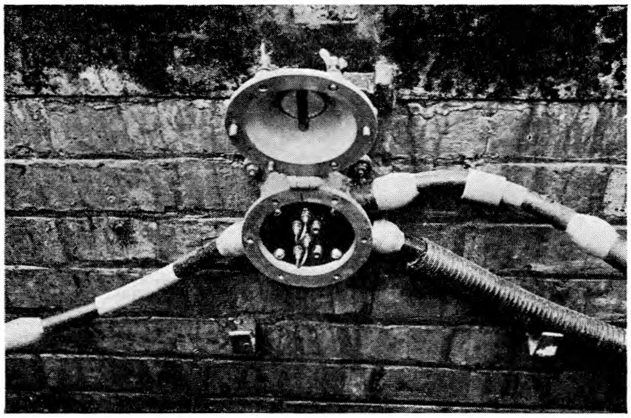


Fig. **7**.—Link Tee Box.

equipment and cameras, to the mobile ultra short wave radio channel, or to the cable equipment, it is essential that means should be provided in each of these so that not only the correct level but also the correct ratio of picture to synchronising signals may be set up in advance so that the modulator can be switched quickly from one to another. The cable equipment has, therefore, been provided with devices for these adjustments, and these are carried out in the receiving amplifier in conjunction with a peak rectifier unit and two meters, one of which is arranged to read the peak synchronising signal and the other the peak picture signal. The second function of this amplifier is to re-establish the direct current and low frequency components. The receiving amplifier is followed by a distribution amplifier, the function of which is to provide a number of outlets, one connected to the modulator of the radio transmitter and the others to the various picture monitors. As at Broadcasting House, rectifiers and voltage stabilisers and a signal monitor are provided.

All the amplifiers in this equipment have been designed and adjusted to have flat characteristics up to about **3** megacycles per second, attention also having been paid to phase correction.

General Arrangement.

The attenuation of the cable is such as to make a repeater section of about 8 miles desirable; the cable was therefore divided into two repeater sections. The first section is of fixed length, about 7¼ miles, and runs between Broadcasting House and Alexandra Palace. The transmitting unit for producing the balanced signals for this section is situated at Broadcasting House, while the remainder of the amplifiers and the equalisers are at Alexandra Palace. The second section is of variable length depending on the tapping point in use and consists of a cable from Broadcasting House to Whitehall telephone exchange, where it can be connected through to a cable running to Victoria Station, or to a cable to St. Margaret's Church, Westminster. All three of these cables have terminal boxes (Fig. **7**) inserted at a number of places so that the cable can be interrupted and connected through a small stub cable to a socket. A flexible twin cable from the scanning van terminates in a plug for connection to these sockets. Tapping points are at present provided at:—

> Grosvenor House; Apsley House; London Pavilion; Colour Court, St. James' Palace; Buckingham Palace; Victoria Station; Horse Guards; the Cenotaph; and St. Margaret's Church.

Provision has been made for inserting other tapping points if necessary. The transmitting unit for this variable length section is provided in the scanning van, while the amplifiers and equalisers are at Broadcasting House. The equaliser has been made adjustable to suit the particular length of cable in service and also equalises the short length of flexible cable used to connect the van to the main cable.

When the circuit is in use the unbalanced signals from the mobile scanning equipment are passed to the transmitting unit in the van where they lose their D.C. component and are transformed into balanced signals. They are then passed over the flexible twin cable to the main cable by which they are transmitted to Broadcasting House. Here they become unbalanced again and are equalised and amplified and are finally passed to the transmitting unit where they are changed to balanced signals for transmission over the cable to Alexandra Palace. At the Palace the signals are again equalised and amplified and the D.C. component is re-established. The ratio of picture to synchronising signal is then adjusted to unity and the signals, which are now an exact reproduction of those produced in the mobile scanning equipment, are finally passed to the modulator of the radio transmitter.

At each place the equipment is arranged on two racks and an idea of these will be obtained from Figs. **8** and **9** which show similar sets of equipment. Fig. **8** shows the front view of two racks with the L.T. panel and H.T. rectifier at the bottom of the left-hand

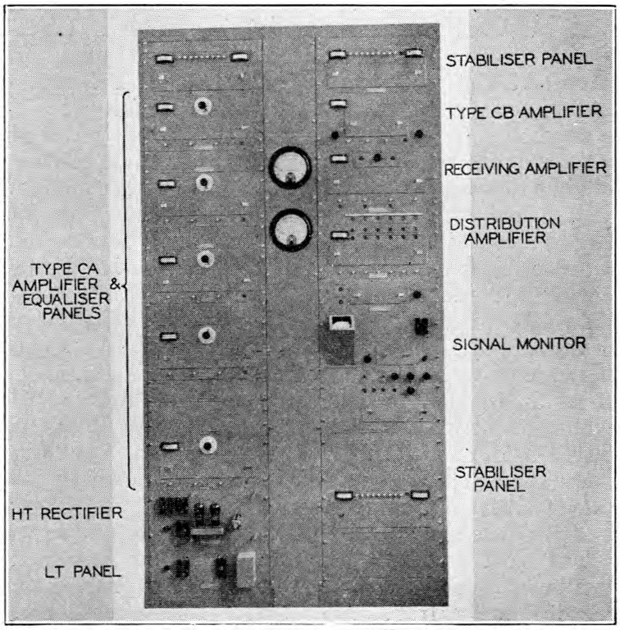


Fig. **8**.—Front View of Equipment Racks at Alexandra Palace.

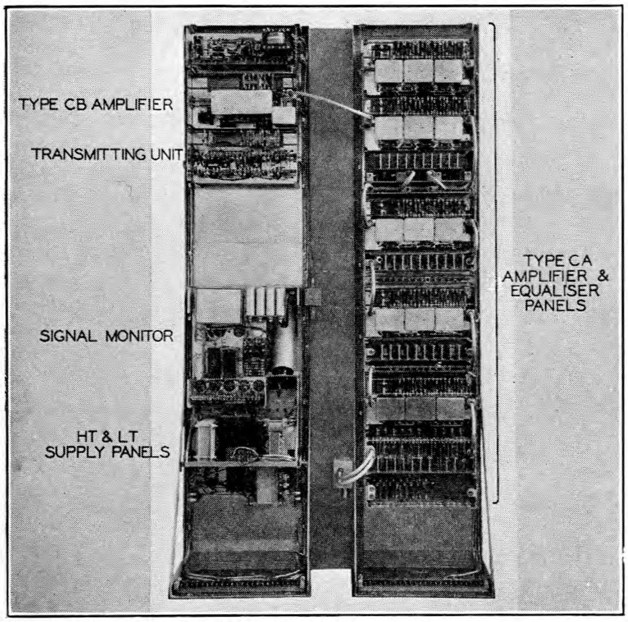


FIG. **9**.—REAR VIEW OF EQUIPMENT RACKS AT BROADCASTING HOUSE.

rack. Above this are alternate CA amplifiers and equaliser panels. On the right-hand rack at the top is a stabiliser panel followed by a CB amplifier, a receiving amplifier with its adjustments for D.C. re-establishment and picture to synchronising signal ratio, a distribution amplifier for supplying the radio transmitter and picture monitors, a signal monitor for checking the signals passing through the circuit and a second stabiliser panel. Fig. **9** shows the back view of two racks with a variable equaliser as used at Broadcasting House. The right-hand rack carries the equalisers and CA amplifiers which are connected by means of flexible coaxial leads so that adjustment of the equaliser can be made to suit the length of cable in service. The last CA amplifier can be seen connected across to the CB amplifier, below which is the transmitting unit for producing the balanced signals. At the lower part of the left-hand rack is a signal monitor, and below are H.T. and L.T. supply panels.

Performance.

A curve is shown in Fig. **10** giving the overall transmission equivalent of the complete link at different frequencies. This curve was obtained by applying a fixed voltage at different frequencies to the cable at Whitehall telephone exchange and measuring the resulting voltage at the output of the distribution amplifier at Alexandra Palace. As will be seen, the curve is flat within the limits of ±0·4 db. over the whole frequency range from 100 to 2,000,000 c.p.s. Below 100 c.p.s. the overall attenuation rises, but this is put right by the process of D.C. re-establishment, so that the complete circuit, when television signals are passing, is effectively flat from zero to 2,000,000 c.p.s. The design value of ± 0·5 db. has therefore been met. The circuit is completely free from interference both in the cables and in the equipment. There is a possibility that high voltages may be induced in the cable if a short-circuit occurs on a neighbouring power cable. Protection of the television cable is therefore provided by insulating it for 1,000 V A.C. Since the cable is terminated at the transmitting end by the low impedance cathode circuits of the transmitting unit, any voltages induced in the cable will appear at the insulated receiving end of the cable. At this end the insulating transformer in the first equaliser panel protects the equipment from harm and is insulated for the same voltage as the cable.

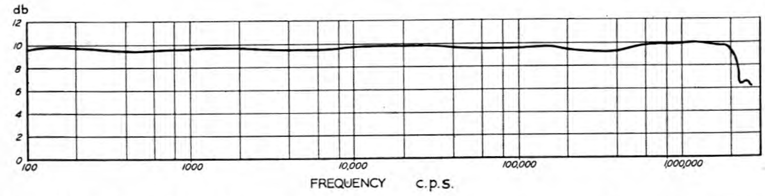


FIG. **10**.—OVERALL TRANSMISSION EQUIVALENT OF THE COMPLETE LINK, WHITEHALL EXCHANGE TO ALEXANDRA PALACE.

The first official use of the cable link was made on May 12th, 1937, when the Coronation procession was televised[2] from Hyde Park. The television cameras and mobile scanning van were placed near Apsley Gate. The signals from the scanning equipment, having been transformed to balanced signals by the transmitting unit in the van, were passed by way of a short length of flexible twin cable to the Apsley Gate tapping point on the main cable. From here the signals passed to Broadcasting House and thence to Alexandra Palace and the modulator of the radio transmitter. The whole broadcast was exceedingly satisfactory and although an ultra short-wave radio link from Hyde Park Corner to Alexandra Palace was held in reserve in case the cable link broke down, there was no occasion to use it.

The success of this television cable link, which forms an outstanding achievement in this new branch of communication engineering, is due to the combined efforts of many engineers, both of the Research Department of Electric and Musical Industries, Ltd., where the link was developed and the equipment manufactured, and of Siemens Bros., Ltd., who co-operated in the development and manufacture of the cable. Thanks are due to these engineers for their work and to the two companies for permission to publish this article.

---

[2] *P.O.E.E.J.*, Vol. 30, p. 115.

Anglo-Dutch Coaxial Cables

R. M. CHAMNEY, B.Sc., A.K.C., A.M.Inst.C.E.

A description is given of the new Anglo-Dutch Submarine Cables, over which one 1+4 and one 12-channel carrier telephone system will be worked.

Introduction.

A DIRECT Anglo-Dutch telephone service was opened in 1924, when a 4-core, gutta percha-insulated, coil-loaded cable was laid between Aldeburgh in Suffolk and Domburg in the Island of Walcheren at the mouth of the Scheldt. This cable provided three circuits, two sides and one phantom. The growth of traffic was rapid and in 1926 a 4-quad, paper-insulated, continuously loaded cable was laid between the same points. This was followed two years later by a second cable of a similar type, also laid between the same points. The three cables provided 27 circuits. Further development was met by an intensive system of phantoming on the two paper core cables which brought the number of circuits available to 35. At a later date six carrier telephone circuits were also added.

The inevitable deterioration in the degree of balance of the cables, which occurs when repairs are carried out, necessitated the subsequent withdrawal from service of the super-phantom circuits. This, together with the demands for new circuits, made the laying of further cables essential. It had also become uneconomical to retain the original 4-core cable in service and this was recovered, thus allowing the new cables to be laid over the same route.

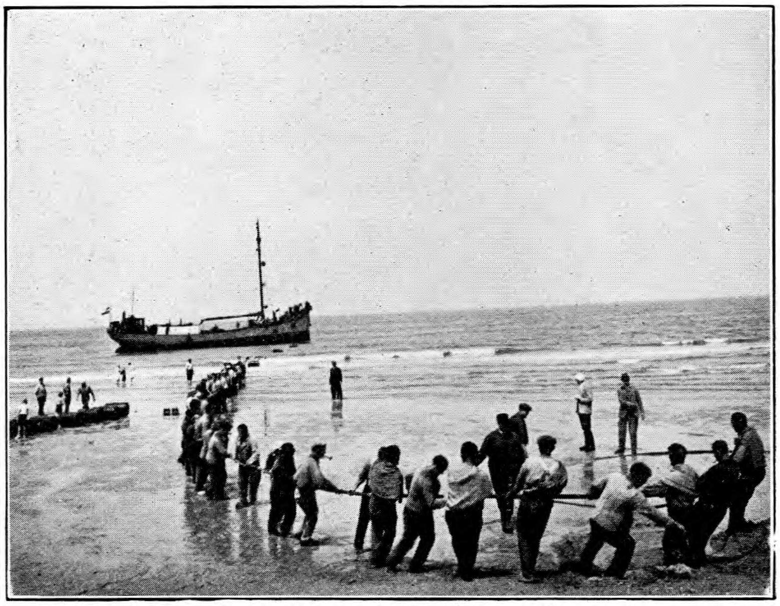


FIG. 2.—LANDING THE SHORE END AT DOMBURG.

FIG. 1.—LAYING THE SHORE END AT ALDEBURGH.

Design of Cables.

The design selected for the new cables was similar to that adopted for the cables laid in the Bass Straits between Australia and Tasmania. The two cables each consist of a centre conductor weighing 508 lbs. per nautical mile, which, for reasons of flexibility, is made up in the form of a solid wire 0·138 inch in diameter surrounded by a helix of six copper tapes each 0·015 inch thick. This is covered with paragutta weighing 690 lbs. per nautical mile to a diameter of 0·62 inch. Paragutta is one of the newer insulating materials of the de-resinated balata type. It has very low dielectric losses and its use results in a substantial reduction in attenuation at high frequencies. The return conductor takes the form of six copper tapes applied over the paragutta with a long lay. Each tape is 0·018 inch thick and the total weight is 850 lbs. per nautical mile.

The return conductor is covered only with the usual jute serving and galvanised iron armouring wires, and is in contact with the sea water. As is usual with this type of construction, alternating speech currents tend to travel only on the outer surface of the central conductor and the inner surface of the return conductor. Therefore in spite of the continuous contact between the return conductor and the sea water, the latter does not form part of the transmission path.

Paragutta deteriorates fairly rapidly when exposed

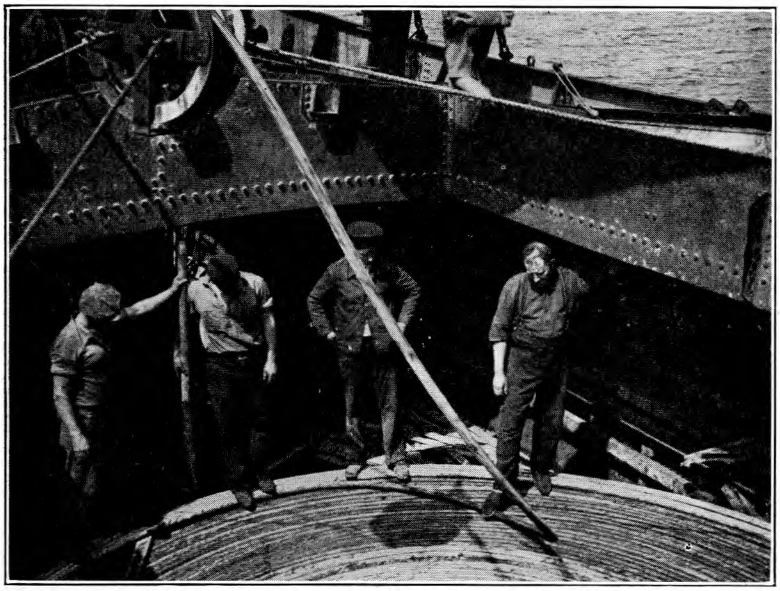


Fig. **3**.—Paying Out the Cable from the " Pallas."

to the oxydising influence of air, and in order to prevent this a thin lead sheath is included under the armouring wires in that portion of the cable laid between low-water mark and the terminations in the two repeater stations.

The order for the manufacture and laying of the cables was entrusted to Messrs. Submarine Cables, Ltd.

Laying Operations.

Laying operations commenced during the first week in June and were completed by the end of June. The cable ship " Faraday " with all the cable on board proceeded to Aldeburgh and there coiled shore ends, each about three nautical miles in length, into the Dutch vessel M.V. " Pallas," which is of sufficiently shallow draught to enable her to approach close inshore. The " Pallas " then proceeded to lay the shore end of the north cable, followed by that of the south cable from Aldeburgh and later carried out similar operations at Domburg. All four shore ends were buoyed ready to be picked up by the " Faraday " for jointing to the main cable. Fig. **1** shows the laying of a shore end at Aldeburgh from the " Pallas." The cable is floated in on drums and then hauled up the beach. The beach at Aldeburgh is steep and shingly, so that it was necessary to trench fairly close down to low-water mark. Fig. **2** shows a shore end being landed at Domburg, where the beach is flat and sandy, and required a large gang of men to haul the cable up to the repeater station. The cable in the hold of the " Pallas " being paid out during laying is shown in Fig. **3**.

Coincident with these operations, the " Faraday " was buoying the route out from Aldeburgh up to the midway position of the north cable. For reasons given later in this article it was necessary for the final splices to be at a central point between the English and Dutch coasts. The weather was extremely calm, but sea mist and low visibility made the operations somewhat slow. It is not easy even with good visibility to take bearings on a mark buoy five miles distant, so that this operation took a considerable time. The accurate laying of mark buoys over the route is an important operation. The subsequent laying of the cable is made following the route of these buoys and any discrepancy in their position may cause a greater length of cable to be laid than is necessary.

The actual laying of the main cables was carried out in good weather making this operation a relatively easy task. Fig. **4** shows the cable being paid out over the bow sheaves of the " Faraday."

On the completion of the laying of the cable the mark buoys are recovered. To a spectator this is an exciting piece of work, but from the seaman's point of view a very dangerous operation. The buoys are anchored by means of a chain and mushroom which must be released before the buoy can be hoisted on to the ship. A boat pulls away from the ship taking two lines, one of which is made fast to the buoy and is used for hauling it up by means of the ship's derrick. The second line is made fast to the anchor chain, which is attached to the buoy by means of a shackle bolt and is released by this bolt being knocked out. This is where the excitement and danger occurs. The buoy and the boat are both bobbing about in the sea and their motions naturally being different the work of the seamen in releasing the bolt is more often miss than hit.

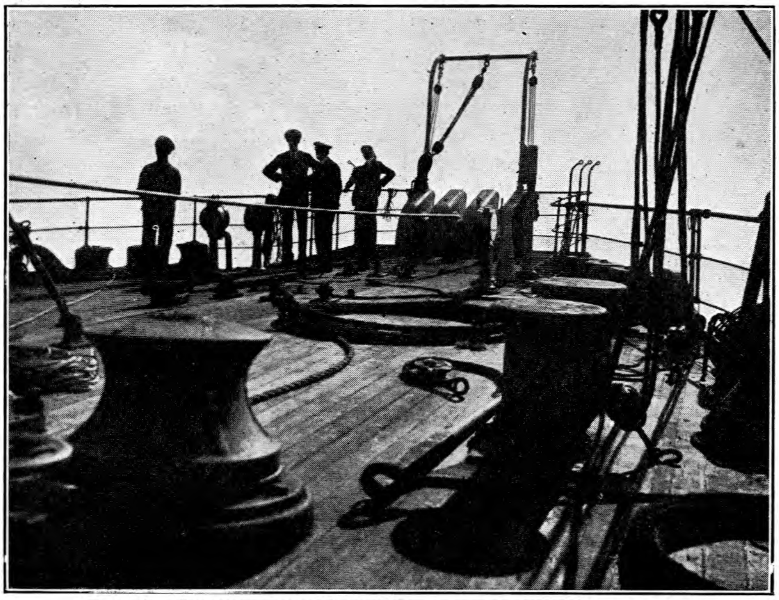


Fig. **4**.—Laying the Main Cable from the " Faraday."

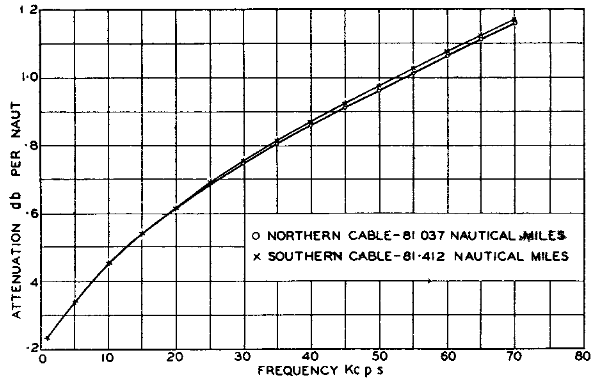


FIG. 5.—ATTENUATION-FREQUENCY CURVES.

Test Results.

On completion of the work the cables were found to comply with the specification in every respect. The attenuation frequency curves for the cables are shown in Fig. **5** and a typical impedance frequency curve in Fig. **6**.

During manufacture elaborate precautions were taken to ensure that the impedance frequency curve should be smooth at the lower frequencies where it might be possible to use " two-wire " working. This was mainly effected by selecting lengths for jointing so that their impedances progressed gradually from a mean at the ends to a maximum or minimum value at the centre point of each completed cable. It was necessary therefore during laying operations to preserve, as far as possible, the relative position of the short " core-lengths " as arranged. It being impossible to determine the exact length of cable required beforehand, the cables were laid from shore to a centre point where the final splices were made. In this way any abrupt changes in impedance would be in the centre of the cable where they would have the least effect on the impedance frequency curve taken from either end.

The manner in which the self-screening tendency of coaxial cables develops as the frequency is raised is illustrated in Fig. **7**, which shows the crosstalk measured between the two cables.

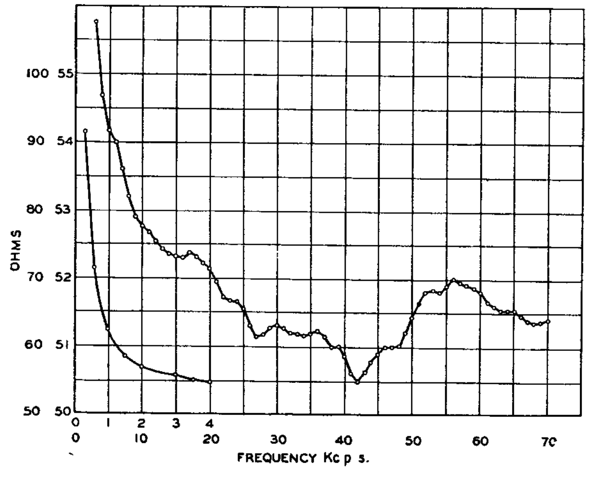


FIG. 6.—MODULUS OF CHARACTERISTIC IMPEDANCE.

Carrier Equipment.

The initial installation of carrier equipment to work on the cables will provide a total of 16 4-wire circuits employing a frequency bandwidth from 200 c.p.s. to 60 kc.p.s. Two separate carrier systems will be used, one occupying the range 200 c.p.s. to 16 kc.p.s. and the other the range of 16 to 60 kc.p.s.

Five circuits are provided in the lower frequency band, the equipment being of the Carrier System No. 4 type (1+4).[1]

The equipment utilising the upper band is of the Carrier System No. 5 type (12 channel). The principles of this system have been described recently in the Journal.[2] Normally the lowest channel of the 12-channel type equipment uses the lower sideband of 16 kc.p.s. carrier, which is also the band used for the top channel of the 1+4 system. The equipment for the bottom channel of the No. 5 System has therefore been omitted and 11 channels only are provided. Separation of the two systems at the terminal stations is effected by means of filters.

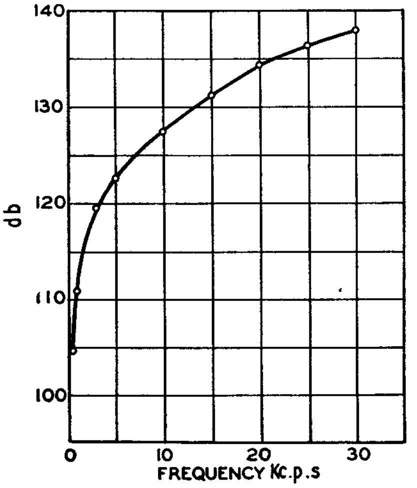


FIG. 7.—CABLE-TO-CABLE CROSSTALK AT ALDEBURGH.

To avoid the loss of all circuits in the event of one of the submarine cables failing, directional filters and a " U " link change-over arrangement have been installed. The directional filters divide the frequency spectrum employed into halves, used one for each direction of transmission. By this device, five 4-wire circuits may be worked on the unaffected cable.

The 1+4 equipment has already been installed and is now working. The 12-channel type equipment will be installed at an early date.

The Research Branch has designed and constructed the Carrier System No. 4 type equipment and the system separating, and directional filters, while the 12-channel type equipment is being manufactured by Messrs. Standard Telephones and Cables, Ltd.

---

[1] *P.O.E.E.J.* Vol. 29, pp. 226 and 294.

[2] *P.O.E.E.J.* Vol. 29, p. 223.

Reproduction of Prints of Drawings and Diagrams in the E.-in-C.O.

A. E. JOHNSTON

The author describes the processes employed by the Engineer-in-Chief's Office Photocopying Group to meet the large demand for drawings and diagrams of all kinds.

Introduction.

THE maintenance and development of the telegraph, telephone and radio services involve *inter alia* the preparation of very large numbers of drawings and diagrams. Many thousands of tracings are extant and, with the intensive development of the telephone services particularly, the number of drawings and diagrams is being augmented day by day.

Engineering officers throughout the country have to be provided with prints of these drawings in order that the day-to-day work of the Engineering Department, both development and maintenance, may be carried out expeditiously and smoothly.

It will readily be appreciated that a vast amount of work is involved in supplying the necessary prints, and a few statistics will indicate at a glance what the Engineer-in-Chief's Office Photocopying Group—which forms part of the Editorial and Office Practices Branch—has turned out during the year ended 31st December, 1936 :—

Blue Prints and Dye-line	243,295 copies
True-to-scale ..	321,616 ,,

The whole story is not told by the foregoing figures, as in addition it was necessary, owing to the extreme pressure which existed in the Print Room in June last, to enlist the aid of outside contractors, and their efforts resulted in the production of upwards of forty thousand copies of drawings and diagrams by the blue print, dye-line and true-to-scale processes.

It should be borne in mind that the figures quoted in the above statement relate to the actual printing carried out in the Print Room and do not include litho prints issued from stock which in themselves totalled about one-quarter of a million. These prints were in the main reproduced in the Rotaprint Group on Rotaprint machines.

But these figures, large as they are, seem to be hardly more than a drop in the ocean when it is noted that in the course of the year 1936 over three million copies of loose-leaf diagrams were produced by the Rotaprint method for distribution to workmen and others throughout the country. Altogether over twenty thousand requisitions for prints are dealt with in the course of a year. The several photographic contact processes employed to meet this demand are described in the following paragraphs.

Blue Prints.

This, the most widely known of the contact processes, dates from about 1842, in which year Herschel read a paper on the subject before the Royal Society. The process consists of placing a transparent original in direct contact with a sheet of paper which has been previously sensitized by coating it with a ferro-prussiate solution and then exposing it to a bright light. The action of the light changes the ferric into ferrous salt which, combining with the ferricyanide of potassium (giving the characteristic blue), becomes insoluble in water. The paper is then washed in water, which removes the unaltered and soluble ferric salt and in turn develops and fixes the print. The print is then dried and the result is a white outline copy of the original tracing on a blue ground. A disadvantage of this process is that the washing in water causes a slight shrinkage of the paper so that it is necessary for the original tracing to be fully dimensioned.

So far as the Post Office is concerned it is a process which will gradually fall into disuse, as it is normally only used when the original tracings are in such a bad condition as to preclude reproduction by other methods, e.g. Dye-line and True-to-scale.

Dye-line.

This process is similar to the blue print process so far as the initial stage is concerned. A paper sensitized with an almost colourless substance is used and the action of light has the effect of neutralising or bleaching the parts unprotected by the ink on the tracing. The image which is almost invisible is then darkened and made permanent by passing the sensitized surface over a motor-driven plated roller running in a trough of developing solution. The damping necessary to effect development is so slight that little, if any, shrinkage of the paper is involved.

This process needs tracings to be in good condition to avoid a dirty background, as creases and discolourations are liable to be reproduced. The prints, which consist of a brown outline on a white ground, have a tendency to fade with long exposure to light, with a resultant degradation of the background.

In both the blue and dye-line processes continuous arc-lamp copiers are used for the production of the undeveloped print (Fig. **1**).

True-to-scale.

This process, known also as the " Ordoverax " process, is in essentials a litho process except that instead of the copies being run off a litho stone they are run off from an etching made on a special gelatine composition.

The gelatine is coated on a special table (Fig. **2**) consisting of an endless band of linoleum running over and under the table. To coat the table with the composition of gelatine and iron salts the linoleum is wound slowly past a trough containing the liquid gelatine. The trough is kept pressed against the vertical part of the lino which in passing takes up a thin coating of gelatine.

Briefly the operations in the process are :—

(*a*) An undeveloped ferro-prussiate print is laid face down on the table, lightly rubbed all over and then removed. The lines, &c., of the blue print etch the surface of the gelatine.

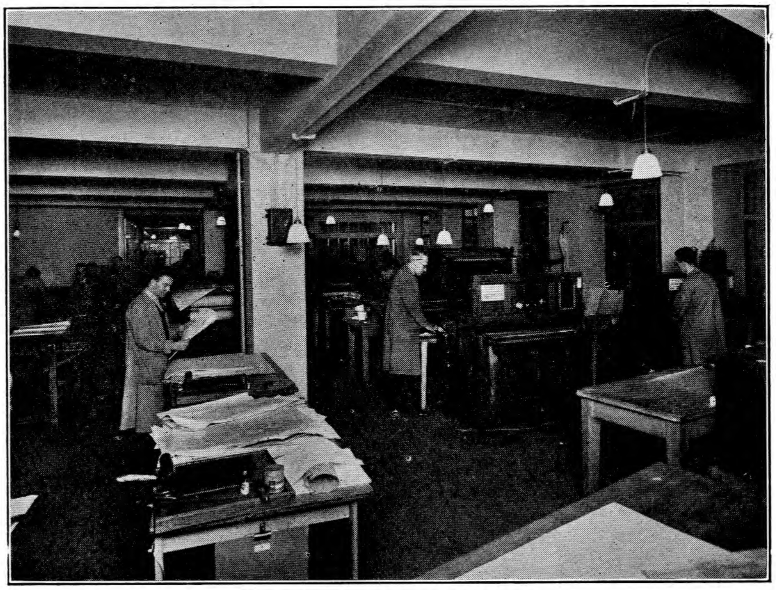


FIG. **1**.—ARC-LAMP COPIERS.

(*b*) Printing ink is then applied with a roller to the surface of the gelatine, the etching only taking up the ink.

(*c*) A sheet of paper is then laid on the gelatine and receives the inked image, the result being a True-to-scale print of the original tracing.

When the whole of the gelatine surface has been covered with images the gelatine is scraped off the linoleum and a fresh coating applied.

It may be added that two or three coloured inks can be used on this process and, in fact, are so used for Call Office Notices prepared for the Telecommunications Department.

The principal advantages of the True-to-scale process are that the copies (*a*) are " true-to-scale " as they are not wetted and there is, therefore, no shrinkage, (*b*) they are permanent in character, and (*c*) that almost any type of flexible material can be printed on, e.g. card, opaque and transparent linen, thin metal and leather. The method is, however, slow.

" Gesteprint."

This is a process which has recently been used experimentally, with a view to providing an alternative to the " True-to-scale " method of reproduction.

Briefly, the Gesteprint process, which is based on the principle that certain colloids are rendered insoluble under the action of light, consists of using a sensitised Gestetner stencil, called a " Gestefilm " and made of Japanese paper, as a photographic medium, and placing it in contact with the original tracing in a " direct-contact " photographic frame. After a suitable exposure, the film is developed in a standard solution, washed in hot water, dried, " spotted out " where necessary and conditioned.

The film is then ready for placing on a Gestetner Rotary Duplicator for the necessary number of copies to be run off.

The great advantage of this process over the True-to-scale method is that a very large number of copies (several thousands) can be run off from one film, whereas in the latter process a fresh " blue " has to be made for every thirty or so copies required. Further substantial advantages of the Gesteprint process are speed of production and the fact that the film can be filed and used for " repeat " orders.

It should be added, however, that only the best tracings can be used for this process, and as a large number of the tracings at present in use in the Engineering Department are in a worn condition there is at the moment a definite limit to the usefulness of the Gestefilm. A further disadvantage lies in the fact that up to now it has not been found suitable for reproduction of tracings containing " hair " lines.

At present the size of prints obtainable from this process is limited to double foolscap (16 ins. by 13 ins.). There is, however, on the market a machine which will give prints of Imperial size (30 ins. by 22 ins.).

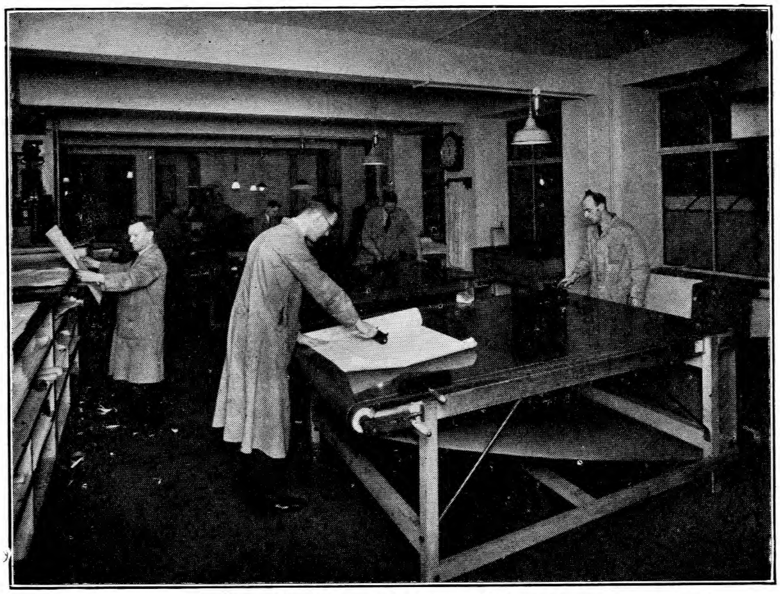


FIG. **2**.—TRUE-TO-SCALE PROCESS.

Rotaprint.

Up to this point this article has, apart from the new Gesteprint process, dealt with processes which are normally to be found in the average Print Room of any large engineering organisation. It has previously been mentioned that about one-quarter of a million litho prints and three million loose-leaf diagrams were produced during the year 1936 by the Rotaprint method. It is not proposed to go into any great detail in describing the Rotaprint system of printing. Suffice it to say that the Rotaprint machine is an offset lithographic printing press on which the heavy metal plate ordinarily used for lithographic printing is substituted by a thin grained flexible aluminium plate (sometimes having a paper backing) ·004 of an inch thick.

For foolscap and loose-leaf litho prints a negative of the original tracing is made either by camera or " direct contact," depending on the condition of the tracing. For loose-leaf diagrams, which are of octavo size, reduced camera negatives of the original tracing are made.

The negatives are transferred photographically to the aluminium sheet in the following manner. The fine-grained surface of the sheet is first washed with water and then coated with a sensitising solution of albumen and an ammonium salt. An even spread of the solution on the surface of the sheet is effected by an electric whirler, which is very similar in construction to a gramophone turntable.

The negative is then placed on the sensitised surface of the metal sheet in a frame with a glass face and exposed for a few minutes to the light of an automatic arc lamp which passes through the transparent portions of the negative and coagulates the sensitised solution, previously applied, rendering it insoluble in water. The metal sheet is then treated with a black developing ink, and after the ink has been washed off with water, an exact image of the original tracing is left on the sheet.

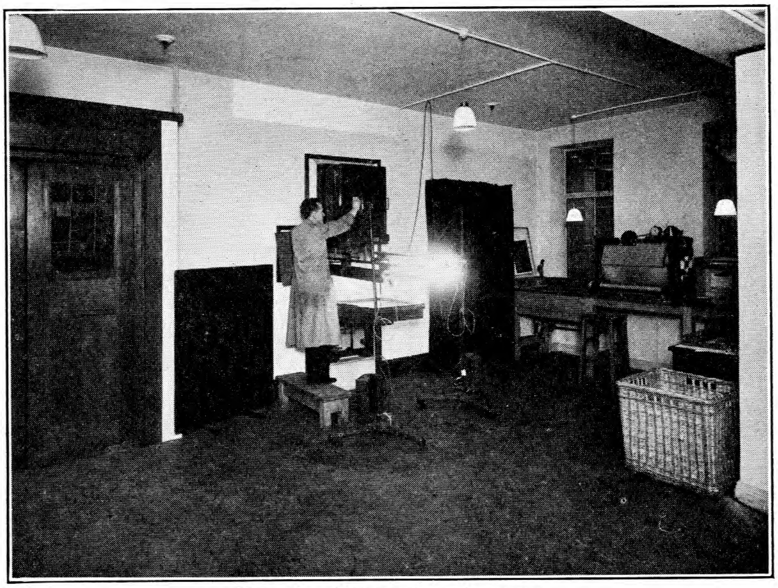


Fig. 4.—Photostat Copying.

The sheet is finally coated with a gum fixing solution (a proprietary article) and fitted to the Rota machine. As a " mirror image " only would be obtained by printing direct from the metal sheet to the paper, an offset roller, covered with a rubber " blanket " is employed. This, with the aid of the compression roller beneath, prints on the sheets of paper which are fed into the machine by an automatic feeding device.

Fig. 3.—Rotaprint Machine Room.

Loose-leaf diagrams, which are octavo size, are printed three " up " on six-hole punched paper 13 ins. by 7 ins. Cutting is effected by a guillotine, two to three hundred sheets being cut simultaneously.

The advantages of the Rotaprint method are :

(*a*) the speed of reproduction ;
(*b*) the quality of the resultant print which is equivalent to first grade lithographic work ;
(*c*) the number of copies which can be taken from one plate (over 10,000);
(*d*) the original negative can be used for making additional plates when necessary, provided the original tracing has not been amended ;
(*e*) tracings up to double foolscap size (16 ins. by 13 ins.) can be reproduced. It is essential, however, that good original tracings be used.

A general view of the Rotaprint machine room is given in Fig. 3.

Photostat.

By means of this machine photographic copies of an original drawing, legal document or other matter can be produced direct on a sensitised bromide paper, i.e. without the intervention of a glass plate or film negative. Photostat paper in contradistinction to ordinary bromide paper has a high tensile strength in relation to its thickness.

The machine (Fig. **4**) comprises a large bellows type of camera fitted with a suitable optical system which prevents lateral reversal, or, in other words, gives the " copy " a positive reading. Below the lens is a table on which the objects to be photographed are placed, the originals being illuminated by mercury vapour lamps.

Enlargements or reductions of any document can be made as desired.

It is a somewhat expensive process and so far as the E.-in-C.O. is concerned is used mainly for the production of copies of legal and other documents for the Solicitor's Department and of Schedules of Prices in connection with engineering works contracts.

Studio.

Many photographs for legal purposes are taken during the course of the year in connection with wayleave, accident and damage cases, and many illustrations for Engineering Instructions are prepared. Much re-scaling of maps is carried out for Surveyors and a considerable volume of work is done for the " Post Office Magazine " and for Green Papers.

The Studio equipment (Fig. **5**) consists of modern copying and enlarging cameras and all those other appurtenances which are necessary for the production of some 8,000 negatives and 10,000 prints per annum.

The photographs illustrating this article were taken by the Studio staff.

Organisation.

The Print Room of the E.-in-C.O. is staffed in the main by grades of officers known as Photoprinters and Assistant Photoprinters.

Broadly speaking, the Photoprinters are engaged on the actual production of prints, e.g. two on the two horizontal arc-lamp copiers, five on True-to-scale tables and Shaw vertical copier and one on the Photostat. The Assistant Photoprinters carry out the duties of trimming and folding, despatch and general assistance to the Photoprinters. Directly in charge of these men is a Foreman Photoprinter. The Studio staff consists of seven Photographers and an Overseer Photographer who is responsible for production generally in the Photocopying Group, which also embraces purely photographic work. Executive control is exercised from Ed.2 Section of the E. & O.P. Branch.

Sufficient has been written to indicate the nature and quantity of work carried out in the Photocopying Group of the E.-in-C.O., and in conclusion it should be emphasised that one of the greatest problems is that of urgency. So many jobs become urgent at the last moment because of avoidable delay in the initial stages. When over 75 per cent. of the work received is marked " Urgent " then the word perforce loses its significance. A vicious state of affairs is created and other words such as " Very Urgent," " Priority " are brought into use. The ideal state is for a definite time period to be allowed for each phase of a particular work, and although it is appreciated that the ideal is seldom obtainable in this life, there is no doubt that if a little forethought is given in the initial planning of a programme of work then sufficient time could and would be allowed to enable the required prints to be reproduced and to be in the hands of the Engineers on the desired date.

In the past production has been severely handicapped by the lack of really suitable accommodation, but the Reproduction Group of the Editorial Branch (Ed. 2), which embraces the Photocopying, Rotaprinting and Assembly units, and a staff of upwards of one hundred, has recently moved to modern premises in Lawrence Lane, Cheapside, E.C.2, and with the provision of additional and more up-to-date equipment it is anticipated that for all practical purposes it will be possible for a day-to-day service to be maintained in the near future.

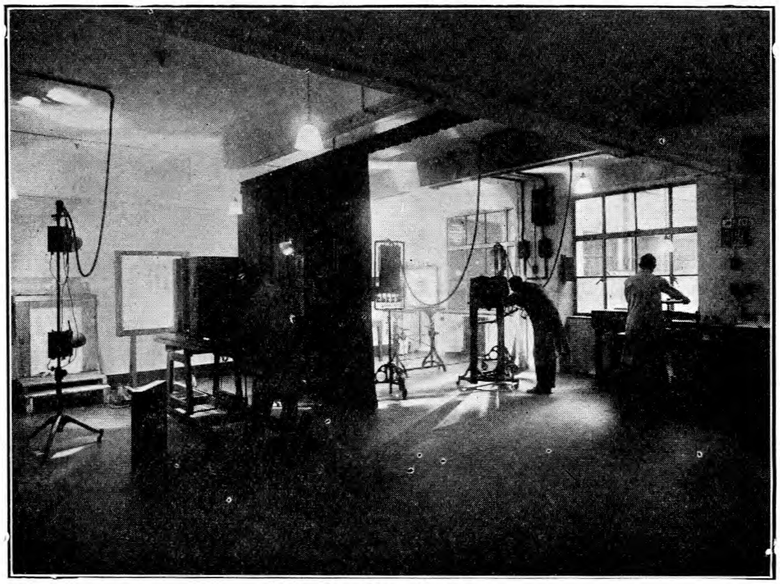


FIG. **5**.—THE STUDIO.

Police Telephone Systems

T. G. MORRIS

A review of police telephone systems is given followed by a more detailed description of the present standard system.

Introduction.

MODERN police problems have shown the necessity for police authorities to have a telephone system which will give rapid inter-communication and signalling between various points in any police area.

The speedy collection and distribution of information is an important factor in efficient organisation and in this connection extreme care is necessary in the selection of sites for street telephone points; the positioning should be arranged to allow easy access by the general public and beat officers. The nature of the traffic carried varies from the extremely important emergency calls in respect of fire, police and ambulance services to the routine calls made at set periods by police officers.

It will be appreciated that the process of establishing a call should, at least in so far as the public are concerned, demand as simple an operation as possible, particularly as many people who use the police telephone in times of emergency are not normally telephone users.

The main requirements of an efficient police telephone system are :—

(*a*) Absolute reliability.
(*b*) Simplicity in operation.
(*c*) Instantaneous fault indication on all lines terminating on street units.
(*d*) Facility for operator to set up a mass call to street points in the shortest possible time.
(*e*) Visible and audible signals to street telephones.

The purpose of this article is to deal briefly with one or two of the early types of system and, in more detail, with the present-day British Post Office standard system.

Simple Visible and Audible Signal System.

The most simple arrangement comprises a simple P.B.X. extension with an associated visual calling signal; this system was, until quite recently, used extensively in the Metropolis. A relay, which is of the mechanically locking type, is connected in series with the bell and operates, at normal ringing frequency ($16\frac{2}{3}$ cycles per second), to complete a mains circuit for the signal lamp. The lamp is mounted on top of a kiosk, or on a wall bracket, situated preferably at a street corner in order that it may be readily observed from as many points as possible by beat officers.

Although attractive in its simplicity, the system is subject to the failing that the mechanically locking relay must be hand released, and this often necessitates a special visit to the street point. In addition, the signals cannot be readily distinguished during hours of darkness from street lamps, etc ; in this respect the use of coloured lamps is not permitted in view of the possible confusion by road users with traffic signals. The method of signalling does, however, possess the feature that ringing current only is necessary for the operation of the signalling relay.

Relay Scheme.

A system was developed by the Post Office in 1934 to meet the requirements of the Metropolitan Police and became known as the Post Office relay system. The telephone was housed in a recessed compartment of Police kiosks and was therefore readily accessible to members of the public from outside the kiosk and to police officers from inside. The particular facilities given by this scheme were :—

(*a*) A signal was given to the switchboard operator to denote that the street point signal lamp had definitely lit when signalling current had been applied to line, and
(*b*) the operator was able to clear down the street point signal at will.

A feature of the signalling system in this circuit is that only a momentary application of ringing is necessary to operate the street signal, the circuit being so arranged that retention of the relay is effected by the mains power lighting the lamp.

The equipment designed to give these facilities was arranged for association with a normal P.B.X; it was found necessary, however, to employ a ringing and signalling unit at the Police Station. As it was desired to dispense with the audible signal at the street point in certain instances, it was deemed necessary to provide a signal lamp inside the kiosk in addition to the external lamp in order that a police officer, while in the kiosk, could be signalled.

Metropolitan Police System

Another system, similar to that just described, has recently been designed for use in certain Divisions of the Metropolitan Police Area. The method of use and the facilities provided are almost identical with those of the relay scheme but a departure was necessary in circuit design in view of the restricted housing accommodation at the street point.

As in the relay scheme the special circuits are terminated on a standard P.B.X. and access to the public network is therefore provided. Unlike the relay scheme, however, it is necessary to apply ringing to line throughout the period during which it is required to flash on the street point signal lamp.

The anti-side tone induction coil is employed in this circuit in order that the street noises reproduced in the street point receiver could be reduced to a reasonable level.

A feature of this circuit (Fig. 1) is the use of an electrolytic condenser in shunt across the coils of relays X and Y in order that a prolonged operation and release of these relays may be effected. The operation of this circuit element is as follows: The relay coils are connected in a non-inductive manner, i.e. equal currents to each coil do not operate the relay. When contact C3 closes, the current in the

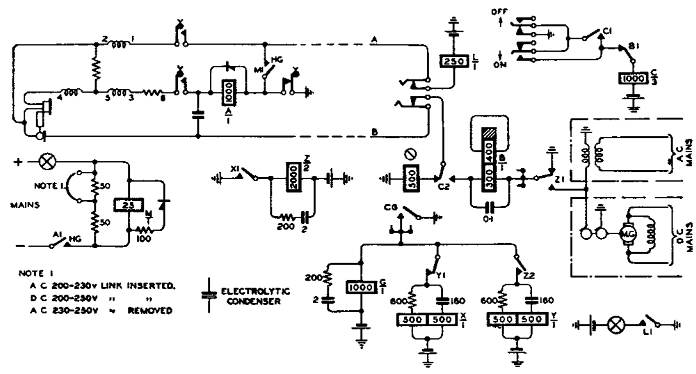


FIG. **1**.—CIRCUIT OF METROPOLITAN POLICE SYSTEM.

condenser leg opposes the current in the resistor leg until the condenser is charged, thus retarding the operation of the relay. On opening the contact C3, the condenser commences to discharge through the resistor, and the two relay coils in series aiding. During this time the current is producing a magnetic flux in both coils tending to hold the relay operated. This arrangement prevents welding at the contact C3 which would arise if a normal condenser shunt were employed on a single coil relay.

To call a street point the operator flicks the non-locking ring key to the " On " position to send pulses of 50 c.p.s. A.C. when available, or alternatively 17 c.p.s. A.C. over the B line. During the time the signal lamp is lit an earth is extended to the switchboard termination over the A line to give an indication that the lamp is functioning. Application to line of the telephone loop causes the calling indicator and switchboard lamp to glow until the operator answers. Where the operator has called the street point and a reply is not forthcoming release of the signal may be effected by a momentary depression of the ring key to the " OFF " position.

City of London Police.

To meet the requirements of this body a special switchboard was designed in 1933. The facility required was the termination of 80 street point circuits, 20 of which were to be arranged for the setting up of broadcast calls with ease and rapidity; a mass call can be set up by the operation of one key per group of ten circuits. The special switchboard was fitted adjacent to a standard P.B.X. and calls from street points may therefore be extended to normal extension circuits.

Signalling is effected by the reversal of direct current to line and the use of a ringing supply is avoided. Unlike the two systems previously described, the arrangement does not give positive indication at the switchboard of the correct functioning of the street point signal lamp.

The street call points take the form of a microtelephone housed in police kiosks or pillars, the calling signal being a lamp arranged to flash at periods of approximately one second on and one second off.

*Switchboard P.A.*101

With the exception of the City of London switchboard, the systems previously described are such that termination of the special police circuits on standard Private Branch Exchanges could be arranged; in addition all circuits have been worked on a direct line basis.

In 1932 the Switchboard P.A. 101 was introduced to meet the particular demands of police authorities and, in order that requirements might be provided on an economical basis, the street point telephone circuits were designed on party line principles. This board was arranged in three sizes each having three panels. Panels one and three housed the street point party line terminations and the normal P.B.X. circuits were located on the centre panel. The street point telephone unit was arranged with a lock-up microtelephone for the use of police officers, and, for public use, a loudspeaker and inset transmitter were located behind an unlocked spring-controlled door.

A modified form of this arrangement was necessary for use in the Metropolitan Police Area as the Metropolitan Police, while realising the advantages to be gained by party line working, did not favour the use of separate instruments for police and public use. A modified street unit consisting of a single microtelephone for joint use was therefore employed in conjunction with a modified form of Switchboard P.A.101.

The experiences gained by the use of this particular switchboard served to show that the facilities provided did not fully meet the needs of all Chief Constables. As previously stated the call points were arranged for party line working but discrimination between the particular points on each circuit was not provided; in addition, it was considered that calls from the public side of street points would not need extending to extension points on the installation. Representations from certain bodies necessitated an investigation which resulted in major modifications in so far as the extension of public calls were concerned and, in order that the scheme might be arranged to meet all known requirements, a superseding item—coded Switchboard P.A.150—was introduced in 1934. The Switchboard P.A.101, however, adequately provided the facilities required in most areas and many are still working and giving every satisfaction.

SWITCHBOARD P.A.150

The British Post Office Standard for Police Work.

This board (Fig. **2**) is arranged in three sizes, each size providing for the termination of 10, 20 and 30 groups of street points respectively. The early issues of this two position, lamp signalling switchboard were not arranged for direct dialling from extensions to the public exchanges; arrangements were made, however, to provide this facility where required by the introduction of units. In view of the rapid conversions to automatic working and the resultant increasing demand for through-dialling it has been decided to add this facility to installations at the outset and the switchboards so arranged have been coded with the suffixed title Switchboard P.A. 150T.D. This switchboard has been adopted by the British Post Office as standard for police work. In addition

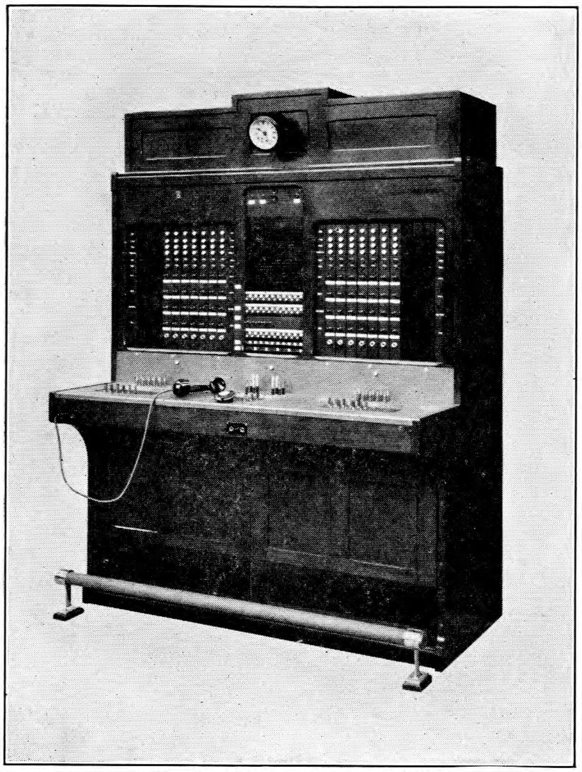


FIG. **2**.—SWITCHBOARD PA150.

to accommodating the street point party line circuits it also meets all the facilities provided on a standard P.B.X.

The complete range of terminations is :—

(*a*) Public exchange lines, to any type of exchange system,
(*b*) Inter-switchboard private wires. These terminations are readily converted to inter-switchboard extensions when required.
(*c*) Internal and external extensions.
(*d*) Public call extensions.
(*e*) Street call-points.

The facilities provided are as follows :—

(*a*) Connection of any street call-point (police side) to the public exchange, an internal or external extension, or an inter-switchboard extension line if required.
(*b*) Connection of street call-points (public side) to the special public call extension (if provided).
(*c*) Speaking from street call-points (police side), with secrecy against public, to other street call-points (police side) on the same, or any other, party line.
(*d*) Signalling (flashing) and speaking to street call-points (police side) either separately or simultaneously, in groups of any number.
(*e*) Distinctive calling signals at the switchboard to indicate whether a call is from a member of the public or from a police officer and from which particular street call-point the call originates.
(*f*) Visual indication, by means of a lamp on the switchboard unit, that the public side of a street call-point has been operated while a police call is in progress at another street call-point on the same party line.
(*g*) Visual indication, by means of steady signal lamps (either internal and/or external at a police kiosk, or external on a pillar), which can be lit, when desired, during the period that the public call door is open, thus attracting the attention of police officers.
(*h*) Automatic fault indication on all lines terminated on switchboard units, i.e. street call-point lines, whereby any fault is visually brought to notice immediately it occurs.
(*j*) In order that the apparatus fault-duration period may be reduced to a minimum, the switchboard units, amplifiers and ringing vibrators are of the unit type and are jacked-in.
(*k*) Through-clearing on exchange calls.
(*l*) Divided clearing on extension to extension calls.
(*m*) Supervision on police calls to police on the same or any other party-line group.
(*n*) Supervision on extended public calls.
(*o*) Through-dialling by extensions on originating calls.

As has been previously stated Switchboard P.A. 150T.D. has been provided in three sizes, the capacity and equipment of each size being :—

Equipment and Circuits	*Capacity*					
	10-line		20-line		30-line	
	Wired	*Equipd.*	*Wired*	*Equipd.*	*Wired*	*Equipd.*
Party lines	10	—	20	—	30	—
Exchange line circuits	10	4	10	5	10	5
Inter-switchboard private wires ..	10	3	10	5	10	5
Extension line circuits	20	10	30	10	30	10
Public call extension circuits	6	6	6	6	6	6
Cord circuits	12	6	16	10	20	12
Operators' circuits	2	2	2	2	2	2
Public call cord circuits	6	4	6	4	6	4
Ringing circuits	2	1	2	2	2	2
Ringing vibrators	—	2	—	3	—	3
Dynamotors, (to supply amplifier H.T.)	2	2	2	2	2	2

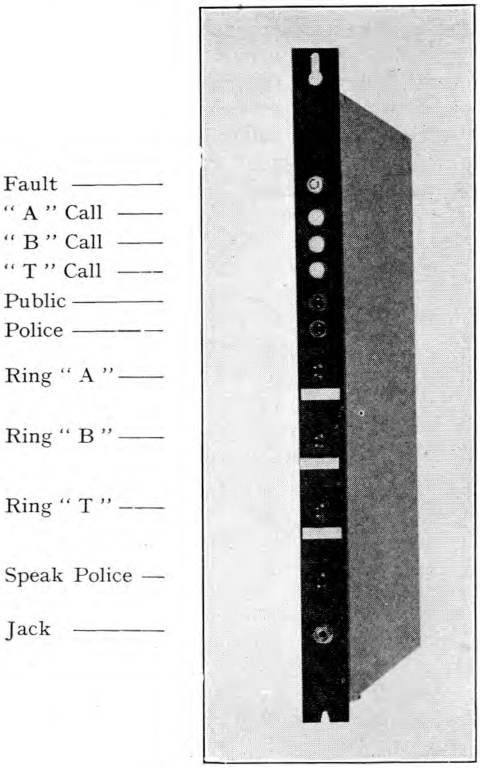


FIG. 3.—FACE STRIP OF THE UNIT.

Switchboard Description.

Of the three panels provided the centre one contains all the normal terminations of a private branch exchange and, in addition, the special extensions arranged to accept public calls. The first and third panels accommodate, in unit form, the street call-point party line terminations; these units contain all the switchboard apparatus required and are arranged on jack-in principles. The face strip of the unit (Fig. 3) contains six lamps, four keys and one jack, the purpose of each lamp being :—

Designation	*Purpose*
Fault	Glows to indicate an earth, low-resistance loop, or disconnection fault.
" A " Call	Glows to indicate a call from the " A " street call-point.
" B " Call	Glows to indicate a call from the " B " street call-point.
Terminal Call	Glows to indicate a call from the terminal street call-point.
Public	Glows in conjunction with a CALL lamp, indicating a call from the public side of a street call-point.
Police	Glows in conjunction with a CALL lamp indicating a call from the police side of a street call-point.

Of the four keys, three are ringing keys and serve to ring the individual party line points; the fourth key is operated to speak to the police side of street points. The jack serves to extend calls from the public side to the special extensions; in addition, this jack is used to provide, from a normal cord circuit, the transmission feed necessary to enable a police officer to talk from one street point to another street point on the same party line.

Keyshelf. The keyshelf consists of three sections, the first and third accommodating the normal cord circuits and the second the amplifier cord circuits necessary for use in connection with the public side of street call points.

Special Equipment.

In addition to the normal P.B.X. equipment and party line units each switchboard accommodates ringing vibrators, amplifiers for use with the special cord circuits and dynamotors to supply the high tension necessary for anode circuits of the amplifier valves.

Power Equipment.

The switchboard battery consists of four 24-volt batteries, forming two sets of 48-volt batteries, the junction of the two 24-volt batteries being connected to earth. Provision is made for 24-volt positive and 24-volt negative potentials for the continuous fault-test feature and for other circuits according to the circuit conditions. In addition, a 6-volt battery is provided for the valve filaments and is trickle charged through a suitable variable resistance.

Two dynamotors (or rectifiers) are necessary, one for charging the positive batteries and one for the negative batteries; the associated charging panel provides facilities for charging the batteries either separately or two simultaneously, this being necessary on account of the unequal drain on the 24-volt batteries under working conditions.

FIG. 4.—STREET PILLAR.

Call Points.

A call-point may take the form of a street pillar (Fig. 4) or a police kiosk. On the street call-point party line there are three stations, the first (or A) station and the second (or B) station being termed side stations, and the third (or last) station on the line being termed the terminal station. Each party line is capable of serving a maximum of three call-points with full selective signalling. One or two additional stations may be provided, if required, and these must be connected one to each of the side stations. The additional stations are signalled at the same time as the side stations to which they are connected, and incoming calls to the switchboard from an additional station are displayed on the same lamp as the side station to which it is connected.

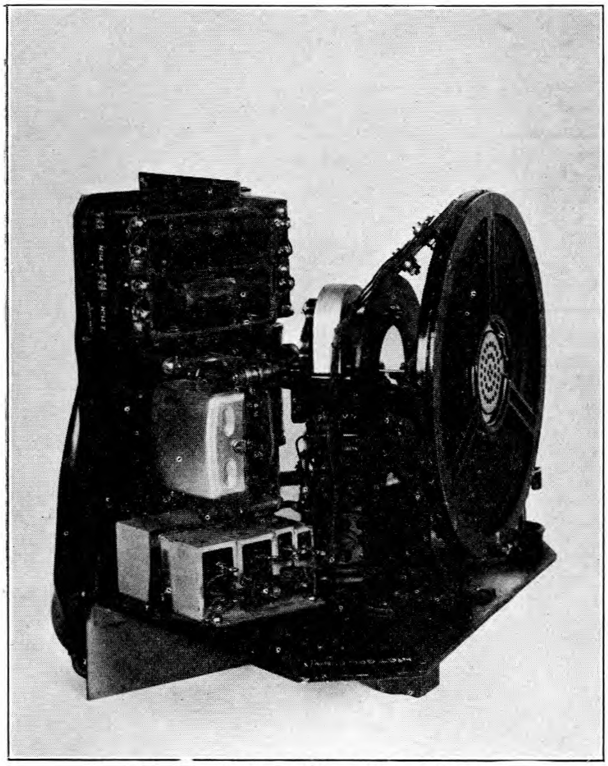


FIG. **5**.—STREET TELEPHONE UNIT.

A specially designed telephone unit Fig. **5** is installed at these points from which dual telephone facilities are provided, i.e. :—

(*a*) By loudspeaker and transmitter available to the public upon simply holding open a door, which is self-closing but non-locking.

(*b*) By a microtelephone available only to the police, or other authorised persons in possession of a key.

Calling from street points is effected by an impulse mechanism which is released on removal of the microtelephone by a police officer or, alternatively, by the opening of the door by a member of the public. The mechanism is a suitably modified Dial Auto No. 10, the cam fitted being in accordance with the position (A, B or T) of the point on the party line. Separate mechanisms are necessary for public and police, the public mechanism being fitted with an auxiliary cam and spring set to enable a follow-on earth to be provided for discrimination purposes. The impulse trains transmitted when the mechanism is released are shown in Fig. **6.** Signalling to the street points is effected by the operation of A.C. relays on the A and B points and by operation of a polarised relay at the terminal points. These relays carry mercury tube contacts which serve to close the mains circuit to the signal lamps.

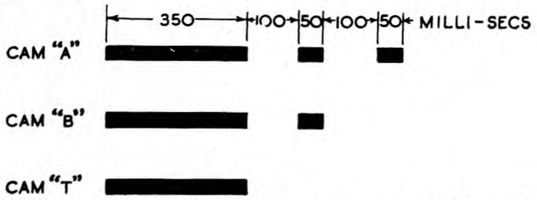


FIG. **6**.—IMPULSE TRAINS TRANSMITTED BY IMPULSE MECHANISM.

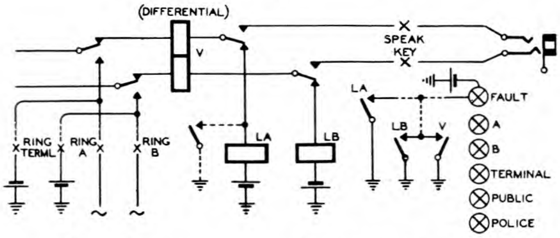


FIG. **7**.—CONTINUOUS LINE TEST CIRCUIT.

Circuit Operation.

Continuous Line Test. A small current (approximately 9 mA) is normally flowing in the line circuit (Fig. **7**) via the terminal point relay to operate relay LA ; due to the higher operate current required by relay LB this relay is unable to operate under fault-free conditions : in addition relay V, being wound differentially, does not operate.

Under fault conditions :

(*a*) Relay LA releases to a disconnection,

(*b*) Relay V operates to an earth. (Relay LB also operates to " B " line earth and LA remains operated to an " A " line earth).

(*c*) Relay LB operates to a loop.

In each case the fault lamp associated with the line is lit.

Call from a Street Point. When the public door is opened or the police microtelephone is removed the impulse mechanism is released and a train of earth impulses transmitted over the B line from contact PD3 or HS3 (Fig. **8**) to operate relay V. (Fig. **7**). A circuit is completed for the A, B or Terminal lamp in the line relay set according to the impulse cam fitted. Discrimination between public and police calls is given by an additional delayed earth transmitted from contact PD4 of the public impulsing mechanism. The operator answers a public call by means of a public call cord circuit and, if required, the call may be extended to a public call extension. Police calls are answered by operation of the line unit " Speak " key.

Call to a Street Point. Calling to street points is effected by operation of the ring keys in the line circuit. Relay K operates and relay IP pulses from a common alarm circuit in order to flash the street point lamp.

The ring A key extends 17 c.p.s. A.C. to the A line.

The ring B key extends 17 c.p.s. A.C. to the B line.

The ring Terminal key extends negative battery to line to operate the polarised relay at the terminal street point.

The remaining circuits terminating on the Switchboard P.A.150 follow the general principles employed on standard private branch exchanges ; the exchange line and cord circuits, however, are arranged so that a battery is always present on a party line when the police side of a street point is extended to another point on the installation. The battery makes possible the intrusion of a public call on the police call.

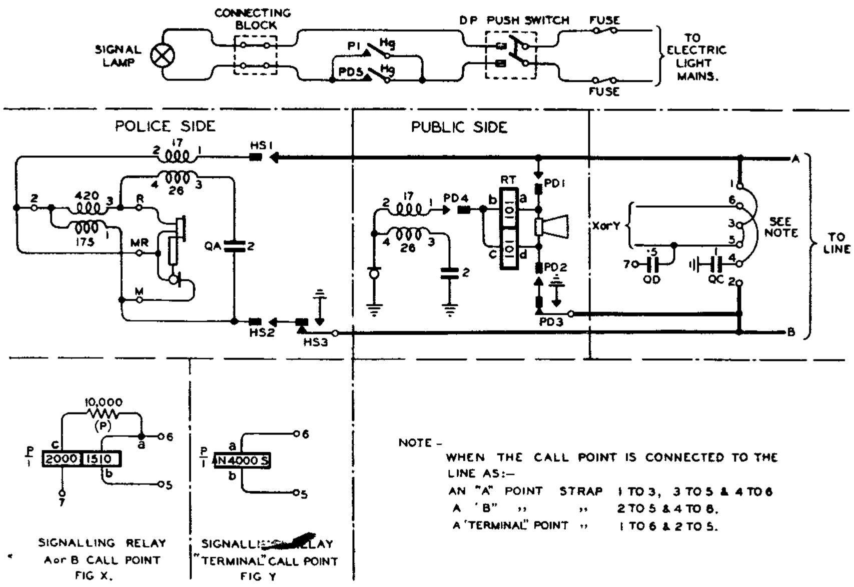


FIG. 8.—CALL POINT CIRCUIT.

Switchboards P.A. 150 *MP.*

As previously stated the standard police telephone and signal system did not meet the needs of the Metropolitan Police Authorities and when intimation was received (in 1935) that an extension of the police telephone system—on party line principles—was required in the metropolis the design of a new switchboard was considered desirable. The resultant item —coded Switchboard P.A. 150 MP.—included both physical and circuit improvements which, from experience gained with switchboards of this type, proved to be necessary.

As with the Switchboard P.A. 101, which was modified for the Metropolitan Police, this body desired to continue the policy of employing a common telephone for the joint use of the public and police officers. This method of use has resulted in a decrease in the equipment required and, therefore, a simplification of circuit design. The circuits employed follow the same principles as in Switchboard P.A. 150 but from the facilities required it will be appreciated that the telephone unit is considerably simplified as a result of the single telephone required at street points; the party line terminating unit also requires less apparatus as discrimination between the different points on the party line only is required. In addition it will be realised that the use of public call cord circuits, amplifiers, etc. is unnecessary. The retention of intrusion facilities, however, is essential and to make this possible the principle of connecting the battery feed from cord circuits and public line terminations is continued. A feature in this respect is that the use of identical circuits on the P.B.X. panel of Switchboard P.A. 150 and Switchboard P.A. 150 MP is made possible.

Conclusions.

The existing police telephone arrangements available appear in general to meet all the requirements of police authorities in this country. The conditions to be met in the Metropolitan Police area are, it is thought, exceptional and the departure from standard would, therefore, appear to be inevitable. With regard to the provinces, however, all demands with the exception of Bradford and Glasgow have been met by standard switchboards. The number of street points required at Bradford necessitated the provision of extension wings to enable an addition of 50 party line terminating units to be housed, while at Glasgow is was considered that, in view of the large number of private branch exchange extensions and exchange line terminations, the practice of team working over both the normal P.B.X. circuits and the street points circuits was, for traffic reasons, undesirable. A special 3 position switchboard (Switchboard P.A. 190) was accordingly designed, positions 1 and 2 being arranged exclusively for the normal P.B.X. terminations while position 3 housed the street point party line units.

The Switchboards P.A. . . . referred to have been designed in conjunction with Messrs. Ericsson Telephones, Ltd.

Loch Awe Submarine Cables

W. BOCOCK, A.M.I.E.E. and G. H. WALTON
(United Telephone Cables, Ltd.)

The authors describe a novel method by which two telephone cables were laid across an inland loch.

Introduction.

THE provision of the Glasgow-Oban trunk cable which, as a backbone trunk is to serve West Scotland, called for the serious consideration of several alternative routes. To avoid a wide detour along a section of road which was scheduled for widening and general improvement near Dalmally, Argyllshire, it was decided to follow a shorter route which involved the crossing of Loch Awe between Port Sonachan and Taycreggan. At this point the loch is 600 yards wide, the maximum depth being 180 ft. A No. 8's steel wire marked at 15 ft. intervals was drawn tightly across the loch and depth soundings were taken by the cabling contractors, United Telephone Cables Ltd. Allowing for the contour of the bed (Fig. 1) a length of 800 yards of submarine cable was required.

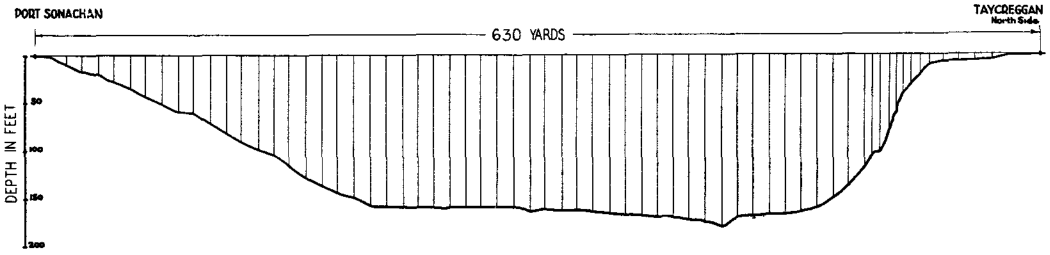


FIG. 1.—CROSS SECTION OF THE LOCH.

The Engineer-in-Chief decided that two 74/20 P.C.Q.T. submarine cables should be laid, provision being made for the "Goes" and "Returns" in separate cables, with additional pairs for local use. The submarine cable specification No. 481 B provides for armouring by No. 2 S.W.G. iron wire. A cross-sectional view of the cable is shown in Fig. 2.

Each cable together with its drum weighed 10½ tons and a careful survey of the numerous old stone bridges spanning the watercourses along the four miles of secondary road between Cladich and Port Sonachan revealed the need for special precautions in transporting the cable drums. Fortunately this operation was effected by means of an eight-wheeled pneumatic tyred lorry without any accident to the cables or bridges, the Road Authority having previously consented to the passage of the cable lorry which exceeded the maximum weight normally allowed to traffic on the road.

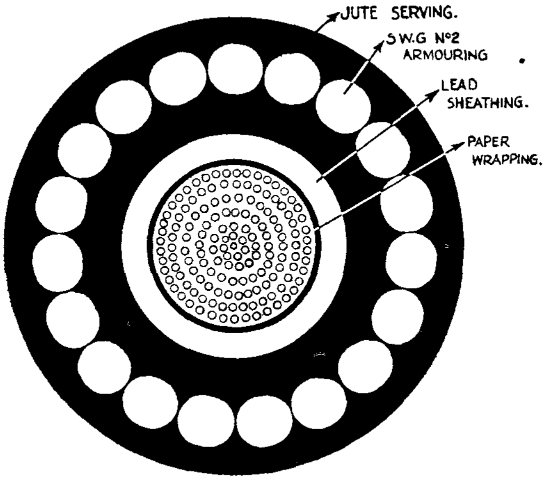


FIG. 2.—CROSS SECTION OF CABLE.

Except for a shallow stream Loch Awe is entirely inland and a suitable boat for cable laying was not available. The drawing of the cable across the bed of the loch was ruled out on account of the excessive strain which would be imposed, and the possibility of damage to the cables due to abrasion. Further, if left unsupported for a distance on the bed of the loch with a tensional strain, a risk of vibrational damage to the cable sheath would be incurred.

To build a raft sufficiently large to transport cables, men and gear, would have resulted in abnormal expense, and difficulty was anticipated in unloading the cable drum from the raft owing to the long shelving beach at Taycreggan.

In these circumstances, the contractors suggested a scheme of drawing over the cables on the surface of the loch using 6-gallon drums as floats attached to the cables, and puncturing the drums at a later stage to sink the cables. This method was favourably reported on by the P.O. Submarine Superintendent (Captain Ramsay) and after further consultation with the contractors was finally approved by the Engineer-in-Chief. To determine the number of drums necessary to float and later sink the cable at a suitable speed, the contractors carried out a series of experiments using a large tank at their works, following which a number of tests were made on Loch Awe. An essential feature of the scheme was that all the floats should be punctured before submerging. The submarine cable weighs 7.8 lbs. per foot and it was demonstrated that with a $\frac{1}{16}$-in. diameter hole on the bottom and a $\frac{3}{32}$-in. diameter hole at the top of the drums, the cable would be floated for a period of approximately 27 minutes before submerging. In all 800 drums were used.

Laying Operations

It was decided to lay each cable separately and, to avoid interference with the steamer pleasure cruises on Loch Awe, it was only possible to commence

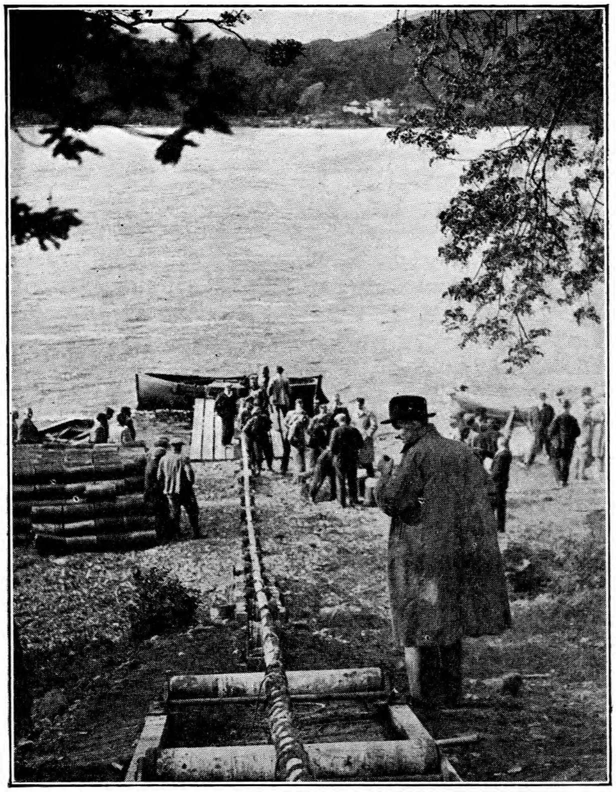


FIG. **3**.—LANDING STAGE AT PORT SONACHAN.

operations each day after 4.30 p.m. A petrol-driven winch with two hand winches in reserve were provided at Taycreggan, the cable drums, braked by two 9 ft. by 3 in. planks, being mounted at Port Sonachan. Landing stages adequately supplied with rollers to facilitate the feeding of the cable had been previously built on each side of the loch (Fig. **3**). The steel hawser, 700 yards in length and $\frac{3}{8}$-in. diameter, was floated over the loch by attaching 6-gallon drums at intervals of 50 yards.

After waiting 24 hours for the wind to subside, operations were commenced at 7.0 p.m. on the 16th June. As the cable was drawn drums, each previously punctured by a $\frac{1}{16}$-in. hole at the bottom, were tied to the cables at 5 ft. intervals (see Fig. **4**). 36 yards of additional cable were pulled over to the Taycreggan side and a bight arranged to provide sufficient cable to reach the bed of the loch at the deepest point, marking buoys being provided to show the proposed line of the cable and the point where the slack in the cable should be positioned. A surplus length of 18 yards was arranged on each side for adjustment purposes if required. Owing to the breezy weather the cable was blown somewhat out of course (Fig. **5**), but was pulled into line again by a hawser attached to a motor boat, and sinking operations were immediately commenced. Four rowing boats, two on each half of the cable, manned by experienced boatmen, equipped with specially shaped hammers for puncturing the floats were employed. As previously stated, it had been demonstrated that by puncturing the floats with a $\frac{3}{32}$-in. diameter hole at the top, sufficient time would be available to hole all the floats before the cable sank. Commencing at the centre of the loch, this operation was expeditiously carried out and occupied 21 minutes. As the floats filled the cable completely disappeared from sight 25 minutes later. As a precautionary measure all the men working in the boats wore lifebelts.

Similar arrangements were made on the following day, the 17th June, for the laying of the second cable. Owing to the more favourable weather experienced, and the absence of wind on the surface of the loch, the cable was floated over in less time.

Signalling between Port Sonachan and Taycreggan across the loch during the operations was effected by an earthed telephone circuit consisting of a single V.I.R. cable, with a short wave radio set equipped by the Radio Branch in reserve. In addition, a visual " Stop and Go " signal consisting of a 5 ft. by 5 ft. board suitably mounted for rotating and painted

FIG. **4**.—TYING ON THE DRUMS.

red on one side and white on the reverse was fitted on each side of the loch.

It was considered unnecessary to provide protectors for the submarine sections of the cable, which accordingly are to be jointed direct to the land cable in manholes adjoining the loch.

The whole of the operations had been carefully studied in advance and in view of the experimental nature and magnitude of the work, great credit is due to the contractors, Messrs. United Telephone Cable Company, for the smooth organisation and expeditious manner in which the cable laying was carried out.

A representative of the Submarine Branch (Mr. Wallis of H.M.T.S. "Monarch") was present throughout the proceedings and rendered valuable assistance.

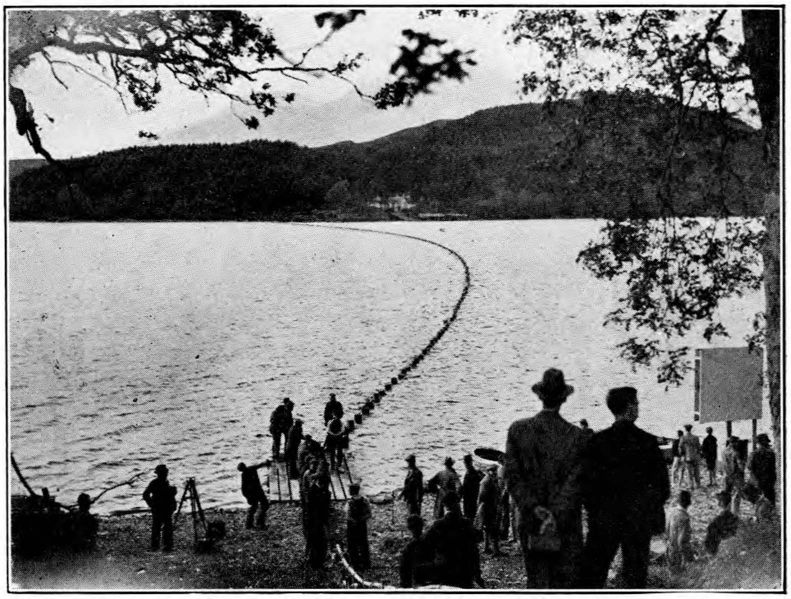


FIG. 5.—FLOATING THE CABLE ACROSS.

Fault Localisation with Gas-Filled Cables

J. M. WALTON

The author describes a method by which cable sheath faults may be detected and located before they have caused interruptions to the cable circuits.

Introduction.

THE localisation of cable faults due to sheath damage is a problem which faces all administrations maintaining communication services via lead covered, paper core, telephone and telegraph cables. Hitherto the localisation of defects in cable sheaths has been carried out almost entirely by electrical testing methods, entailing the use of costly apparatus by highly trained staff. Furthermore, these methods are applicable only when the cable circuits have themselves become affected. Thus the ideal of detecting and repairing cable sheath faults without interrupting the circuits is impracticable.

Much thought has been given to alternative schemes to overcome this disability and a system has been devised by which, it is claimed, 90 per cent. of the cable sheath defects which have occurred since its adoption, have been found and remedied without interruption to the cable circuits. This system relies on keeping the cables filled with gas under pressure and has been effectively put into practice in South America by Messrs. Cables & Wireless, Ltd., and in Spain, Buenos Aires and U.S.A. by Messrs. International Telephone & Telegraph Company. Its use is being extended considerably.

FEATURES OF MESSRS. CABLES & WIRELESS INSTALLATIONS

When laid the cable is filled with carbon dioxide under pressure and the perfection of the sheath proved by its ability to hold this pressure. A drop in pressure indicates a leak which must be located and repaired. At a large leak there will be an audible escape of gas. A small leak is located by painting the suspected pothead or joint with soap solution and watching for the production of bubbles.

After a cable has been tested during laying a permanent low pressure of not more than 10 lbs. per square inch is maintained in it to indicate any leaks which may appear subsquently. In addition to indicating a leak, the escape of gas delays the ingress of moisture so that the fault may be located and repaired before the cable circuits are affected.

Localisation of Sheath Faults.

When a leak in a cable is indicated by a drop in pressure and no point of leakage is apparent, measurements of pressure are taken at convenient points along the line. These pressure measurements are plotted against distance to form a graph of the pressure gradients, sloping towards a low-pressure point. The point of intersection of these gradients gives the position of the fault.

Damage to a cable sheath results in a relatively slow escape of gas, and the internal pressure drops slowly, because of the considerable impedance offered to the gas flow by the closely packed paper and copper forming the cable core. This impedance, combined with the large volume of gas contained in a gas-tight section, produces a condition of graduated pressures, starting with a low point at the fault and rising in both directions to maxima at the ends of the sections. In a tightly packed telephone type cable the impedance so restrains the flow that the loss of gas from a completely severed end is not appreciably greater than that from a relatively small puncture. The drop in pressure resulting from a leak at the midpoint of a section may not be evident at the end for some time.

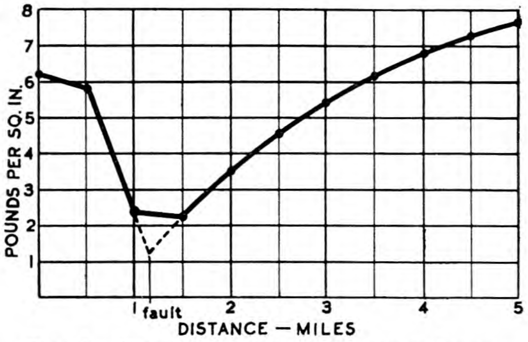


Fig. 1.—Typical Pressure Gradient Graph.

A typical pressure gradient graph is shown in Fig. **1**.

In general, locations made by this means are accurate enough to indicate that the leak is in a particular section of cable. Where the underground cable is accessible final determination of the exact point of leakage can usually be made by painting the suspected portion with soap solution and watching for bubbles. Over long lengths the pressure gradients should indicate that the fault is in a certain portion of the line. That portion of the line is then isolated, the pressure raised again, and further tests carried out to localise the fault.

When taking pressure readings down a line with the object of locating a fault by means of a pressure graph the series of readings should be taken as quickly as possible, since the relative pressure in the cable under test is constantly varying with changes in the atmospheric conditions and because of the escape of gas through the fault. A correction can be made when plotting the graphs for large variations in barometric pressure. With a long line, which takes some considerable time to test, it is advisable to start testing from each end simultaneously and to continue testing well past the point of lowest pressure.

Fittings Required on a Line.

To enable efficient pressure testing and maintenance to be carried out it is essential that (1) the terminations and joints of the cable should be air-tight and able to withstand pressure, (2) sufficient pressure testing points should be available to enable reasonably accurate locations by pressure gradients to be obtained, (3) it should be possible to isolate any particular section of the line for further testing and to separate a long line into reasonably short gas-tight sections for observation.

In an existing line sufficient testing points should be inserted to enable pressure tests to be made at least every quarter-mile unless joints are a slightly greater distance apart.

When a cable is reasonably accessible such as one laid in ducts with manholes, a Schrader valve (Figs. **2** and **3**) should, if possible, be fitted at each manhole. The valves may be fitted directly into the cable when it is of sufficient diameter, or into the normal sleeve joint. In a buried cable, testing points consist either of a valve or a nozzle fitted to each sleeve joint. Where nozzles are fitted a nozzle cap with a valve attached, as shown in Fig. **4**, is used for testing purposes.

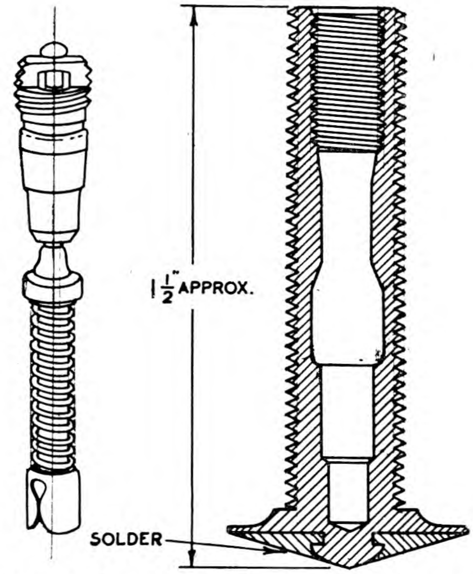


Fig. **3**.—Schrader Valve Core and Stem.

The Schrader valve is fitted with a steel spring and requires a pressure of 40 lbs. per sq. in. over the inside pressure to open it.

The valve stems are soldered to the cable sheath and the sheath drilled by special tools which ensure that the cable is not damaged by these operations.

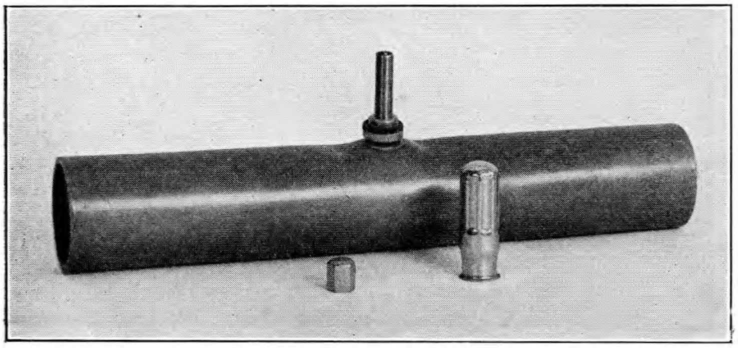
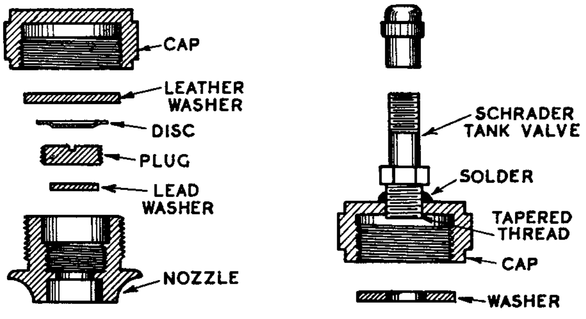


Fig. **2**.—Schrader Valve fitted to $1\frac{1}{2}$-in. diameter Lead Sleeve.

A valve cap with a lead seat is used in all positions where valves are left permanently in position. Cable valve stems which are exposed in manholes or other positions are further protected by fitting a dust cap, shown in Fig. **5**.

Bourdon Type Pressure Gauge.

Pressures are measured by means of Bourdon pressure gauges which depend for their action on the tendency of a bent flattened phosphor bronze tube to straighten under internal pressure. The free end of the tube controls, by means of link mechanism and a toothed sector, the movements of a pointer.



(a) (b)

FIG. 4.—(a) AIR NOZZLE AND (b) AIR NOZZLE CAP FITTED WITH VALVE.

All gauges are checked, and if necessary adjusted or calibrated, against a mercury manometer.

Features of Messrs. International Telephone & Telegraph Co.'s Installation

The features of this system are basically the same as those already described. The gas used is carbon dioxide at a pressure of approximately 25 lbs. per square inch above atmospheric pressure.

The cables are divided into sections of approximately seven miles in length and each section is provided with a pressure indicator. Contacts are fitted to this indicator and these short-circuit a pair in the cable when the pressure drops to, say, 15 lbs. per square inch.

The section where a drop in pressure takes place is located by resistance measurement to the point where the contacts close.

A foreman then travels along the section with a pressure gauge and attaches it in turn to nozzles which are fitted at every joint. The joints are spaced at distances of approximately 130 yards. He plots the gauge readings against distance from one end and the minimum of the curve gives the fault position.

The nozzles are fitted with small discs with a tiny hole in them. These discs prevent the escape of much gas when the foreman tests the pressure. The discs may be removed, making a large orifice if it is desired to reduce pressure at a point quickly.

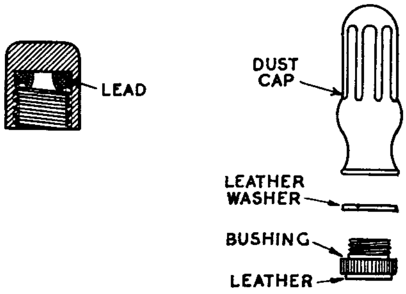


FIG. 5.—DUST CAP AND METAL SEAT VALVE CAP.

It may be anticipated that plumbing a cable under pressure would be difficult, but a leak can be plumbed if the nozzles at the side of the point are left fully opened for a period. Temporary wax seals have been used to keep internal pressure away from points where plumbing is required.

For cables of a fairly large size three days are required to bring up the pressure all along the cable. It is usual to apply the gas at both ends. A further three or four days are required for the pressure to equalise. Just as it takes a long time to get pressure up in the cable, so it takes a long time for it to escape, and water is kept from entering at a break in the sheath for quite a long period. No gas reservoir of any kind is employed. When once pressure is brought up on a seven-mile section it remains up for very long periods—in fact, for years.

Armoured cables and cables in ducts similar in every way to British cables have all been treated satisfactorily.

Conclusion.

The puncturing of the lead sheath for the fitting of the pressure gauges in both of the systems described may be considered undesirable because of the increased liability to faults. This objection could be overcome by inserting a small barometer of the Aneroid type inside the cable at the jointing points. It would require to be fitted with electrical contacts and ample movement of the contacts could be ensured by making up the barometer from a number of flexible diaphragms joined in series as is done in Regency type barographs. The complete barometer would require to be small and would probably be quite cheap to manufacture.

The pressure used by the International Telephone & Telegraph Co. appears very suitable for use in a gas pressure system. The margin between the gas-tight condition of 25 lbs. and the leak condition of 15 lbs. is large enough to give a very positive movement of the alarm contacts, and the pressure remaining in the cable after the alarm has been given should be sufficient to prevent ingress of moisture for an extensive period.

A nominal gas-tight section of 10 miles is favoured, since if the sections are too long the time necessary to saturate the cable with gas and bring the pressure up would be considerable.

Loaded cables would require to have a by-pass fitted between the UP and DOWN sides of the loading pots, but with co-axial and carrier cables the sections would be between repeater stations or between repeater stations and cable huts.

A New Form of Radio Interference

Details are given of a number of instances in which spurious emissions have resulted from external inter-modulation between two radio transmitters in close geographical relationship. The cause is so far unknown.

A SOURCE of interference which is co-incident with the simultaneous emission from certain pairs of sending stations is becoming more in evidence as the result of progress in receiving technique and with the practice of the grouping of high power radio transmitters.

The phenomenon appears to be associated with sending stations which are in close geographical relationship. Stations which have been observed to give rise to the interference are, for example, the two B.B.C. Stations at Brookmans Park, two Italian stations—2RO and 1RE, two Polish stations, two American stations and two Norwegian stations. America also reports that two Rugby transmissions are likewise involved. It was ascertained from Warsaw that the two Polish stations are separated geographically by about 14 kilometres.

Examples of the Effect.

The foregoing pairs of stations give rise to radiation on frequencies the strongest of which are the sum and difference of their respective frequencies. Thus, for example, the London National and Regional Stations at Brookmans Park give rise to spurious emissions on 272 kc.p.s. and 2026 kc.p.s., the frequencies of the two stations being 1149 kc.p.s. and 877 kc.p.s. respectively.

In addition to these simple sum and difference frequencies several cases have been observed where these frequencies in turn produce further sum and difference frequencies by inter-action with a third station. Thus, for example, GBV (78 kc.p.s.) telegraph station at Rugby has been heard on the frequencies of 2104, 1948 and 350 kc.p.s. when the two stations at Brookmans Park have been in simultaneous operation.

2104 kc.p.s. = 78 + 2026 kc.p.s.
1948 kc.p.s. = 2026 − 78 kc.p.s.
350 kc.p.s. = 78 + 272 kc.p.s.

The further terms which might be expected have not been observed.

In addition to the GBV station several other powerful long wave stations have been observed to be modulated by these spurious frequencies of 272 and 2026 kc.p.s.

Reports from America regarding transmissions from two of the British Post Office Stations at Rugby state that the spurious emissions have interfered with the reception in New York of Paris—TYE—operating on 18,090 kc.p.s. The British stations are GAW on 18,200 kc.p.s. and GAS on 18,310 kc.p.s., and the products in this instance seem to be a straightforward case of intermodulation of 2a − b :—

2 (18,200) − 18,310 = 18,090 kc.p.s.

In the same category as these examples is the identification of GBR (16 kc.p.s. on 1770 kc.p.s. when the London Regional Station is in operation :—

2 (877) + 16 = 1770 kc.p.s.

Cause of the Phenomenon.

Having regard to the frequencies observed it is obvious that the combination frequencies are produced at some common point having non-linear characteristics. The interference, in general, may be said to be of a character similar to non-linear crosstalk set up by third order products in repeatered telephone lines handling a plurality of carrier channels. In this connection the non-linear nature of neighbouring twin transmitting antennæ associated with their final output stages might, of course, explain the source of production, or cross modulation might conceivably occur in their common earthing system. With the high degree of selectivity obtainable on receivers the evidence so far accumulated seems to indicate that the modulation is external to the receiver end. No conclusion regarding the probable cause of the phenomenon has, however, yet been reached. Several cases have arisen of cross modulation effects due to rectification in imperfect conductors near to receivers. This effect, however, has so far been observed only in localities near to powerful twin transmitters. It is therefore thought that this trouble may not be directly related to the phenomenon in question.

G. T. E.

British Association 1937 Meeting

The Engineering Department was again represented at the 107th meeting of the British Association for the Advancement of Science held this year from the 1st-8th September in the delightful surroundings of the University College, Nottingham. Fully 2,000 members and visitors from all parts of the world attended and perfect weather favoured the proceedings throughout.

The inaugural address was delivered at the Albert Hall, Nottingham, by the President—Professor Sir Edward Poulton, D.Sc., LL.D., F.R.S. Sir Edward reviewed the progress of evolutionary thought from the time of his first meeting at York in 1881, a period of over 50 years within his own experience.

Sectional meetings during the week on branches of science, engineering and economics were full of interest ; the presidential address by H. G. Wells, D.Litt., at the Educational Science Section being in typically provocative style. Local excursions and visits to manufacturers in the district were varied and very popular.

Much of the success of the meeting must be attributed to the courtesy and unfailing generosity of the Lord Mayor of Nottingham and the City Corporation in placing most of the amenities of the City at the disposal of their visitors.

S. J. H.

Fire Extinction in Telephone Exchanges

H. J. MOBBS

The requirements of an ideal fire extinguisher for use in telephone exchanges are discussed and the new Teletetra extincteur, which has been designed to meet these requirements, is described.

Introduction.

DURING the past few months a new type of portable fire extinguishing appliance has made its appearance in certain telephone exchanges, mostly in the London area. The present supply is experimental and experience will determine whether, or not, modifications to the design are required, but in view of certain novel features a few notes on the construction and use may be of interest.

The name Teletetra has been adopted to distinguish the new pattern of fire extinguisher from that previously supplied, known as the Petrolex. Both are " pressure " type extincteurs, i.e., the propellant and the fire extinguishing liquid are contained in the apparatus. One important point of difference exists, however, in that in the Petrolex extinguisher the propellant, compressed CO_2, is contained in a small " bulb " 5½ ins. long by ⅞ ins. diameter projecting from the top of the instrument into the body of the container which holds Carbon Tetrachloride (C.T.C.), whereas in the Teletetra the propellant, Nitrogen gas, and C.T.C. are filled together into the container or " bottle " at a pressure of 100 lbs. per sq. inch. See Figs. **1** and **2**. To use either type a knob at the top of the apparatus is struck, when a pin attached to this knob pierces a thin metal disc with the result that a stream of liquid is thrown about 20 ft.

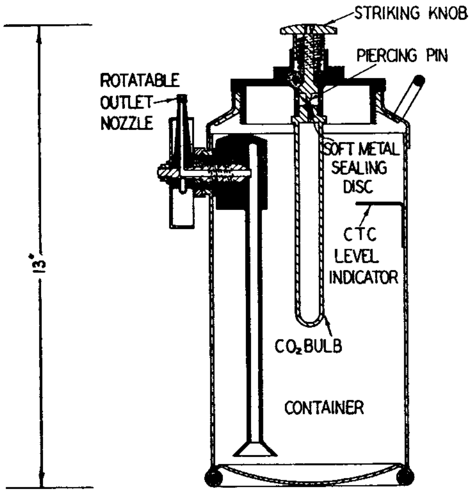


FIG. **1**.—PETROLEX EXTINCTEUR

One of the objections to the Petrolex extincteur has been the difficulty of knowing when sufficient C.T.C. and pressure exist in the appliance. With the view to overcoming this objection the base of the Teletetra extincteur is provided with a disc, about 120° of which is coloured black and the remainder red. In the centre of this disc there is a screw with a plain shank from which a small pin protrudes at right angles. If, on rotating the screw, the pin can be turned into the red area it is to be assumed that the pressure in the bottle will be insufficient to render the extinguisher jet effective.

The new extincteur is far more convenient in use than the Petrolex type. Apart from the fact that it is only half the weight of the latter it is easier to handle, being little over half the diameter. It contains, however, only half the quantity of extinguishing liquid.

A comparison of the dimensions of the two appliances and also of a similar extincteur of the pump type is given in Table I. The use of an extincteur of the pump type has been considered, but in its present form it is not so suitable as other types for use in telephone exchanges.

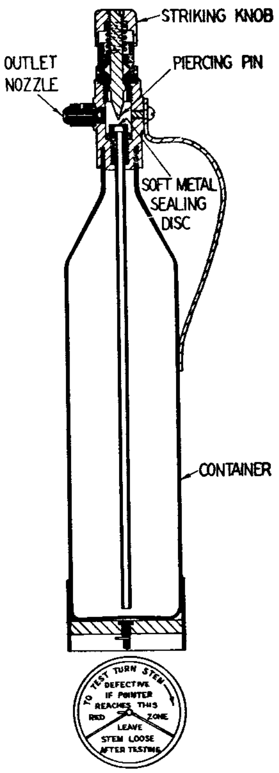


FIG. **2**.—TELETETRA EXTINCTEUR

TABLE 1

	Petrolex	*Teletetra*	*Pump Type*
Total weight (including C.T.C.)	15 lbs.	8 lbs.	6 lbs.
Dimensions			
Diameter	5 ins.	3⅜ ins.	3 ins.
Length	13 ins.	17½ ins.	14 ins.
Amount of C.T.C. in one charge	2 quarts	1 quart	1 quart

Fire Risks in Telephone Exchanges.

To appreciate the problems involved when seeking a suitable fire-extinguishing medium it is necessary to consider the fire risks involved in a telephone exchange. Apart from the risks normal to any building there is that attached to electrical apparatus. Fault conditions may cause the overheating of wires or metal parts employed to carry the current, and may produce extremely high temperatures. Alternatively, the breakdown of insulating material may cause an electric arc to be set up. Either of these conditions may result in the ignition of adjacent inflammable materials or the generation of explosive gases. It will be seen, therefore, that in considering the method of fire protection for electrical fire risks the nature of the materials likely to become involved must be taken into account. The ignition of insulating material, oil, wax, rubber, bitumen, shellac, varnish, cotton and paper, commonly occurs.

Where electrical equipment is concerned, it is essential, for the safety of those using the appliance that any fire extinguishing medium applied to a fire shall be a non-conductor of electricity. For this reason the use of water is to be deprecated. It is also extremely desirable that the medium shall damage the electrical equipment as little as possible. Water fails also on this count. Moreover, the application of water to most highly inflammable substances may be extremely dangerous and even spread the flames. Being frequently heavier than the burning fluid, usually the substances in question are fluid or become so under the action of the heat, the water jet splashes into it, sinks below the surface and helps to extend the area of the fire.

Means Available for the Extinguishing of Fires.

From this it will be obvious that what is required is some medium which will blanket or smother the fire from above. It may either cut off the air supply entirely, as by a covering of foam, or it may dilute or impregnate the air immediately above the fire with a gas or gaseous vapour which smothers it by reducing the oxygen content of the air to below the volume necessary for combustion.

The media generally used to smother fires of the types under consideration are :—

Foam
Sand
Powder
Carbon Dioxide
Methyl Bromide
Carbon Tetrachloride

Foam. This may be produced as " chemical foam " or " mechanical foam," the former being due to the action of interacting chemicals and the latter to physical action.

In most portable chemical foam appliances, an alkali and an acid, usually sodium bicarbonate with a foam stabiliser and salt solution (aluminium sulphate) respectively, are provided in separate compartments. The extinguisher comes into action immediately the two solutions are brought together, which is usually effected by turning it upside down.

No chemical action enters into the production of mechanical foam, the foaming agent being an inert liquid which is automatically expanded into foam by means of air drawn into the appliance. This is, however, intended for large fires, and therefore unsuitable in exchanges for use by the staff.

All foam extinguishers, however, employ water in one form or another, and for this reason are not suitable for use on telephone equipment.

Sand is, naturally, very difficult to apply to a fire, but the main objection to its use in exchanges is that irreparable damage can be caused to apparatus.

Powder. Many materials can be used but, owing to the difficulty of application, they are only effective for very small fires, are messy and may cause damage to delicate appliances.

Carbon Dioxide. For the generation of a blanket or smother over fires in which telephone or other electrical apparatus is involved CO_2 is very suitable. It is quick in action, dry, non-damaging and a non-conductor of electricity. It is used extensively in the U.S.A. for the protection of apparatus in telephone exchanges. CO_2 is a gas at normal temperature and pressure, but in commercial extinguishers is supplied in liquid form, under pressure. When it is released from the container, CO_2 gas, 450 times the volume of the liquified carbon dioxide, is produced.

Portable CO_2 extinguishers can be obtained containing 7 or 12 lbs. of liquid. These consist of strong steel cylinders usually provided with a valve, a length of hose and a cone-shaped distributor. The main objections to the use of CO_2 in telephone exchanges are that the containers are heavy and difficult to handle and that the average " throw " is only 6-8 ft.

Carbon Tetrachloride. This is a very volatile, colourless, liquid, and when its temperature is raised to 170° F is converted into a dry, gaseous vapour, 4½ times heavier than air. The volume of vapour generated is 233 times that of the liquid used. This vapour blankets the fire by diluting the air in the vicinity of the conflagration, thereby excluding the oxygen necessary for combustion.

There has been considerable discussion regarding the danger of using this chemical owing to the toxic nature of the fumes generated.

It is generally agreed that this danger exists and that it is undesirable to use a manually operated C.T.C. extinguisher in a confined space such as a basement or room that cannot easily be ventilated. The fumes themselves are anæsthetic and other fumes of an objectionable nature are formed by the decomposition of the C.T.C. Recently, owing to the discharge of a 12 gallon C.T.C. extinguisher in one of the basements of the Paris Halles, one man died and 19 others became seriously ill. It has been conclusively proved, however, that no danger exists in properly ventilated rooms, and for this reason whenever C.T.C. has been used to extinguish a fire indoors a current of air should be induced in the room as soon as it becomes safe to do so.

Methyl Bromide. This chemical is similar in most respects to C.T.C. It has been adopted by the Royal Air Force and is, normally, supplied under pressure in containers similar in form to that of the Teletetra extincteur.

As with C.T.C., the fumes of Methyl Bromide are certainly poisonous, but opinions as to the relative toxicity of the two are sharply divided. One experiment showed that 1 per cent. was lethal to guinea pigs in 30 minutes. The consensus of the opinions of experts indicates, however, that Methyl Bromide is the more dangerous of the two, and this appears to be the reason why its use is almost exclusively confined to outdoor risks.

It will be seen, therefore, that when the Teletetra extinguisher was being designed the available chemicals which could be used satisfactorily in exchange equipment rooms were small in number, in effect, three—Carbon Dioxide, Methyl Bromide and C.T.C. The first, owing to the bulky nature of the apparatus involved, was considered unsuitable for the rapid extinction of small fires, thus leaving the choice to be made between Methyl Bromide and C.T.C.

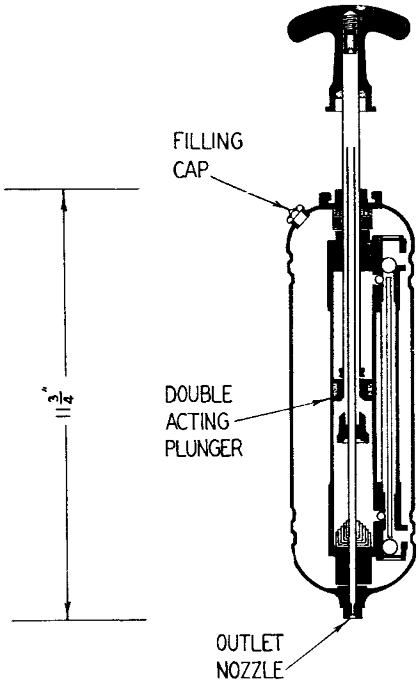


FIG. 3.—PUMP TYPE EXTINCTEUR

Future experiments may indicate that the dangers of the former have been overstressed and that it is no more toxic than C.T.C., in which case, if desired, it could be substituted in the Teletetra or other similar pressure type extinguisher without change of design. Meantime, however, there appears to be a risk which it has been considered inadvisable to take.

Thus the position of C.T.C. is, for the moment, unchallenged. It is effective for the extinction of small fires such as those with which the staff in the equipment rooms are likely to be called upon to deal, it is a non-conductor of electricity, and it cannot cause damage to the most delicate apparatus. The effectiveness of C.T.C. receives striking confirmation from the fact that most motor vehicles on the road to-day, both in this country and abroad, are fitted with pump type extincteurs using this medium. An extincteur of this type is shown in Fig. 3.

Conclusion.

The properties which an extincteur, ideal for the purpose under consideration, should possess may be summarised as follows :—

1. It should be easy to manipulate by either male or female staff.
2. An indicator should be available to show that the instrument is in a satisfactory condition, both in respect of the presence of liquid and, if of the "pressure" type, the propellant.
3. The extincteur should, when not in use, be sealed in such a manner as to prevent loss of liquid either by evaporation or misuse.
4. An average jet of 20 ft. range should be obtainable.
5. It should be of simple design.
6. It should be possible to refill the extincteur easily and quickly after use.

The Teletetra extincteur fulfils all these conditions except No. 6, and, in order to meet this difficulty, it it proposed that reserves shall be held at certain centres.

Long Distance Teleprinter Working

Teleprinter working over normal telephone trunk circuits by Telex. methods has been available to Holland for some considerable time. In April, 1937, similar facilities were provided to Belgium and Germany. To Germany, telephone circuits are used only as far as the international teleprinter exchange, Amsterdam, at which point extensions to Germany are made over the German teleprinter network, which is worked on a D.C. basis. To render this possible special converters are necessary at Amsterdam to convert the A.C. signals incoming from Great Britain to D.C. signals and vice versa.

Tests have recently been carried out between London and the places detailed in the following table, using normal telephone trunk circuits. The length of the circuits and the number of repeater stations in circuit are also shown.

Country	Town to which tests were made	Length of circuit in miles	Number of repeater stations en route
Norway	Oslo	1403	24
Sweden	Stockholm	1298	23
Czecho-Slovakia	Praha	797	16
	Zlin	952	

In each case the calls were set up as for an ordinary telephone conversation and the teleprinters and associated apparatus were not in any way specially adjusted for the tests. Satisfactory teleprinter working was obtained both with manual and automatic transmission.

Notes and Comments

H.E. Marchese Marconi

By the death on Tuesday, the 20th July, of Guglielmo Marconi, the world has lost one whose pioneering work in radio development has profoundly influenced civilisation. At the hour of the funeral all B.B.C. transmitters and all stations of the Post Office, and Cables & Wireless, Ltd. observed two minutes silence. Rugby, which links up the British Empire by radio telephone, paid this mark of respect as well as the Post Office coast wireless stations which maintain communication with ships. Post Office wireless telegraph stations operating to the Continent from this country also participated.

The Postmaster-General sent the following telegram of condolence to the Italian Minister of Communications at Rome: -

" The British Post Office deeply deplores the death of the Marchese Marconi to whose discoveries and researches in the field of wireless communications the whole world is greatly indebted. The British Post Office is proud to have been associated with the Marchese Marconi both in his early experiments in this country forty years ago and since then in the world wide development of wireless communications in which his inventive genius played so important a part."

We have pleasure in publishing the following appreciation of the Marchese Marconi by Mr. E. H. Shaughnessy late Asst. Engineer-in-Chief of the British Post Office.

" The news of the death of Senator Marconi from a heart attack after a few hours illness on July 20th was received with profound regret by scientific circles and especially by those who were fortunate enough to have been associated in any way with him personally or with the great work of which he was both founder and father. He was born in 1874 and was educated at Leghorn and Bologna University. It was in 1895 that his outstanding genius led him to conclude that the invisible electric waves, predicted by Maxwell and later proved to exist by Hertz, could be utilised as a means of telegraphic communication through space without the aid of wires. During that year, near Bologna, using a spark coil as a transmitter and a coherer as a detector, he successfully demonstrated the feasibility of such communication over a distance of about a mile.

In 1896 he came to England and saw Sir William Preece the Engineer-in-Chief of the Post Office, who was much impressed and interested in the new invention and who encouraged Mr. Marconi to experiment further with Post Office engineers, first between the London G.P.O. and the Thames Embankment and later across Salisbury Plain. These experiments were highly successful and in May, 1897, Marconi established connection between Lavernock and Flatholm in the Bristol Channel and later across the Bristol Channel from Lavernock to Brean Down, a distance of nine miles. Marconi then returned to Italy and successfully established communication between a fixed land station and ships of the Italian Navy over a distance of twelve miles. Later in the same year Marconi returned to England and, again co-operating with Post Office engineers, achieved communication beween Salisbury and Bath, a distance of 34 miles.

In 1897 Marconi's Wireless Telegraph Co., Ltd., was formed and from that time onwards his untiring energy and undamped enthusiasm were rewarded by steady and continuous progress. In 1899 a number of ships of the British Navy were equipped with Marconi apparatus and in the same year Mr. Marconi read a paper on " Wireless Telegraphy " before the Institution of Electrical Engineers of which he was a member.

By the early part of 1901 Marconi had increased the distance over which he could communicate to about 250 miles. This led him to contemplate inter-oceanic communication but, like most pioneers in the application of pure science to commerce, he received little encouragement from the theorists who regarded the electric waves as being subject entirely to the laws governing light waves and consequently incapable of following the curvature of the earth's surface. Mr. Marconi, however, felt that though the theorists might be right in drawing this conclusion from the known laws of light, there might be something unknown about these electric waves still to be discovered, and encouraged by the success he had already achieved and with his characteristic optimism he determined to try out a new line of research. In December, 1901 he confounded the theorists and attained an epoch-making success by receiving signals sent from Poldhu, England, at St. Johns, Newfoundland (a distance of 1,700 miles) despite the curvature of the earth between those points.

Marconi was the moving spirit in the Marconi Wireless Telegraph Company which has erected many powerful and efficient wireless telegraph stations for inter-oceanic communication in many parts of the world. He collected around him a number of engineers and scientists whom he fired with his own enthusiasm and who worked ceaselessly and loyally with him in extending and improving wireless telegraphy. In 1926 Marconi and Franklin achieved another epoch-making success by the introduction of Marconi's short wave " Beam " system which was capable of working at speeds up to 200 words per minute between stations situated at the remotest distances apart on the earth's surface—England and Australia. The introduction of this system resulted in a reorganisation of Empire Telegraph communications and brought about the amalgamation of the services of submarine cables and wireless systems as adjuncts to each other.

Senator Marconi was only 63 when he passed away and until quite recent years seemed to retain all his youthful enthusiasm. He never tried to impress one with the mysteries of wireless telegraphy and was always as simple as possible in his discussions on this subject. He was ever ready to encourage and listen to any suggestions for the improvement of wireless telegraphy. I had the honour and privilege of associating with Senator Marconi on many occasions and always found him a courteous, loveable man, and I, with many whose lives were made the richer and more interesting by being employed for many years in the art of wireless telegraphy, wish to place on record the high esteem in which he was held and to acknowledge the great debt we owe to his original genius. Our deepest sympathy goes out to his relatives and to the Italian nation in their great loss."

E. H. SHAUGHNESSY.

Transatlantic Telephone Calls

Our readers will be interested to know that the number of telephone calls made between this country and the United States during the three months ended May 31st last was 5,511 and the average duration of the calls about seven minutes. The last negotiations concerning the transatlantic telephone rates resulted, a year ago, in a reduction of the rate to the New York zone of the United States from 40s. to 28s. a minute during the day and from 28s. to 20s. a minute at night and on Sundays. Similar reductions were made in the rates to the more remote zones and the charge for calls to ships on the Atlantic, set up via New York, was reduced from 48s. to 33s. a minute. Some further reductions were made at the beginning of July of this year in the charges for calls to places beyond the New York zone.

W. R. Culley, Esq., I.S.O.

Readers of the Journal will regret to learn of the death, at the age of 85, of Mr. W. R. Culley who was for many years Submarine Superintendent. Mr. Culley was appointed Asst. Submarine Superintendent in 1878, Submarine Superintendent at Dover in 1890 and Superintendent at Woolwich from 1897 to 1912 when he retired.

Erratum

It is regretted that two errors appear in the article entitled " Protection of Post Office Circuits in Northern Ireland," published in the July issue :—

1. Figures 13 and 14 should be interchanged.
2. The end of Appendix 1 should read as follows :—

If R = Resistance required to limit the fault current to 57 amps

Then $\frac{\sqrt{3 + 33{,}000}}{(3R + 90) + j188} = a + jb$ where $\sqrt{a^2 + b^2} = 57$

from which R = 300 ohms.

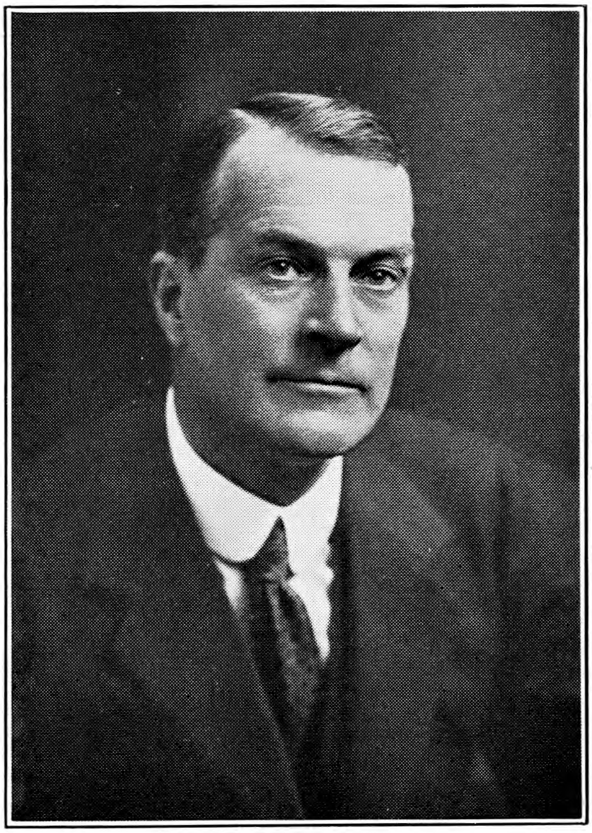
Retirement of Mr. T. T. Partridge, M.I.E.E., M.I. Struct. E.

Mr. Partridge, first Superintending Engineer of the Northern Ireland District, retired on September 30th, 1937. His early years were spent in Nottingham as Sorting Clerk and Telegraphist, Junior Clerk and Sub-Engineer. From 1904 to 1908 he was in charge of the Carmarthen Section and was then transferred to the Engineer-in-Chief's office to take part in the inventory and valuation of the National Telephone Company's external plant prior to the transfer of the undertaking to the State. In 1914 he was transferred to Nottingham as Executive Engineer, and in 1930 was promoted to the rank of Assistant Superintending Engineer, South Lancashire District. In November, 1933, Mr. Partridge was transferred to Belfast as Assistant Superintending Engineer in charge of the Northern Ireland District and was promoted to the rank of Superintending Engineer in the following year. During his tenure of office in Northern Ireland very rapid development has taken place in telephone and telegraph engineering. Belfast has been converted to one of the largest Multi-Office Automatic systems in the kingdom, about 80 smaller exchanges have been converted from manual to automatic working, and the first commercial multi-channel ultra-short-wave radio telephone trunk lines in the British Isles have been established between Belfast and Port Patrick.

His efforts were largely responsible for the formation of the Northern Ireland Sub-Centre of the Institution of Electrical Engineers of which he was the first Chairman.

His desire to further the interests of the members of the staff under his control, his keen personal interest in their welfare, and his active participation in their social life made him very popular among all who had the privilege of serving under him.

C. E. W.



H. S. Thompson, M.I.E.E.

Mr. H. S. Thompson was educated at the King Edward VI Grammar School and Mason's College, Birmingham. He entered the service of the National Telephone Company at Birmingham in 1896, was appointed to the Engineer-in-Chief's staff at the N.T. Co.'s headquarters in 1903, whence he came to the Telephone Section, Engineer-in-Chief's Office, G.P.O., in 1912. In 1927 he was appointed Assistant Staff Engineer in the Equipment Section where he was largely responsible for the design and provision of telephone exchange installations.

He was a member of a commission sent to the United States in 1930 to investigate and report on the American system of handling long-distance telephone traffic and, on the return of that commission, was intimately connected with the introduction of " Demand " working and the accompanying general rehabilitation of the trunk switching system. In 1932 he was transferred to the South-Western District as Assistant Superintending Engineer and became Superintending Engineer of the South Wales District in 1933. While in the latter district, Mr. Thompson lost few opportunities of participating in every inter-Section sporting contest and social function, and the resulting contacts with practically every member of his somewhat scattered staff must have proved invaluable. His place as Chairman at the numerous gatherings of this kind will be difficult to fill and we part with feelings of real regret coupled with our best wishes for his future health and happiness in his new sphere of activity in Northern Ireland.

H. J. H.

Colonel H. Carter, T.D., B.Sc., A.R.C.Sc., M.I.E.E.

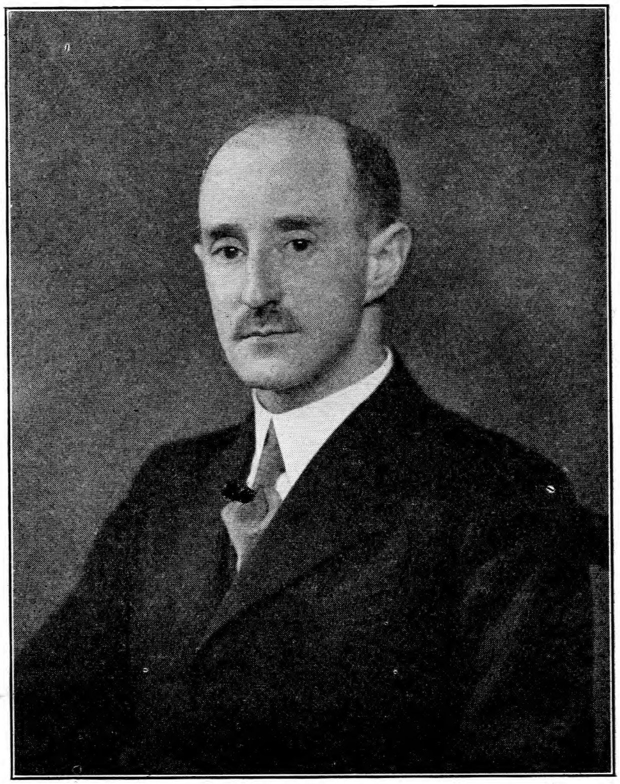
Colonel H. Carter, transferred from Staff Engineer in charge of the External Plant and Protection Branch of the Engineer-in-Chief's Office to Superintending Engineer, South Wales District, on October 1st.

He entered the Engineering Department in 1911 by open competition and served as Assistant and Executive Engineer in the Construction Section of the Engineer-in-Chief's Office until 1933. During the later part of that period he specialised in protective measures against power circuits and cable sheath corrosion. From 1933 to 1936 he was Assistant Superintending Engineer in the S.E. District, and in January, 1936, he returned to his old Branch of the Engineer-in-Chief's Office as Staff Engineer.

He has represented the Post Office on many outside committees including the C.C.I.F., the C.M.I., the British Standards Institution and the Electrical Research Association. During his last period in the Engineer-in-Chief's Office he has been a member of the Board of Editors of this Journal.

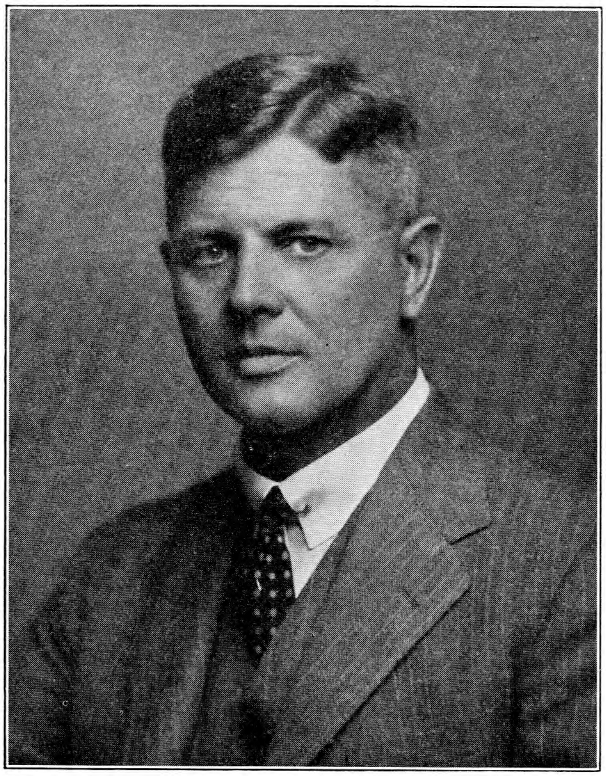
After pre-war service with London University O.T.C. (Artillery) and the East Kent Yeomanry, Colonel Carter served throughout the War with R.E. Signals in France where he had experience as Artillery Signal Officer and as officer in charge of No. 4 Signal Construction Company, and was mentioned in despatches. He continued his Territorial service after the war with the newly constituted Royal Corps of Signals and completed his term of command of the London Air Defence Signals in 1933 when he was promoted Colonel (T.A.).

Colonel Carter's many friends at Headquarters unite in wishing him every success in his new sphere.



P. B. Frost, B.Sc., M.I.E.E.

Mr. P. B. Frost has been appointed Staff Engineer in the External Plant and Protection Branch at Headquarters and his many friends, both inside and outside the Civil Service, join in offering their hearty congratulations on his promotion.



Mr. Frost completed his educational course in electrical engineering at Finsbury Technical College in 1905. This was followed by three years' workshop experience at Edison and Swans and at Siemens Brothers dynamo works. He afterwards worked for one year in a high tension sub-station of the L.C.C. tramway Department.

Mr. Frost was first employed in the Post Office Engineering Department in 1909 and he subsequently passed through the grades of Inspector, probationary Sub-Engineer, Assistant Engineer and Executive Engineer in the Inspection, Power, Exchange Equipment and Accommodation, and External Plant and Protection Branches at Headquarters.

In 1934 he was promoted to the grade of Assistant Staff Engineer in the External Plant and Protection Branch, where he specialised on power circuit interference, corrosion and allied problems. In the early part of this year Mr. Frost was transferred to the London Telecommunications Region as Assistant Superintending Engineer in charge of Underground Construction and Maintenance.

He has represented the General Post Office on a number of E.R.A., B.S.I. and I.E.E. Committees and he has been a delegate to C.C.I.F. and C.M.I. conferences in Paris, Stockholm, Budapest, Copenhagen, etc. He has also been chairman of two C.M.I. investigating committees.

Mr. Frost's friends and colleagues are confident that his wide knowledge in different phases of electrical engineering, his zeal and his calm judgment, will enable him to maintain in fullest measure, the high traditions for progressive service of the old "Construction Section."

A. O. G.

Junior Section Notes

Southampton Centre

All members, together with new entrants and Youths-in-Training are invited to attend the lectures to be given during the forthcoming session.

The provisional programme is :—

October 21st.—" The Relationship of the Drawing Office to the Department." By B. Wicks.

November 18th.—" U.A.X.'s No. 13." By S. E. Harvey.

December 15th.—" Unit Costs and Construction Data." By V. Smith.

January 22nd.—" Repeaters." By A. G. Chuter.

February 19th.—" Overhead Construction and Subbing." By J. Compton.

March 19th.—" An Informal Meeting." (Open.)

Visits to " Civic Centre Clock " and the " Power Station " are being arranged.

The scope of the lectures for the coming session should be of interest to all. The younger members are asked to take advantage of the facilities of the library and lectures to further their technical education and to embrace the other activities of the Department's many sections. The test desk and controlling officers are asked to urge every member of the staff to come along, join us and support us.

Our thanks are due to all the senior officers who helped to make the past session a success, also to W. Bell, Esq., Secretary Senior Section, Reading ; the Dollis Hill staff for loan of slides, etc. ; and Professor Menzies, Physics Professor of Southampton University College, for use of projectors.

Salisbury Centre

The third Annual General Meeting of the Centre was held at the Head P.O., Salisbury, on June 9th, 1937. Mr. G. Parrott presided over a meeting of 21 members.

The report on the last session was delivered by the Secretary (Mr. W. Hatcher), and it was unanimously agreed that the session had been very successful. Mr. Hatcher also offered his congratulations to the Chairman on his promotion to the rank of Asst. Engineer, and wished him every success and happiness.

Following upon this, the Treasurer gave his report.

The election of officers for the forthcoming session then proceeded.

The following were elected :

Chairman—E. H. Granger.
Vice-Chairman—R. H. Read.
Secretary—W. Llewellyn.
Treasurer—S. N. Wathen.
Committee—S. A. Vokes, H. J. King, L. J. Cox.
Auditors—A. E. Pearcey, E. W. Brown.

The Chairman then called for offers of lectures, etc., to be delivered during the coming session. Numerous offers were received, and it was left to the committee to draw up the programme.

In his remarks, the Chairman thanked the Secretary for his good wishes, and expressed regrets at having to leave Salisbury. He expressed the hope that the Centre would continue to further its objects, laying particular stress upon the need for more active participation in the doings of the Centre by the younger members of the staff and by members of the external staff.

The meeting closed at 9.15 p.m. when a vote of thanks to the Chairman for his services so willingly rendered to the Society since its inception was proposed, seconded and unanimously carried.

Institution of Post Office Electrical Engineers

ESSAY COMPETITION, 1937

The Council has decided to offer Five Prizes of Two Guineas each for the five most meritorious essays submitted by members of the Engineering Department of the Post Office below the ranks of Inspector and Draughtsmen, Class II, and, in addition, to award a limited number of Certificates of Merit.

A prize-winner in any previous competition is not eligible to enter, but this restriction does not apply to a competitor who has been awarded a certificate only.

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 large number of entries. Marks will be awarded for originality of essays submitted.

Information concerning the competition is given in the leaflets which have been issued to the centres for distribution. The Council hopes that supervising officers generally will bring the competition to the notice of those eligible to compete.

The Essays must reach the Secretary, The Institution of Post Office Electrical Engineers, G.P.O. (Alder House), E.C.1, before the 31st December, 1937.

LIBRARY FACILITIES

A new catalogue of the Institution Library has recently been issued and, as there has been a very considerable change in the membership since the last catalogue was issued, it is thought that a brief reference to the facilities afforded by the Institution Library may be welcomed.

While the primary objects of the Institution are to promote the general advance of electrical, telegraphic and telephonic science, it has been the policy of the Council, particularly in recent years, to give these functions a wide interpretation. In this connection the Institution Library has been affiliated to Lewis's Scientific Library and The Management Library. Members therefore have at their disposal a wide selection of literature covering not only technical and scientific subjects but also administrative and allied problems.

Every effort is made to keep the Institution Library up to date, and, to this end, it is the policy not only to keep the Library stocked with up-to-date publications, but also, by the constant review of the Library, to eliminate all books which become out of date. While it is clearly neither expedient nor desirable to include in the Library all new publications issued, members wishing to obtain books not in the Institution Library are invited to make known their requirements to the Librarian in order that endeavour may be made to borrow the required publications from other sources. If this is not possible, the desirability may be considered of inclusion in the Institution Library.

Library facilities are available to all corporate members of the Institution, including Junior Section members and honorary and retired members.

Particulars of the facilities afforded are given in more detail in the following notes.

Messrs. H. K. Lewis & Co., Medical and Scientific Library.

An arrangement has been made which enables members to borrow from the extensive library of Messrs. H. K. Lewis & Co., Ltd., through the Librarian of the Institution. This brings within the reach of members practically all technical and scientific works of any importance (English, American and translated foreign publications). It is important to note that new books and new editions of books are added to Lewis's Library immediately on publication. A catalogue of this Library is available on loan to members. Lewis's Library is so comprehensive, however, that a member requiring a particular scientific or technical book not included in the Institution Library is invited to requisition the required volume (using an ordinary library requisition form) from the Librarian without reference to Lewis's catalogue.

The Management Library.

A similar arrangement exists which enables members to borrow from the Management Library, which contains an exhaustive collection of literature relating chiefly to management and organisation, general economics, cost accounting, cost control and industrial psychology. A more complete list of the main subjects covered by this Library is given in the Library catalogue. The Management Library catalogue, which is also available on loan to members, is known as The Business Man's Guide to Management, and is a very interesting and useful publication in that it contains short descriptions of a wide range of the Library's books.

New Catalogue of the Institution Library.

A copy of the new catalogue has been issued to each member of the Institution and two copies to each of the Junior Section Centres. The layout of the catalogue has been completely reviewed and revised to facilitate reference. A Library Bulletin will be issued in March, June and September of each year and a supplement to the catalogue in December (commencing 1938).

For the information of Junior Section members, who will not receive personal copies of the catalogue, a brief summary of the contents of the Library will probably prove helpful. The Institution Library contains an extensive collection of books on chemistry, civil, electrical and mechanical engineering, mathematics, physics (including magnetism and electricity), radio, telegraphy, telephony, transport and motor engineering and various other technological and scientific subjects, together with books on economics, finance, psychology, statistics, etc., and copies of examination papers for the City and Guilds of London Institute, Probationary Assistant Engineers' and Probationary Inspectors' examinations, Institution of Electrical Engineers' Graduateship Examination Papers and University of London intermediate and B.Sc. examinations in engineering, Printed Papers of the Institution, Essay Competition Prize Essays, Prize Papers read by members of the Junior Section, bound volumes of "The Post Office Electrical Engineers' Journal," and copies of "The Journal of the Institution of Electrical Engineers" are also available on loan to members.

T. C. GOODWAY,
Librarian.

District Notes

South Midland

PORTSMOUTH HARBOUR—SUBMARINE CABLES.

There is little doubt that Portsmouth Harbour is one of the busiest, as well as one of the most interesting harbours in normal times, and this is particularly apparent in this year of grace, 1937, due to the great Coronation Naval Review, the Combined Forces Air Exercises, and the ever-popular Navy Week.

From shore to shore, from the historic " Point " of Portsmouth to the equally eminent " Hard " at Gosport, the fairway extends for some 700 yards. Under this famous seaway, furrowed by innumerable keels of imperishable memory, from Nelson's " Victory " to the efficiently grim " Nelson " of our time (known in naval parlance as " Queen Anne's Mansions " because of the peculiar flat-like appearance of the forward superstructure), are placed the submarine telephone cables on which the exchanges serving the growing borough of Gosport and the strategically important Air Service base, Lee-on-Solent, are dependent.

These exchanges are satellite on Portsmouth, that veteran of automatic exchanges, which has seen 21 years of service, and on which the prehistoric " Keith " line-switches still " plunge in " to the accompaniment of the clattering solenoid of the hunting master-switches. It is recognised that this is mere jargon to the modern automatic telephone expert, but many may be pleased to hear that the old place is still carrying on, though doomed to replacement (line-finders, 2,000 type selectors, 3,000 type relays, auto-routiners) in 1941. Incidentally, there are no less than seven distinct types of " finals " in the old Portsmouth Exchange to-day, the nucleus of a fine museum.

Just before the Naval Review, certain premonitory symptoms were noticed which indicated that the condition of the largest of the submarine cables from Portsmouth across the harbour to Gosport was not quite all that it should be. The time was very short and the traffic up and down the harbour fairway was abnormally heavy, so it was decided to improvise an ordinary lead-covered P.C.Q.L. cable, 100/10, to avert the impending breakdown. This expedient is not without precedent in more sheltered waters, but its adoption across Portsmouth harbour with the greatest naval traffic of modern times, i.e. kedges and anchors being released in all directions, despite the red warning " diamond " at the land terminations of the cables, was viewed with much interest and more trepidation. However, the faulty cable failed exactly one day before the Naval Review was due to open.

A very hectic few hours of emergency advices for the cable, arranging the hire of suitable craft, settling the " depth course and position " of the cable with the King's Harbour Master, and many other minor but essential operations ensued, and the cable was laid on the night before the special review circuits were required for service. The finishing touches were applied on the following morning just as His Majesty's royal yacht " Victoria and Albert " steamed out of harbour conveying Their Majesties to the review of the Fleet. When the yacht arrived at the Fleet anchorage the work had been completed, and the connection of the circuits was effected to scheduled time ; but the margin of time was negligible. Everyone concerned breathed freely for a while, but it was the considered opinion of the assembled experts that the P.C. cable would not last five minutes. A drive for the provision of a permanent cable was initiated in consequence. The normal manufacturing time for a submarine cable of the size required is something from 60-80 days. Obviously, heroic measures had to be taken, and the outcome was that Messrs. Pirelli laid the new cable on July 14th, little more than six weeks after the failure of the previous cable.

During this period the temporary cable had carried the traffic normal to the satellite exchanges, the special circuits for the Naval Review, and very important lines for the Combined Air Exercises. Details of the extensive telephonic network provided for the Air Exercises cannot be given for obvious reasons, but it may be revealed now that the pseudo-submarine paper-core cable, laid by this Department's staff, was a very significant link in the chain.

The main features of the new cable are :—

Length (shore to shore), 730 yards.

Size of completed cable, 2.9 inches diameter ; total weight, 14 tons ; drum diameter, 10 ft. 6 ins.

160 pairs 20 lbs. conductors ; electrical constants, etc., normal, and call for no comment. P.C.Q.T. formation.

Armouring, double, inner layer 43 No. 10 wires ; outer layer, 40 No. 8 wires.

The double-armouring with two comparatively small sizes of steel wires instead of a single lay of large section wires appeared to improve the flexibility of the cable and thus facilitated handling. For this reason the contractors decided to lay direct from the drum, which was mounted on a lighter and towed across the fairway. Some little excitement was occasioned by the near approach of a passenger steamer while the lay was in progress. The wash from this craft caused a nasty swell, and the consequent movement of the lighter displaced the braking arrangements on the drum, which was, for a few seconds, in danger of being unshipped. The danger was averted and the lay was completed without further incident.

It is perhaps worthy of remark that the temporary paper core cable is still functioning perfectly after a period of nearly four months, thus confounding the expressed opinion of the experts. It is truly remarkable that this cable has withstood the conditions for so long.

MERCHANT NAVY WEEK—SOUTHAMPTON.

The Post Office Services were much in evidence at the first Merchant Navy Week held at Southampton. A Post Office exhibit, attractively designed by the Public Relations Department, was on view. It consisted of a working Post Office, Sorting Display, Savings Bank Counter, Automatic Telephony Demonstrations, Research Counter, Submarine Cables, Air Mail Exhibit, etc., and was of particular interest to the thousands visiting the exhibition. Included in the demonstration apparatus was a $\frac{10 + 30}{50}$ P.B.X., which was used to supply telephone service to the various exhibitions. 8 exchange lines, 20 extensions and 5 kiosks were provided for this purpose.

Included in the programme was the annual Missions to Seamen Service, which was transferred from Winchester Cathedral to the Docks. This service was broadcast on the National Programme, the local wiring and microphone leads being fitted by the Post Office.

South-Eastern

CANTERBURY—POST OFFICE EXHIBITION.

A Post Office Exhibition was opened on August 12th at Canterbury by Alderman Frank Hooker, J.P., the Deputy-Mayor. The Post Office was represented by Lt.-Col. G. T. Crutchley, C.B., C.M.G., C.B.E.; P. W. McIntyre, Esq., Surveyor, S.E. District; A. B. Morice, Esq., Asst. Superintending Engineer, S.E. District; W. G. Bowley, Esq., Head Postmaster of Canterbury; and B. R. Mead, Esq., District Manager, Canterbury.

Many of the exhibits have been seen and described elsewhere, but mention should be made of the Roneo Neopost stamp cancelling machine, with a speed of 700 letters per minute. The machine, the first of this design to be exhibited, is a great attraction to the public and its performance is being watched with interest by the demonstrators.

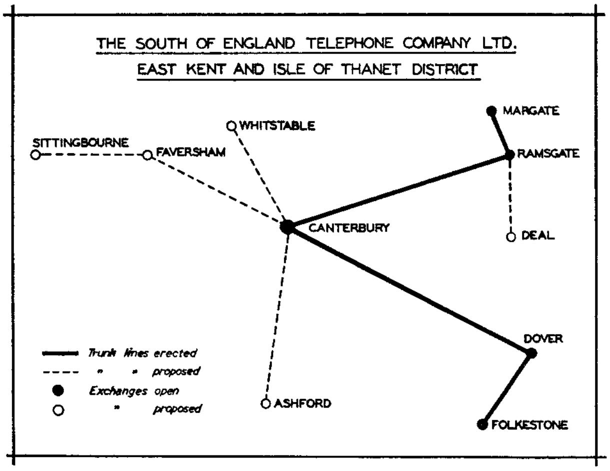
Other exhibits range from reproductions of postmen's uniforms to the more complicated automatic demonstration set and the cathode-ray tube.

The teleprinters are proving a popular source of interest not only to the visitors but to the Canterbury Sectional Engineer's office, where a souvenir telegram in the following terms has been received.

> " The exhibition is marvellous and the telephone is a very useful instrument, but when are you going to fit mine? "

Needless to say, this challenge produced a ready response!

The exhibition has been instrumental in bringing to light, through the courtesy of one of the visitors, a telephone directory for the East Kent area, dated February, 1889. The directory was produced by the South of England Telephone Company and comprised one double sheet. The East Kent and Thanet District had exchanges at Ramsgate, Margate, Folkestone, Dover and Canterbury. The latter place was apparently the head office with about 51 subscribers. The tariff for Canterbury (within one mile of the local exchange) with use of trunk wires was £10 per annum.



A portion of the directory showing the area served is reproduced in the diagram.

A very interesting feature of the exhibition is the large attendance. During the fortnight it has been open, 28,000 people have visited the exhibition; this is more than the total population of Canterbury.

Eastern

BEDFORD AUTO MANUAL EXCHANGE EXTENSION.

Due to the rapid increase of trunk and junction traffic following the reduction of trunk charges and also to the increase in parent exchange traffic involved by the conversion of dependent exchanges in the area from manual to U.A.X. working, the Bedford manual exchange capacity and floor capacity for extensions were utilised long before the anticipated date of exhaustion.

For relief it was intended to provide a new exchange building with a new manual room as an extension of the existing building. New auto-manual equipment was to be installed in the new building. This scheme obviously required considerable time to execute owing to the building programme congestion and the difficulties in obtaining apparatus supplies. As an interim measure, to reduce delay in providing relief and to postpone the major expenditure, also to obtain longer life from existing equipment, the writer suggested a minor building extension of the manual room, second floor, and the first floor below, over the Departmental entry at the side of the exchange building. By this means, an increase of 50 per cent. could be given to the manual room floor area. The extension of the first floor would give space also for auto apparatus extensions.

The suggestion was also made that the existing manual switchboards should be slewed into the new positions necessary to permit of manual switchboard extensions being made, to facilitate extension operations, and to limit expenditure.

The Surveyor having decided that the building extension, when made spare by the eventual removal of the exchange to a new building, could be utilised for Postal purposes, Headquarters authorised the building extension.

The proposal to slew the existing switchboards by Departmental labour was also agreed. The extension of the building was a rather difficult operation, particularly as it was decided to widen and increase the height of the side entrance to facilitate the passage of main vans. The extension was, however, so planned by the Office of Works and executed by their Contractor as to cause minimum disturbance to services. Plans were prepared for the shifting of the manual switchboards by a detailed survey of all multiple and other cables (*a*) as existing and (*b*) as required in the new positions. Some of the cables required lengthening before the removal while others would require shortening after removal, due to the changes in the angle positions.

The pre-removal cabling alterations and other works were then carried out, entailing six weeks' work for the available staff. Scale models of the suite of switchboards were prepared, wired and placed on a scale plan of the switchroom, showing existing and new suite positions, in order to check the practicability of the operations proposed and to plan the stages of the removal in advance of the operations.

Shortly before the removal was to be done the sections to be moved individually were unbolted and the wooden fronts and angle pieces were removed. Sections 7 and 8 and 13 and 14 were left bolted together as they were in straight formation and were required in straight formation in their new positions.

Under each of the sections two hardwood strips were placed and screwed to the ironwork. To each of the strips were fixed two piano castors of the ball type

(Fig. **1**). Preparatory trials had shown that the castor fittings enabled the positions to be moved by hand, also that, with the precautionary measures taken, no undue strain on cables and wires would be involved.

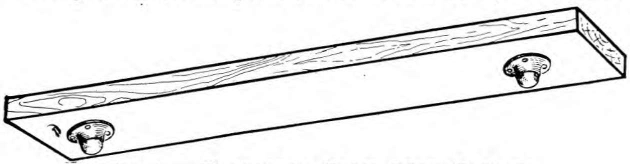


FIG. **1**.—HARDWOOD STRIP WITH CASTORS.

The work of removing the positions was commenced at 11.30 p.m. on Saturday, May 29th, 1937, and the switchboards were all in their new positions by 7.30 a.m. on Sunday, May 30th.

In fuller detail the operations were as follows :—

The recovery of the false work at angles made gaps of 5 inches at the face of each of the angles and also gave some slack in the multiple and other cables.

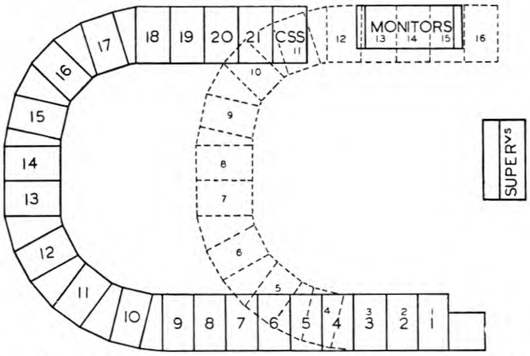


FIG. **2**.—PLAN OF SWITCHBOARD BEFORE AND AFTER EXTENSION.

At the commencement of the removal operations section 12 was moved across the intervening gap to section 11. Next 13 and 14 were moved up to section 12, then 15 to 14, then 16 to 15. The next sequence of operation was 11 to 10, 12 to 11, 13 and 14 to 12, 15 to 14 and 16 to 15. Similar operations were repeated until the final positions were reached. Longer shifts became practicable when No. 16 position had passed the obstruction of the side wall.

Six men were employed on the removal.

No interruptions, faults, cable or wire breakages were caused during the removal.

At later stages the castor strips were recovered, woodwork replaced and new iron and woodwork fitted at angles. Cables and wires which had become too long by reason of the removal were shortened where necessary.

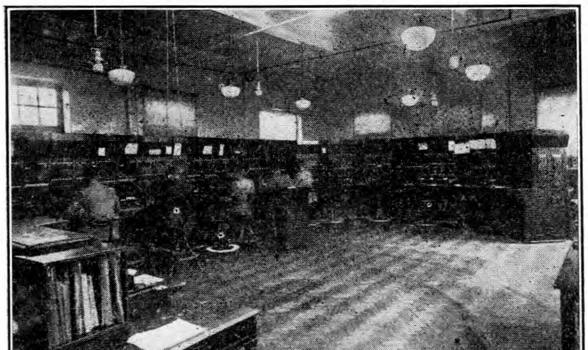


FIG. **3**.—VIEW OF THE NEW SWITCHROOM.

On completion of the removal work, contractors commenced the installation of additional equipment.

Fig. **2** gives plans of the switchboard before and after operations, and Fig. **3** is a photograph of the new board. The line of the switchboards before removal is clearly to be seen on the floor. The additional sections 16 to 21 which are being installed by contractors are shown on Fig. **2**.

North Western

The District was honoured by a visit of the Director-General during the latter end of July. Sir Thomas Gardiner was accompanied by Mr. J. Innes. The matters of accommodation for area purposes had been occupying the various departments for some time previously, and the Director-General confirmed the arrangements which were in hand.

Both Sir Thomas and Mr. Innes took a keen interest in the affairs of the District, and a feature of the visit was the number of personal contacts with members of the staff. Their personal interest and sympathetic encouragement were much appreciated by the various grades in the North-Western District.

South Lancs

MANCHESTER, " EAST " AUTOMATIC TELEPHONE EXCHANGE.

The above-named telephone exchange was opened on Saturday, July 10th, 1937, when approximately 1,300 subscribers in the area formerly served by the East manual exchange were transferred to the automatic system.

The transfer was effected without a single fault. It is the 28th automatic telephone exchange opened in the Manchester Area since the introduction of automatic working into the South Lancashire District in 1930.

Scottish Region

BROADCASTING.

During July two interesting initial cases of broadcasting development occurred as stated below. Both exemplify the efforts now being made to relieve the isolation of the Scottish Islands and to bring them into closer affinity with national affairs.

Broadcast from Barra.—On July 31st the Rt. Hon. W. E. Elliot, M.C., Secretary of State for Scotland, broadcast a talk in the B.B.C. Scottish Regional programme from the fishing cruiser " Minna," lying at Castlebay, Barra, in the Hebrides. In his talk Mr. Elliot made reference to the programme of Post Office enterprise which will result in the connection by radio links, of the Hebrides, Orkneys and Shetlands with the national telephone system.

Mr. Elliot spoke through the short-wave transmitter forming part of the equipment of the vessel. A special receiver supplied by the Engineer-in-Chief was fitted at Tobermory and connected by wires specially erected to Tobermory exchange. Transmission from Tobermory was carried over the existing circuits modified by the insertion of B.B.C. music repeaters at Inverary and Oban exchanges.

Reception by listeners has been very favourably commented on.

Broadcast from the Orkney Islands.—The first broadcast from the Orkney Islands was made by the B.B.C. on July 29th on the occasion of the octo-centenary of St. Magnus Cathedral, Kirkwall.

The circuit arrangements comprised the use of the Kirkwall–Wick trunk (which includes a long section of submarine cable), the physical line of the Wick–Inverness single-channel carrier, and the Inverness–Aberdeen portion of an Inverness–Glasgow trunk. Special tests were made during the week preceding the broadcast, which was entirely satisfactory.

SCOTTISH EMPIRE EXHIBITION, GLASGOW.

The above will be held in Scotland during the summer of 1938 and will be located in Bellahouston Park, Glasgow. Provision has been made for the installation of a telephone exchange (to be known as Exhibition exchange). The equipment will be installed under contract by the Automatic Telephone & Electric Co., Ltd., of Liverpool, and will be ready for service on March 1st, 1938. Provision is being included for 920 subscribers' lines and 21 operators' positions and the exchange will be of the C.B.10 type. The complete specification for the exchange has been prepared by the Engineering Branch of the Scottish Region.

It is anticipated that the equipment will be recovered in November, 1938.

North Wales

MACHYNLLETH POWER STATION FAILURE.

It is often said that the unexpected always happens. The expression is generally used when recounting some minor pleasant surprise, but when the worst possible calamity takes place without warning the full unpleasant truth of the adage is apparent.

The Welsh National Eisteddfod had been in full swing for three days and the town of Machynlleth, where this year's ceremonies and festivities were being held, was crowded with distinguished visitors. Elaborate illuminations, never before seen in the town, had been erected along the streets, and hotels, boarding houses and shops were breaking all previous business records.

At 12.15 a.m. on August 5th, when the town was beginning to retire for the night and most of its electric lamps were in use, a burst of flame from the power station of the electricity supply company coincided with the cutting off of all electric lights in the town, and in a few seconds the only source of illumination for miles around was the glow in the sky from the blazing power station.

The Post Office staff which had been working at full pressure with its unprecedented mail, had to postpone work and grope for oil lamps and candles.

The Engineering Inspector stationed at Machynlleth saw the first glow of the approaching fire and rushed to the power station to satisfy himself that the supply of current was permanently dislocated. He then returned to the Post Office and disconnected such circuits from the exchange battery, which could be dispensed with, in order to conserve what current was held in charge.

The teleprinters installed for the Eisteddfod traffic a carrier circuit and, of course, the lighting of the building, being fed direct from the mains, were out of use. The time-check signal working from an A.C. mains oscillator was also out of action.

Arrangements were at once made to provide an alternative power supply. An old A.B.C. set was obtained from Chester to charge the low tension batteries, a Stewart Turner Race Course Set was rushed from Birmingham and installed in the Post Office yard to provide current for the teleprinters, and service was restored on these circuits at 7 p.m. the same day.

Twenty-four 72-amp.-hour cells were borrowed from a neighbouring U.A.X. in course of construction, and installed in the Post Office yard as a standby for the 3-channel carrier low tension and exchange batteries.

To meet the need for an early supply of lighting current a charging set giving 80 volts, with a quantity of 60 volt lamps, was obtained from Birmingham.

Two charging plants were already running in the Post Office yard, and it was impossible to install the 80 volt set there, so it was placed in the adjoining Wynstay Arms yard and leads passed over the wall. The set was used to charge the carrier equipment high tension battery and provide lighting current for the Post Office and Exchange. It was brought into use at midnight on the 6th instant.

The trunk timing equipment oscillator, being worked from the A.C. mains, could not be used, but service was restored at 1 p.m. on the 9th instant by tapping the 1,000 cycle oscillator on the carrier equipment. Aberystwyth carrier circuit also required A.C. mains and had to be withdrawn, but the trunk was brought into use by superimposing on two Aberystwyth trunk lines.

At the end of the week everyone concerned had had quite enough of Eisteddfods for a year or two.

London

THE REBUILDING OF CHELSEA BRIDGE.

In October, 1934, construction of a temporary footbridge was commenced on the downstream side of Chelsea Bridge. This bridge was the same structure that had done duty at the rebuilding of Lambeth Bridge and at present is again being rebuilt at Wandsworth.

The Department had five cables on the old bridge carried in steel pipes. In some places, however, the cables carried the steel pipes as, owing to vibration, the latter had been unseated where they entered the jointing chambers. Provision for expansion was made by forming the cables into irregular loops in the bases of the two towers. These loops were nominally supported on hardwood rollers, but did not ride on them satisfactorily. The travel of the cables was over an inch at each loop, and this was demonstrated by a mark on the cables where they touched the hardwood rollers. These loops were provided in the wrong place, as the correct place is at the ends of the span, i.e. in the abutments.

Six steel pipes were provided on the temporary footbridge under the wooden decking. They rested on cross members of the bridge structure. Special jointing chambers were built of wood and surmounted by standard No. 6 joint box frames and covers in pairs. The boxes were lined inside with sheet steel and were provided with boiler plate bottoms. In order to draw in the cables, it was necessary to take them off the drums and manhandle them on the bridge as the rolling load of a loaded drum was too heavy for the bridge to take.

The consulting engineers to the L.C.C. were Messrs. Rendell, Palmer & Tritton and the contractors were Messrs. Holloway Bros. The contract was for £350,000. The excavations for the piers of the new bridge were carried 30 feet below the bed of the river, and at this depth the London clay was quite hard and dry. At one point the steel piling of one of the coffer dams was displaced, but no water entered. The old bridge piers had been built on piles, but for the new bridge concrete rafts were laid at the bottom of the excavations. A temporary pier of wooden piles was erected in midstream to support the centre of the span at a height of 4 ft. 6 ins. above its normal level. When the ropes had been fixed and the span suspended therefrom with hanger rods, the span was gradually lowered with jacks as the loading of the bridge with the road surface, etc., proceeded. When the normal level was reached, the temporary hinge in the span was replaced by a fixed joint and the central pier removed. The two main towers are hinged at their bases so that when the span was at the higher level they sloped outwards and

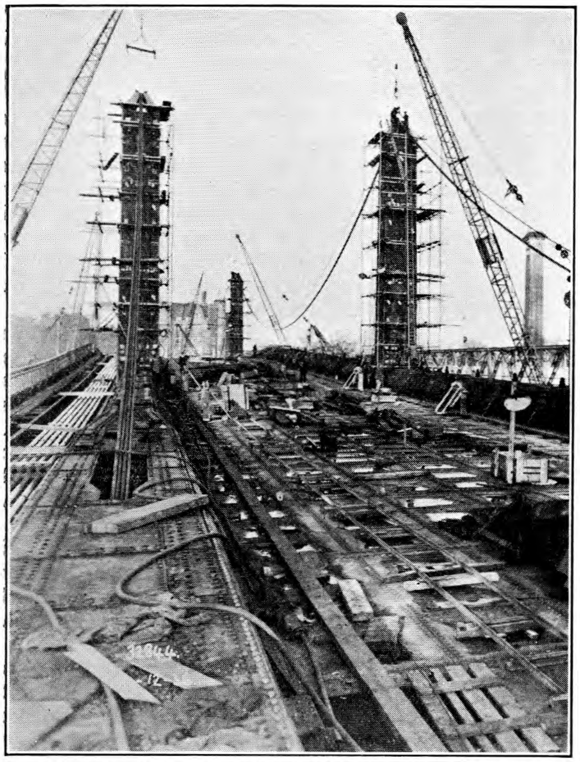


FIG. 1.—VIEW OF BRIDGE UNDER CONSTRUCTION.

gradually assumed the vertical position as the lowering proceeded.

There are 37 suspension ropes on each side. Made of galvanised steel, they were pre-stressed at the manufacturers' works to a tension of 35 tons. Each rope is 800 feet long. The 1,500 tons load of the bridge is taken by 41 forged steel hanger rods on each side. In the old bridge, the ropes were anchored deeply in the ground on each side, but the new bridge is self-anchoring, i.e. the ropes are secured to each end of the span so that the latter acts like a strut.

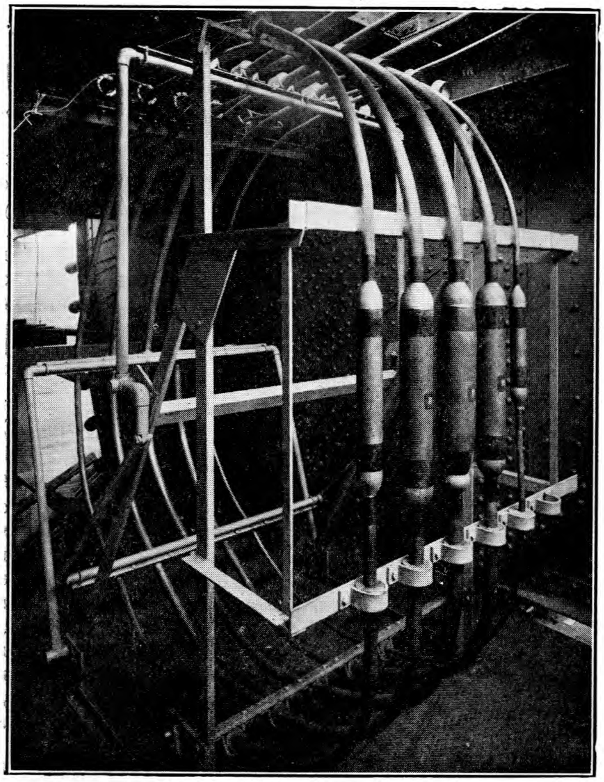


FIG. 2.—EXPANSION LOOPS.

The footways were mounted on cantilevers on the sides of the main span. The Department's pipes are accommodated in the space between two stringers under the footway and supported on cross members to which they are secured by U-bolts. There are six on each footway, those on the downstream side being at present spare. The upstream pipes are clearly shown in Fig. **1**. Special jointing chambers built of steel sections and boiler plate and utilising four standard No. 5 covers are provided in mid span. Expansion loops are located in the abutments and a general view is shown in Fig. **2**. Large chambers exist adjacent to the fan girders, one of which is seen in the photograph. The platform is quite distinct from the suspended portion of the bridge and is erected some 12 feet from the floor. The spider arrangement shown was designed in the Superintending Engineer's office and permits a circumferential movement of the cable loops without any tendency to distort their shape. The tubular members move but the angle irons are fixed. The joints are held rigidly and are free from vibration. The cables on the bridge have cadmium alloy sheaths. At the top of the photograph is the cabling entrance which is built of rolled steel sections with two standard No. 5 J.B. covers.

The bridge was opened on May 6th by Mr. Mackenzie King, Prime Minister of Canada, who was gratified to note that Canadian timber was used in its construction.

It is desired to express thanks to Messrs. Holloway Bros. for information and to Messrs. Rendell, Palmers & Tritton for the loan of photographs in connection with the preparation of this article. F. C. G. G.

PROVISION OF EQUIPMENT AT THE LONDON FIRE BRIGADE HEADQUARTERS

A special type of P.B.X. has been provided at the London Fire Brigade headquarters, and the following information may be of interest. Fuller details will be given in a separate article which will appear in the January issue of the Journal.

The headquarters has been transferred to a new and specially designed building on the Lambeth Embankment. In this building the whole of the administrative control for the London Fire Brigade is situated, and accommodation is provided for the local Fire Station.

The telephone network plays an important part in the efficient control in that all the numerous Fire Stations are catered for at headquarters on a specially designed 5-position switchboard. In this board a departure has been made from standard practice by the use of Nigerian walnut for the woodwork and the provision of a black key shelf. The equipment provided includes 10 direct exchange lines, 100 extensions, 10 private wires, 20 tie lines and multi-phone facilities, whilst the local fire alarm network is terminated on the Gamewell system by two loops, with 17 points on the one and 18 points on the other. A repeat loop to the Superintendent's Station is also installed, and an illuminated display panel associated with the equipment indicates the address of each alarm post.

A training centre is housed in the building, and demonstration equipment of all items of telephone and fire alarm apparatus has been provided for general instructional purposes.

Demonstrations of fire fighting methods to which the public are admitted are held every Wednesday afternoon.

WIRING OF MODERN BUILDINGS

Considerable advances are evident in the facilities which are being provided for the Post Office in large new buildings situated in the City area, although there are still some architects who do not give full consideration to the requirements of the telephone service. Excellent examples of both these classes of building are to be found adjacent to one another in this area.

The best of its kind is perhaps Plantation House, where every opportunity has been taken to effect an efficient internal distribution scheme. As usual the Main Distribution Case is situated in the basement, housed together with the controls for the common services to the building, but reasonably separated to effect sufficient protection. Its accessibility is a special feature and the internal cables are led from the case to the various floors through special conduits. The draw wires are left in the pipes by the Building Contractor, and with such facilities the work of installation is materially simplified. Several pipes are led to each floor, and each one is designed to serve a certain area, so that the provision of leads to separate instruments will not present any difficulty.

An example of work which is not quite so effective is to be found close by. Although pipes are led to each floor, it has been left to the several services to provide facilities from a mezzanine cupboard. Consequently, a house telephone system and the Department's wires can be laid only along the skirting boards and some of the more particular renters have gone to the expense of providing heavy moulded cases to cover this method of distribution. The owners of the building have not been very willing to share the cost of this work, but in certain of the principals' rooms, where some unsightly hot water pipes and ducts for the ventilating system had to be covered, a considerable portion of the cost was shared. This shows how eminently desirable it is to impress the architect at the outset with the necessity for providing full facilities for common services, and, in particular, for telephone distribution.

DANGEROUS WATER

For some time past the ducts between Meymott Street and Waterloo exchange have been acting as a very suitable draining system for the surrounding area. Samples of the water have been taken and analysed, and it has been decided that various dangerous compounds in solution are principally due to a large amount of oyster shells buried in the vicinity. The resulting solution will act chemically on both concrete and lead, and is thus dangerous from the Department's point of view.

In order to prevent the access of this fluid to the exchange, both ends of the duct route have been sealed and the bottom of the seals have been tapped so that the water can be drained off. Here difficulty arose because the adjacent sewer is only at such a depth that will give a fall of 5 inches in 12 feet to the pipe from the manhole, and in case of flooding of the sewer, considerably more damage might result than if no draining system had been installed in the manhole.

It would be a simple matter to provide an automatic pump to raise the water to a sufficient level to prevent flooding back from the sewer. The cost of this is highly prohibitive and, as in all such things, a compromise had to be effected.

The work is now going ahead on the installation of an interceptor which, although allowing the water to drain from the manhole down into the sewer, will not allow water to flow back into the manhole from the sewer. During periods of excessive rainfall, which may result in a full sewer, the trap will be closed against the egress of water from the manhole, but these conditions are considered to be so unusual that the cheaper method of providing this interceptor is considered to be the best which circumstances permit.

Book Reviews

"The Physics of Electron Tubes." L. R. Koller, Ph.D., 234 pp. 84 Illustrations. McGraw-Hill. 18s.

This volume of the International Series in Physics now appears in its second edition. In the three years since it first appeared there have been considerable advances in electron physics and much new material has been added to the book, e.g., sections have been added on electron optics, secondary emission, multipliers, ignitrons, etc. In these new sections and in his revision of the whole book, the author has maintained his original plan of dealing purely with the physics of electron tubes without mention of the external circuits.

The book may be divided roughly into three sections dealing respectively with electron discharges, gaseous discharges and photo-electricity.

Early chapters deal with the theory of thermionic and secondary emission and with the characteristics of thoriated tungsten and coated filaments. The effects of temperature, presence of gases, and anode voltage are discussed in the following chapters in which the 3/2 power law is explained. Chapter IX gives a summary of a number of ways in which electron tubes can be applied, particularly in the field of electron optics.

Gas discharge tubes are dealt with in the centre section of the book, particular attention being given to grid controlled arcs.

The liberation of electrons under the influence of light and the effect of light upon the conductivity of various substances is discussed in the final chapters.

Each chapter is furnished with an adequate bibliography and a series of problems.

Although the book is written primarily for the physicist, the ground covered is of considerable interest to the engineer. The terms and symbols used are readily comprehensible, with but one or two exceptions, e.g., the American terms Kenotron, Pliotron and a UX 201 Radiotron. Altogether this is an excellent work for giving a survey of the physics underlying the operation of modern electron tubes.

H. L.

"Electric Wiring Diagrams." W. Perren Maycock, M.I.E.E., revised by H. C. Fabian, M.R.S.T. 155 pp. 258 Illustrations. Pitman. 5s.

This little volume, mainly composed of material from Perren Maycock's well-known book on Electric Wiring, has been revised and brought up to date. It is intended as a practical manual for those preparing for the City & Guilds Examinations and chiefly as a reference book of connections for those engaged in wiring work for electric light and power circuits of all kinds, for bell, alarm, telephone and clock circuits in buildings, and for electric signs. It is essentially a book of diagrams with a minimum of explanatory letter-press and admirably serves the purpose of being a practical book for the practical man engaged in installation work.

J. Mc. G.

Staff Changes

PROMOTIONS.

Name	From	To	Date
Chamney, R. M.	Actg Staff Engr , E -in-C.O.	Staff Engr , E.-in-C O.	1-10-37
Frost, P. B.	A S E , London	Actg. Staff Engr., E.-in-C.O.	1-10-37
Boryer, W. F.	Exec Engr , London	Actg A S E , London	1-10-37
Radford, J	Exec Engr , E -in-C O.	Actg. A.S E., E.-in-C.O.	1-1-38
Hanford, S.	Exec Engr., E -in-C O.	Actg. A S E , E.-in-C.O.	14-8-37
Barnes, E. J.	Exec. Engr , E -in-C O.	Actg. A S E , E -in-C.O.	14-8-37
Somerville, H. B.	Exec. Engr , London	Actg. A S E , S. Western	To be fixed later.
Bocock, W.	Actg. Area Engr , Scot. Reg.	Area Engr , Scot Reg.	1-7-37
Shaw, H.	Asst. Engr , N Western	Actg. Exec. Engr., N. Western	24-6-37
Little, W. R.	Asst. Engr , London	Actg Exec. Engr , London	1-7-37
Dunford, L G.	Asst Engr , E -in-C O.	Actg Exec. Engr , E.-in-C.O.	17-8-37
Stanesby, H.	Asst Engr , E -in-C O.	Actg Exec Engr , E.-in-C.O.	17-8-37
Bolton, G. F.	Asst Engr , N. Wales	Actg Exec. Engr , N. Wales	1-9-37
Mitchell, C. A.	Asst. Engr , S. Eastern	Actg Exec Engr , E -in-C.O.	To be fixed later.
Sawyer, R H. W.	Chief Insp , E -in-C O.	Asst Engr , Scot. Reg.	12-8-37
Hull, S. D.	Chief Insp , E -in-C O.	Asst. Engr , E -in-C O.	12-8-37
Reynolds, E. J.	Chief Insp , Eastern	Asst. Engr , Eastern	12-8-37
Josephs, H J.	Chief Insp , E.-in-C O.	Asst Engr , E -in-C O.	24-6-37
Missen, H.	Chief Insp., E -in-C.O.	Asst. Engr , E -in-C.O.	24-6-37
Thompson, J. W.	Chief Insp , S Lancs.	Asst Engr , S. Lancs.	24-6-37
Langford, L. C.	Chief Insp , London	Asst Engr , London	1-7-37
Turley, T. G.	Chief Insp , London	Asst Engr , London	1-7-37
Faulkner, C. G.	Chief Insp , Eastern	Asst. Engr , N Western	24-6-37
Parrott, G.	Chief Insp , S. Midland	Asst Engr , N Midland	11-7-37
Arnold, W H.	Chief Insp , S Midland	Asst. Engr , N Midland	4-7-37
Green, W.	Chief Insp , Eastern	Chief Insp. with Allce., Eastern	23-8-37
Harris, S. R.	Chief Insp , S Western	Chief Insp with Allce., S. Western	13-6-37
Mitchell, A. F.	Mech -in-Charge, Grade I, London	Tech Asst , Nottingham	27-6-37
Randle, W.	Insp., N. Wales	Chief Insp , N Wales	25-4-37
Copeland, W.	Insp , Eastern	Chief Insp , Eastern	16-5-37
Hall, H.	Insp , Scot. Reg.	Chief Insp , Scot. Reg.	13-6-37
Benson, W. K.	Insp , S. Lancs.	Chief Insp , S. Lancs.	21-2-37
Saville, E. W.	Insp., N E Reg.	Chief Insp , N.E. Reg.	13-5-37
Iles, S. B.	Insp., S Lancs.	Chief Insp , Scot. Reg.	13-6-37
Turtle, G. R.	Insp , N. Wales	Chief Insp., N. Wales	16-4-37
Wood, R.	Insp., S. Western	Chief Insp., S. Western	9-5-37
Davidson, W. B.	Insp., Scot. Reg	Chief Insp , Scot. Reg.	4-4-37
Drew, L. C.	Insp , Eastern	Chief Insp , Eastern	6-5-37
Greenwood, G. C.	Insp , Eastern	Chief Insp , Eastern	6-4-37
Peddle, H. W.	Insp , N. Midland	Chief Insp , N. Midland	3-1-37
Palmer, R. N	Insp , N. Midland	Chief Insp , N Midland	18-7-37
Thompson, A. J.	Insp , Eastern	Chief Insp , Eastern	22-4-37
Roy, D M.	Insp , Scot. Reg.	Chief Insp , Scot. Reg.	15-4-37
Gibbs, F J	Insp , S Midland	Chief Insp , S. Midland	22-4-37
Drane, H. J.	Insp , Eastern	Chief Insp , S. Western	13-6-37
Frost, W.	Insp , N Wales	Chief Insp , London Postal Reg.	17-7-37
Green, R G	Insp , S. Lancs.	Chief Insp , S. Lancs.	24-6-37
Osborne, A. D.	Insp., London	Chief Insp , London	1-7-37
Denny, E	Insp , London	Chief Insp . London	1-7-37
Venus, W. A. H.	Insp , London	Chief Insp , E.-in-C.O.	8-6-37
Spooner, J. W.	Insp , N.E. Reg.	Chief Insp , N.E Reg.	30-5-37
Soons, A. F.	Insp , E -in-C O.	Chief Insp , E -in-C O.	4-6-37
Power, E M.	S.W I , S Eastern	Insp , S Eastern	2-5-37
May, G	S.W I , S. Western	Insp , S Western	1-7-37
Richards, J.	S W.I , S Western	Insp , S. Western	23-5-37
Jefferies, G. J.	S.W I , S Western	Insp , S Western	1-11-36
Mundy, C. F.	S W I , S Western	Insp , S Western	21-3-37
Platts, T. J.	S.W.I , S. Western	Insp , S. Western	20-6-37
Ferguson, O. A K.	S.W I , S Western	Insp , S. Western	28-6-37
Moore, W.	S.W.I., N Midland	Insp , N Midland	2-2-37
Stokes, W. G.	S.W.I , N Midland	Insp , N Midland	20-12-36
Archer, E.	S.W I , N. Midland	Insp., N. Midland	13-12-36
Porter, R. W. R.	S.W.I , N. Midland	Insp , N Midland	2-2-37
Stafford, D. E. H.	S.W I., N. Midland	Insp., N Midland	18-7-37
List, V. P.	S W I., N. Midland	Insp., N Midland	9-5-37
Anthistle, A. W.	S W I., N Midland	Insp , N Midland	6-6-37
Thompson, A. E.	S.W I., N. Ireland	Insp., N Ireland	7-10-36
Ogle, T.	S W I , N Ireland	Insp , N. Ireland	20-6-37
McDonald, T H.	S.W I , N. Ireland	Insp., N. Ireland	20-5-37
Gardner, D. H.	S.W I., N. Ireland	Insp., N Ireland	23-5-37
Topham, L. C.	S W.I., N. Midland	Insp., N. Midland	1-7-37
Bath, R. J.	S.W.I., Eastern	Insp , Eastern	16-5-37

Name	From	To	Date
Brinkley, A. G.	S.W.I., Eastern	Insp., Eastern	28-7-37
Brown, L.	S.W.I., Eastern	Insp., Eastern	6-6-37
Clements, A. E.	S.W.I., Eastern	Insp., Eastern	2-2-37
Giles, R. C.	S.W.I., Eastern	Insp., Eastern	2-2-37
Howlett, A. F.	S.W.I., Eastern	Insp., Eastern	26-7-37
Mann, D.	S.W.I., Eastern	Insp., Eastern	2-2-37
Ross, T. C.	S.W.I., Eastern	Insp., Eastern	2-2-37
Sizer, V. E.	S.W.I., Eastern	Insp., Eastern	2-2-37
Axton, A. A.	S.W.I., S. Midland	Insp., S. Midland	14-3-37
Barfoot, M.	S.W.I., S. Midland	Insp., S. Midland	2-2-37
Blake, E. C.	S.W.I., S. Midland	Insp., S. Midland	20-6-37
Bougourd, C. F.	S.W.I., S. Midland	Insp., S. Midland	10-7-37
Hatcher, W. E.	S.W.I., S. Midland	Insp., S. Midland	2-2-37
Hills, G. W. P.	S.W.I., S. Midland	Insp., S. Midland	23-5-37
Reade, N. J.	S.W.I., S. Midland	Insp., S. Midland	11-7-37
Robertson, F.	S.W.I., S. Midland	Insp., S. Midland	1-2-37
Toomer, R. A.	S.W.I., S. Midland	Insp., S. Midland	2-2-37
White, C. F.	S.W.I., S. Midland	Insp., S. Midland	16-8-37
Blease, R. C.	S.W.I., S. Lancs	Insp., S. Lancs.	14-1-37
Wilson, A.	S.W.I., S. Lancs.	Insp., S. Lancs.	23-1-37
Allen, G. W.	S.W.I., N. Midland	Insp., N. Midland	5-4-37
Richards, J. E.	S.W.I., N. Midland	Insp., N. Midland	1-1-37
Saunders, C. T.	S.W.I., London	Insp., E.-in-C.O.	4-7-37
Bennett, J. S.	S.W.I., S. Lancs.	Insp., S. Lancs.	13-3-37
Oldham, A. F.	S.W.I., S. Lancs.	Insp., S. Lancs.	21-3-37
Earp, E. F.	S.W.I., N. Midland	Insp., N. Midland	16-5-37
Aizlewood, E. L.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Crosby, J. J.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Cooper, H. E.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Dean, G. A.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Edwards, J. R.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Friday, L. H.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Holder, T.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Horton, A. E. E.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Keen, F. L.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Nock, F. H.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Nock, I. H.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Rushworth, F. R.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Truman, B. J.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Wildig, G. S.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Williams, E. S.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Wren, H. G.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Mann, H. F.	S.W.I., Rugby Radio Station	Insp., N. Wales	19-4-37
Kewley, T. W.	S.W.I., S. Lancs	Insp., N. Wales	21-3-37
Dawson, J.	S.W.I., S. Lancs	Insp., N. Wales	2-2-37
Sammon, T. B.	S.W.I., N.E. Reg	Insp., N. Wales	24-4-37
Frizelle, G. H. H.	S.W.I., N.E. Reg	Insp., N. Wales	30-5-37
Hargreaves, F. C. B.	S.W.I., N.E. Reg	Insp., N. Wales	27-5-37
Kinroy, J. W.	S.W.I., N.E. Reg.	Insp., N. Wales	18-4-37
Calvert, W.	S.W.I., N.E. Reg.	Insp., N.E. Reg	22-3-37
Moscrop, J.	S.W.I., N.E. Reg	Insp., N.E. Reg.	2-5-37
Farmery, C. B.	S.W.I., N.E. Reg	Insp., N.E. Reg.	21-3-37
Faulkner, J. H.	S.W.I., S. Lancs.	Insp., S. Lancs.	7-4-37
Morris, S. W.	S.W.I., S. Eastern	Insp., S. Eastern	1-7-37
Taylor, T. A.	S.W.I., S. Lancs.	Insp., S. Lancs	3-4-37
Soutar, J. B.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	20-4-37
Cameron, N. B.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	3-4-37
Paton, R.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	20-4-37
Martin, F.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	28-2-37
McLean, K. B.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	18-4-37
Tait, J. M.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	10-1-37
Moffatt, J.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	6-3-37
McCubbin, W. J. K.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	17-7-37
Baker, W. H.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	7-1-37
McDonald, A.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	1-8-37
Stevenson, A.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	17-7-37
Barrett, R.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	23-5-37
Crawford, R.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	17-7-37
Wilson, A. A.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	31-5-37
Martin, T. W.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	22-11-36
Buchan, A. C.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	20-4-37
Birss, A.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	6-3-37
Ferguson, C.	S.W.I., Scot. Reg.	Insp., Scot. Reg	1-8-37
Gibson, J.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	22-1-37
Milne, W. J.	S.W.I., Scot. Reg.	Insp., Scot. Reg	19-1-37
White, J. S.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	1-3-37

Name	From	To	Date
Morton, A. S.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	14-3-37
Callander, A. D.	S.W.I., Scot. Reg.	Insp., Scot. Reg.	10-5-37
MacDougall, D.	S.W.I., Scot. Reg.	Insp., Scot. Reg	14-3-37
Arthur, C. W.	S.W.I., N. Western	Insp., N. Western	2-5-37
Jackson, A. A.	S.W.I., N. Western	Insp., N. Western	27-7-37
Lightbourn, A.	S.W.I., N. Western	Insp., N. Western	27-7-37
Rothwell, A.	S.W.I., N. Western	Insp., N. Western	27-7-37
Spencer, W. C.	S.W.I , N. Western	Insp., N. Western	16-5-37
Wood, J.	S.W.I., N. Western	Insp., N. Western	27-7-37
Tubbs, C. F.	S.W.I., London	Insp., London	To be fixed later.
Stone, C. H.	S W.I., London	Insp , London	To be fixed later.
Crowhurst, J S.	S.W I , London	Insp., London	To be fixed later.
Martin, J. W.	S.W I , London	Insp , London	To be fixed later.
Williams, H.	S.W.I., London	Insp., London	To be fixed later.
Denchfield, T. M.	S.W.I., London	Insp., London	To be fixed later.
Oliver, G. C.	S.W I., London	Insp , London	To be fixed later.
Lawson, P. G.	S.W.I., London	Insp., London	To be fixed later.
Dix, L. F. T.	S.W.I , London	Insp., London	To be fixed later.
Clarke, L L.	S.W.I., London	Insp., London	To be fixed later.
Jarman, R. A.	S.W.I., London	Insp., London	To be fixed later.
Smith, F. J.	S.W.I., London	Insp., London	To be fixed later.
Gosling, S. E.	S.W.I., London	Insp., London	To be fixed later.
Wooding, W. J.	S W.I., London	Insp., London	To be fixed later.
Teale, J. C. C.	S.W I , N.E Reg.	Insp., N.E. Reg.	23-3-37
Bliss, H. J.	S.W.I , London	Insp., E.-in-C.O	21-2-37
Welch, W. T.	S.W.I , St Albans Radio Station	Insp., E.-in-C.O	14-2-37
Franks, B A.	S.W.I., E -in-C.O.	Insp., E.-in-C.O.	24-7-37
Search, C. J.	S.W.I , E.-in-C O.	Insp., E.-in-C.O.	27-2-37
Weatherley, L. G.	S.W.I., E -in-C O	Insp., E -in-C.O.	11-2-37
Walker, B. A.	S.W.I , E -in-C.O.	Insp , E -in-C.O.	20-3-37
Tuddenham, R. J. S.	S W.I., E -in-C O.	Insp., E.-in-C O.	28-4-37
Buchanan, R. C.	S.W.I., E.-in-C.O.	Insp., E.-in-C.O.	7-2-37
Mercer, P. T.	S.W.I., E.-in-C.O.	Insp., E.-in-C.O.	29-11-36
Ratcliffe, K. S.	S.W.I., E.-in-C.O.	Insp., E.-in-C.O.	28-4-37
Hollerton, F.	S.W.I., S. Lancs.	Insp., S. Lancs.	26-5-37
Miles, H	S.W.I., S. Lancs.	Insp., S. Lancs.	18-4-37
Briggs, F. J.	S.W.I., S. Lancs.	Insp., S. Lancs.	24-6-37
Pearce, T. H.	S.W.I., S. Lancs.	Insp., S. Lancs.	1-8-37
Hannah, C. R.	S.W.I., S. Lancs.	Insp., S. Lancs.	23-5-37
Watson, J. H.	S.W.I., S. Lancs.	Insp., S. Lancs.	11-4-37
Atkinson, J. W.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	19-5-37
Burnett, C.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	19-5-37
Thompson, W. G.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	26-3-37
Hudson, P.	S.W.I., S. Lancs.	Insp., S. Lancs.	31-5-37
Neville, J.	S.W.I., S. Lancs.	Insp., S. Lancs.	30-5-37
Housley, R. D.	S.W.I., S. Lancs.	Insp., S. Lancs.	13-6-37
Frowde, E. M.	S.W.I., S. Lancs.	Insp., S. Lancs.	19-6-37
Whiteley, A.	S.W.I., S Lancs.	Insp., S. Lancs.	13-6-37
Hayward, A. A.	S.W.I., S. Lancs.	Insp., S. Lancs.	15-6-37
Johnstone, E. J.	S.W.I., S. Lancs.	Insp., S. Lancs.	26-6-37
Parkinson, S.	S.W.I., S. Lancs.	Insp., S. Lancs.	19-6-37
Mockford, A. F.	S.W.I., S. Midland	Insp., S. Midland	6-6-37
Biles, A. H.	S.W.I., S. Midland	Insp., S. Midland	11-7-37
Wills, C. P.	S.W.I., S. Midland	Insp., S. Midland	5-9-37
Hill, W. I.	S.W.I., S. Midland	Insp., S. Midland	13-6-37
Watson, G. G.	S.W.I., S. Midland	Insp., S. Midland	28-8-37
Piper, R. F. L.	S.W.I., S. Midland	Insp., S. Midland	14-8-37
Perrin, F. W.	S.W.I., S. Midland	Insp., S. Midland	22-8-37
Francis, B. J.	S.W.I., S. Midland	Insp., S. Midland	6-6-37
Stancy, P. H.	S.W.I., S. Midland	Insp., S. Midland	27-6-37
Wilson, H. W. R.	S.W.I , London	Insp., London	To be fixed later.
Frith, A. C.	S.W.I., London	Insp., London	To be fixed later.
Vincent, C. F.	S.W.I., London	Insp., London	To be fixed later.
Kelly, F. C. F.	S.W.I., London	Insp., London	To be fixed later.
Crosby, G.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	17-8-37
Skelly, J. E.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	16-6-37
Andrews, R.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	9-5-37
Cawood, R. J.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	6-6-37
Bottomley, F. K.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	10-8-37
Southwell, C. E.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	15-8-37
Chapman, A.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	27-5-37
Staynes, W. V.	S.W.I., S. Lancs.	Insp., S. Lancs.	To be fixed later.
Brierley, J. E. B.	S.W.I., S. Lancs.	Insp., S. Lancs.	To be fixed later.
Honeywill, T. C.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Harding, W. G.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Wilson, A. J. F.	S.W.I., S. Western	Insp., S. Western	To be fixed later.

PROMOTIONS—*continued*

Name	From	To	Date
Hopkins, W. J. B.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Rudge, C. H. O. J.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
McMullin, T.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Glover, W. A.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Robinson, H. E.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Fox, S. C. F.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Shepstone, L. C.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Burnett, E. C.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Percival, C. C.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Booker, G. T.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Wildeman, G. A.	S.W.I., S. Western	Insp., S. Western	To be fixed later.
Sykes, F.	S.W.I., S. Lancs	Insp., S. Lancs.	To be fixed later.
Briscoe, H. R.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	1-7-37
Miller, H.	S.W.I., N.E. Reg	Insp., N.E. Reg	2-7-37
Clark, T. W.	S.W.I., N.E. Reg	Insp., N.E. Reg.	2-7-37
Layne, A.	S.W.I., N.E. Reg.	Insp., N.E. Reg	2-7-37
Brewster, W. C.	S.W.I., Test Sec., B'ham.	Insp., Test Sec., London	To be fixed later.
Howlett, G. R.	S.W.I., London	Insp., Test Sec., London	To be fixed later.
Cooper, C. J.	S.W.I., London	Insp., Test Sec., London	To be fixed later.
Nicholls, P. A.	S.W.I., London	Insp., Test Sec., London	To be fixed later.
Glover, G.	S.W.I., N. Wales	Insp., N. Wales	To be fixed later.
Martin, W. H.	S.W.I., S. Lancs.	Insp., S. Lancs.	To be fixed later.
Batch, H. R.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Bird, J. R.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Bokenham, W. R.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Brown, S. F.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Goodchild, C. W.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Stayes, R. G.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Pearce, F.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Prewett, P. J.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Sayer, J. F.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Storrie, A. R.	S.W.I., Eastern	Insp., Eastern	To be fixed later.
Harrison, T. C. R.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	29-8-37
Wilton, J. J.	S.W.I., N.E. Reg.	Insp., N.E. Reg.	29-8-37
Neall, E. W.	Draughtsman II., S. Midland	Insp., S. Midland	1-11-36
Roberts, H. E.	Draughtsman II., N. Eastern	Insp., N.E. Reg.	1-8-37
Davies, W.	Draughtsman II., S. Lancs.	Insp., N.E. Reg.	30-5-37
Elkin, W. L.	S.W.II., N. Wales	Insp., N.E. Reg.	To be fixed later.
Galletley, C. N.	S.W.II., N. Wales	Insp., N.E. Reg.	To be fixed later.
Hood, J. B.	S.W.II., N. Wales	Insp., N.E. Reg.	To be fixed later.
Potts, F.	S.W.II., N. Wales	Insp., N.E. Reg.	To be fixed later.
Johnson, E. S.	S.W.II., N. Wales	Insp., E.-in-C.O.	24-1-37
Fraser, W. A.	Draughtsman I., E.-in-C.O.	Senior D'sman (Actg.), E.-in-C.O.	2-7-37
Wiskin, A. R.	Draughtsman I., E.-in-C.O.	Senior D'sman (Actg.), E.-in-C.O.	2-7-37
White, F. C.	Draughtsman II., E.-in-C.O.	Draughtsman I (Actg.), E.-in-C.O.	2-7-37
Whiting, H. C.	Draughtsman II., E.-in-C.O.	Draughtsman I. (Actg.), E.-in-C.O.	2-7-37
Holland, R.	Draughtsman II., London	Draughtsman I., London	20-12-36
Hill, R.	Draughtsman II., N. Midland	Draughtsman I., S. Western	28-2-37
Wainwright, S. W.	Draughtsman II., S. Lancs.	Draughtsman I., S. Eastern	7-3-37
Josselyne, S. G.	Draughtsman II., S. Wales	Draughtsman I., S. Wales	22-3-37
Jones, F. C.	Draughtsman II., Eastern	Draughtsman I., S. Wales	28-2-37
Sabine, D. C. W.	Draughtsman II., N. Wales	Draughtsman I., S. Western	21-3-37
Owles, F. H.	Draughtsman II., S. Eastern	Draughtsman I., S. Eastern	11-11-36
Cridland, J. F. S.	Draughtsman II., London	Draughtsman I., London	1-3-37
Barber, A.	Draughtsman II., London	Draughtsman I., S. Midland	11-4-37
Gaulley, A. G.	Draughtsman II., N. Wales	Draughtsman I., N. Wales	24-5-37
Stonebridge, W. W.	Draughtsman II., Eastern	Draughtsman I., Eastern	20-7-37
Boyce, C. H.	Draughtsman II., Eastern	Draughtsman I., Eastern	9-6-37
Lunn, C. H.	Draughtsman II., N.E. Reg.	Draughtsman I., N.E. Reg.	8-5-37
Whitton, J.	Draughtsman II., N.E. Reg.	Draughtsman I., N.E. Reg.	8-5-37
Bale, J. F.	Draughtsman II., S. Western	Draughtsman I., Eastern	17-8-37
Lea, E. J.	Draughtsman II., N.E. Reg.	Draughtsman I., N.E. Reg.	15-8-37

DEATHS

Name	Rank	Location	Date
Radford, W. E.	Insp.	N. Wales	20-8-37
Hudson, W. J.	Insp.	Eastern	12-6-37

TRANSFERS.

Name	Rank	From	To	Date
Carter, Col. H.	Staff Engineer	E.-in-C.O.	S. Wales	1-10-37
Thompson, H. S.	Suptg. Engr.	S. Wales	N. Ireland	1-10-37
Franklin, G.	Asst. Engr.	Eastern	E.-in-C.O.	1-7-37
Sawyer, E. C.	Chief Inspr.	S. Western	S. Midland	22-8-37
Lakey, J.	Tech Asst.	London	E.-in-C.O.	1-7-37
Day, J. V.	Insp.	E.-in-C.O.	N.E. Reg.	13-6-37
Cleary	Insp	E.-in-C.O.	N. Western	1-7-37
Daniel, R. G.	Insp	N. Western	E.-in-C.O.	1-7-37
Blanchard, J. A.	Proby. Insp.	E.-in-C.O.	N.E. Reg.	1-9-37
Burchell, J. R. L.	Proby. Insp.	E.-in-C.O.	London	1-9-37
Burstow, A S.	Proby. Insp.	E.-in-C.O.	London	1-9-37
Wilson, J. C.	Proby. Insp.	E.-in-C.O.	London	1-9-37
Whittaker, E. N.	Proby. Insp.	E.-in-C.O.	N. Midland	1-9-37
Johnson, D. E. N.	Proby. Insp.	E.-in-C.O.	Scot. Reg.	1-9-37
Linney, H. H.	Proby. Insp.	E.-in-C.O.	N. Wales	1-9-37
Galloway, J.	Proby. Insp.	E.-in-C.O.	S. Lancs.	1-9-37
Oxlade, W. J.	Proby. Insp.	E.-in-C.O.	London	1-9-37
Hunt, C. S.	Proby. Insp.	E.-in-C.O.	London	1-9-37
Bennett, G.	Proby. Insp.	E.-in-C.O.	N.E. Reg.	1-9-37
Skuse, C. E. C.	Proby. Insp.	E.-in-C.O.	London	1-9-37
Wright, G.	Proby. Insp.	E.-in-C.O.	S. Lancs.	1-9-37
Peck, D. G.	Proby. Insp.	E.-in-C.O.	N. Ireland	1-9-37
Sanders, F. S. B.	Proby. Insp.	E.-in-C.O.	London	1-9-37
Stancy, V. J.	Proby. Insp.	E.-in-C.O.	Test Sec., London	1-9-37
Unwin, J. M.	Proby. Insp.	E.-in-C.O.	S. Midland	1-9-37
Stafford, L.	Proby. Insp.	E.-in-C.O.	Test. Sec., B'ham	1-9-37
Powell, G. F.	Proby. Insp.	E.-in-C.O.	S. Lancs.	1-9-37
Seager, E. F.	Proby. Insp.	E.-in-C.O.	S. Eastern	1-9-37
Upchurch, S. W. J.	Proby. Insp.	E.-in-C.O.	S. Eastern	1-9-37
Lunt, L. S.	Proby. Insp.	E.-in-C.O.	Test Sec., B'ham	1-9-37
Stewart, W. F. G.	Proby. Insp.	E.-in-C.O.	Scot. Reg.	1-9-37
Smith, A. F. C.	Proby. Insp.	E.-in-C.O.	N. Midland	1-9-37
Chant, L.	Proby. Insp.	E.-in-C.O.	London	1-9-37
Lennard, G. F.	Proby. Insp.	E.-in-C.O.	Eastern	1-9-37
Flavell, J. A.	Proby. Insp.	E.-in-C.O.	S. Wales	1-9-37
Tough, J. L.	Proby. Insp.	E.-in-C.O.	S. Western	1-9-37
Eccles, J.	Proby. Insp.	E.-in-C.O.	N. Wales	1-9-37
Sheppard, J.	Proby. Insp.	E.-in-C.O.	S. Wales	1-9-37
Venus, A. L.	Proby. Insp.	E.-in-C.O.	N. Wales	1-9-37
King, E. S. F.	Proby. Insp.	E.-in-C.O.	S. Midland	1-9-37
Burley, N.	Proby. Insp.	E.-in-C.O.	Eastern	1-9-37
Philips, G. J. A.	Proby. Insp.	E.-in-C.O.	S. Midland	1-9-37
Ansell, G. V.	Proby. Insp.	E.-in-C.O.	S. Wales	1-9-37
Thompson, J.	Proby. Insp.	E.-in-C.O.	N. Western	1-9-37
Burton, R. N.	Proby. Insp.	E.-in-C.O.	N.E. Reg.	1-9-37
Emms, W. G.	Proby. Insp.	E.-in-C.O.	S. Midland	1-9-37
Parker, P. M.	Proby. Insp.	E.-in-C.O.	S. Eastern	1-9-37
Croft, E.	Proby. Insp.	E.-in-C.O.	N.E. Reg.	1-9-37
Boyle, C.	Proby. Insp.	E.-in-C.O.	N. Western	1-9-37
Moorcroft, H. C.	Proby. Insp.	E.-in-C.O.	N.E. Reg.	1-9-37
Hulme, R.	Proby. Insp.	N. Western	S. Lancs.	1-9-37
Rimmer, E. G.	Proby. Insp.	E.-in-C.O.	S. Lancs.	1-9-37
Eley, A. C.	Proby. Insp.	E.-in-C.O.	N. Wales	1-9-37
Row, L. N.	Proby. Insp.	E.-in-C.O.	S. Eastern	1-9-37
Croisdale, A. C.	Proby. Insp.	E.-in-C.O.	N.E Reg.	1-9-37

RETIREMENTS

Name	Rank	Location	Date
Smart, E. V.	Asst. Suptg. Engr.	London	30-6-37
Bell, R. W. S.	Exec. Engr.	N. Wales	31-8-37
White, H. W.	Asst. Engr.	E.-in-C.O.	2-8-37
Smith, R. P.	Asst. Engr.	E.-in-C.O.	2-8-37
Lancaster, T. S.	Asst. Engr.	N. Wales	19-8-37
Grieve, T.	Chief Insp.	N. Midland	30-6-37
Stewart, R. T.	Chief Insp.	N.E. Reg.	15-6-37
Hill, J. T.	Insp.	London	30-9-37
Bush, G. W.	Insp.	Test Sec., London	31-8-37
Wilson, P. F.	Insp.	Scot. Reg.	5-6-37
Noble, J.	Insp.	Scot. Reg.	31-7-37
Mayhew, W. C. A.	Insp.	E.-in-C.O.	31-7-37
Jones, L. J.	Insp.	S. Wales	31-7-37
Prudden, P. W.	Insp.	S. Eastern	30-6-37
Buckley, T.	Insp.	London	7-7-37
Aldenton, W. P.	Insp.	London	17-7-37
Wanless, G. G.	Insp.	Eastern	4-7-37

APPOINTMENTS

Name	From	To	Date
Rule, F. T.	Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Glazier, E. V. D.	Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Ellen, L. W.	Insp., London	Proby. Asst. Engr., London	1-9-37
Easterling, C. E.	Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Lawrence, J. A.	Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Harding, J. P.	Insp., London	Proby. Asst. Engr., S. Eastern	1-9-37
Burgess, A. G.	Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Hickox, W. F.	Insp., S. Eastern	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Wheeler, L. K.	Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Goford, R.	Insp., London	Proby. Asst. Engr., Eastern	1-9-37
Raby, R. E.	Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Bealby, G.	Insp., Scot. Reg.	Proby. Asst. Engr., Scot. Reg.	1-9-37
Saville, W.	Proby. Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Glass, C. G.	Proby. Insp., London	Proby. Asst. Engr., S. Western	1-9-37
Cox, R. H.	Proby. Insp., N. Wales	Proby. Asst. Engr., N. Wales	1-9-37
Harding, T. C.	Proby. Insp., N. Wales	Proby. Asst. Engr., S. Midland	1-9-37
Winterborn, E. E. L.	Proby. Insp., E.-in-C.O.	Proby. Asst. Engr., N.E. Reg.	1-9-37
Burr, A. H.	Proby. Insp., E.-in-C.O.	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Ackroyd, J. O.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Piggott, J.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Cortlandt-Simpson, J. W.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Newley, E. F.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Simmonds, J. C.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Hopwood, R. W.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Christmas, A. N.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Gleadle, G. M.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Finlason, W. E.	—	Proby. Asst. Engr., E.-in-C.O.	1-9-37
Short, P.	—	Proby. Asst. Engr., E.-in-C.O.	6-9-37
Looser, R. C.	—	Proby. Insp., E.-in-C.O.	1-5-37
Kirkpatrick, F. E.	Insp., S. Western	Asst. Elect. Engr., Admiralty	9-9-37

Communications

All Communications should be addressed to the Managing Editor, *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: NATional 6321. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

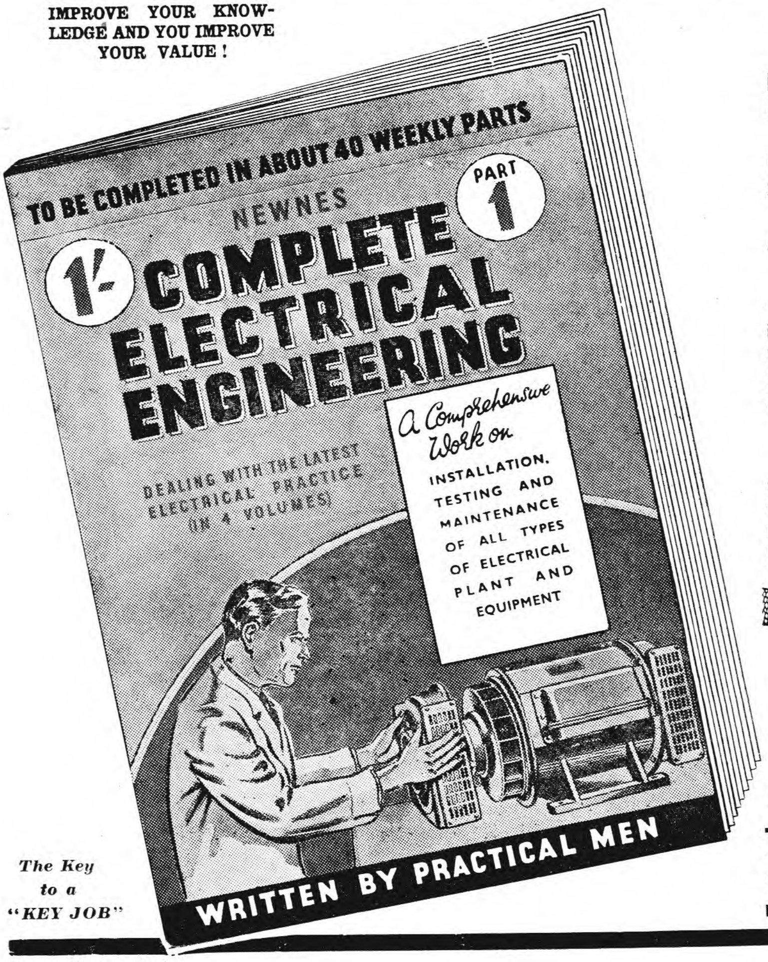
Binding cases are available, and may be obtained from the Local Agents for 1s. 9d. Subscribers can have their copies of Volumes bound, at a cost of 3s., by sending the complete sets of parts to the Local Agents or to the *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering will be the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the Journal, which is published quarterly, is 1s. (1s. 3d. post free) per copy, or 5s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. each (1s. 3d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

Advertisements

All communications relating to space reservations should be addressed to the Advertisement Editor, *P.O.E.E. Journal,* Alder House, Aldersgate Street, London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. Birch & Whittington (Prop. Dorling & Co. [Epsom], Ltd.), Station Road, Epsom, Surrey.


TO BE COMPLETED IN ABOUT 40 WEEKLY PARTS
PART 1
NEWNES
1/-
COMPLETE ELECTRICAL ENGINEERING
DEALING WITH THE LATEST ELECTRICAL PRACTICE (IN 4 VOLUMES)
A Comprehensive Work on
INSTALLATION, TESTING AND MAINTENANCE OF ALL TYPES OF ELECTRICAL PLANT AND EQUIPMENT
WRITTEN BY PRACTICAL MEN

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

PRINTED PAPERS

The following papers contributed to the proceedings of the Institution have been printed by authority of the Council and may be obtained, if still in print, from

**"THE LIBRARIAN,
THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS, G.P.O. (ALDER HOUSE), LONDON, E.C.1."**

The prices do *not* include postage, and in every case, Members, Associate Members, and Associates have the privilege of purchasing copies at two-thirds the stated price.

No. **140.** "SOME NON-METALLIC SUBSTANCES AND THEIR CHARACTERISTICS." —**Capt. N. F. Cave-Browne-Cave, B.Sc., A.M.I.E.E.** 1931 .. .. **9d.**

No. **142.** "PRIVATE BRANCH EXCHANGE INSTALLATIONS."—**R. T. A. Dennison.** 1932. **1/3**

No. **143.** "ELECTRIC WAVE FILTERS."—**G. J. S. Little, B.Sc.** 1931 .. .. **1/3**

No. **146.** "LAYING ARMOURED CABLE BY MEANS OF A MOLE-DRAINER."—**L. G. Semple, B.Sc.(Eng.), and R. O. Bocock, B.Sc.(Eng.)** 1932 .. .. **9d.**

No. **147.** "DESIGN AND CONSTRUCTION OF ELECTRIC WAVE FILTERS."—**R. J. Halsey, B.Sc., etc.** 1932 .. .. **1/3**

No. **148.** "STORES SPECIFICATIONS AND ACCEPTANCE TESTING."—**Capt. J. Legg, B.Sc., A.M.I.E.E.** 1933 .. .. **9d.**

No. **149.** "RECENT DEVELOPMENTS IN UNDERGROUND CONSTRUCTION, LAYING AND LOADING ARMOURED CABLES." —**J. E. Z. Bryden, B.Sc.(Eng.), A.M.I.E.E., and T. Hargreaves, A.M.I.E.E.** 1933 .. **1s.**

No. **150.** "TELEPRINTERS." — **E. S. Ritter, M.I.E.E.** 1933 .. .. **1s.**

No. **151.** "RECENT REPEATER STATION INSTALLATIONS."—**Major F. E. A. Manning, M.C., B.Sc.(Eng.), M.I.E.E., A.M.I.Mech.E.** 1933 .. .. **1s.**

No. **152.** "SOME NOTES ON EXCHANGE EQUIPMENT FACTORY COSTING AND THE ECONOMICS OF PRODUCTION."—**S. J. Husband, Assoc.I.E.E.** 1933.. .. **1/3**

No. **153.** "MODERN DEVELOPMENTS IN TELEPHONE TRANSMISSION OVER LINES." **J. Stratton, A.C.G.F.C., and W. G. Luxton.** 1933. **1/3**

No. **154.** "THE TELEGRAPH POLE."—**W. H. Brent, B.Sc., A.M.I.E.E.** 1933 .. .. **1s.**

No. **156.** "MODERN TENDENCIES IN THE SUPPLY OF POWER TO TELEPHONE EXCHANGES."—**H. C. Jones, B.Sc. (Eng.).** 1935. **9d.**

No. **157.** "RECENT ADVANCES IN CARRIER TELEPHONY."—**R J Halsey, B.Sc.(Hons.), A.C.G.I., D.I.C.** 1935 .. .. .. **1/3**

No. **158.** "ULTRA SHORT WAVE RADIO TELEPHONE CIRCUITS."—**D. A. Thorn, B.Sc.(Eng.), A.M.I.E.E., and H. T. Mitchell, A.M.I.E.E.** 1935 .. .. **1s.**

No. **159.** "MODERN ELECTRIC PASSENGER LIFTS."—**R. S. Phillips, A.M.I.E.E.** 1935 **9d.**

CONTRACTORS TO THE GENERAL POST OFFICE

TUNGSTONE

STORAGE BATTERIES
FOR
Central Stations·Works·House Lighting

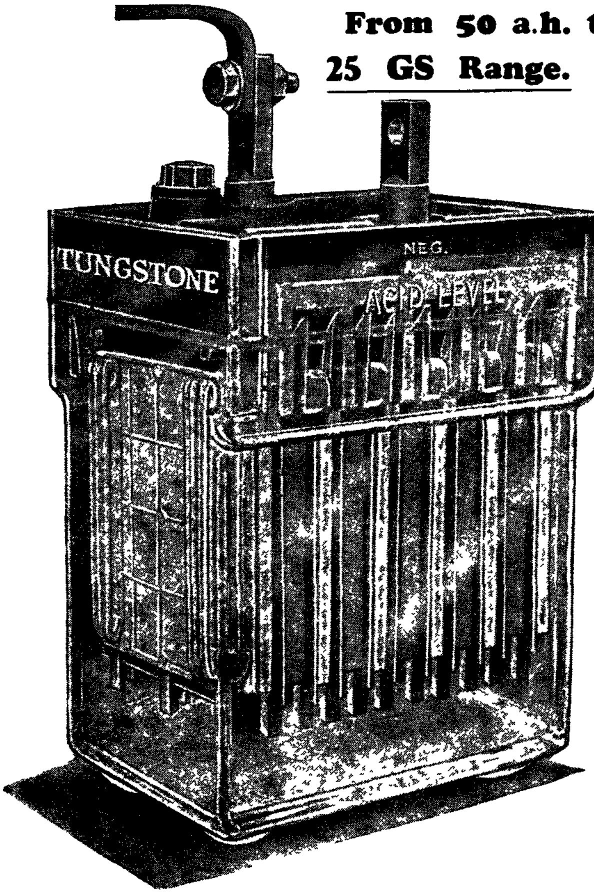
Entirely of British Origin and Workmanship. British Empire Lead exclusively used.

THE INDEPENDENT BATTERY OF THE BRITISH EMPIRE

Enclosed or Sealed type Planté Cells

From 50 a.h. to 125 a.h. Capacities at 10 hr. Rate.

25 GS Range.



Height over Intercell Connectors 16⅞".

Constructed to conform to British Standard Specification.

All Plates are built under our Standard High Pressure Machine Die-Cast process, guaranteeing Maximum Storage Capacity and longest working life.

Positive Plates. Very heavy Planté Type. 4⅞" wide, 6½" deep, 12 m/m thick.

Negative Plates. BoxType, 4⅞"x6½" deep, 8 m/mthick.

Separators. Specially treated Port Orford Cedar, suspended from the top of plates leaving space clear at bottom of Cell.

Containers. Strong glass with heavy plate supports. Positive and Negative terminal positions clearly marked and acid-level shown all round Cell.

Assembly. Cells are supplied fully assembled Positive and Negative lug pillars of different height prevent wrongly connecting up. Lead covered bolts, and nuts and lead washers supplied. End springs are secured in position on the negative plates.

All enclosed type Cells can be delivered filled with acid and fully charged for immediate use.

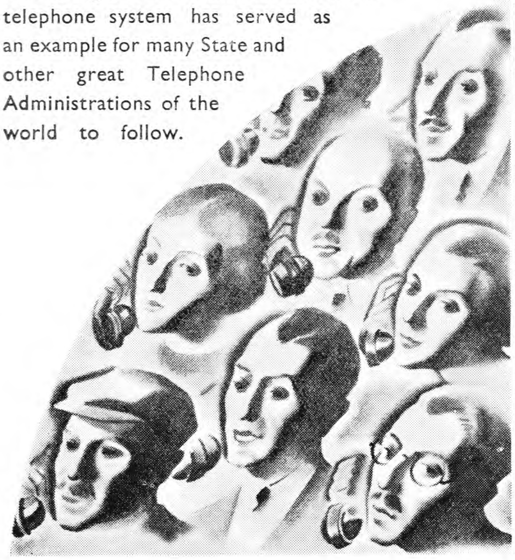
Type No.	A.H. Capacity	Charging Rates		Discharge Rates in Amperes			Weight of Cell Filled	Quantity of Acid per Cell	External Dimensions of Cell			Pitch of Cells
		Normal	Max.	10 Hours	5 Hours	1 Hour			Length	Width	Height	
							lbs.	gallons	inches			
25G5S	50	7	11	5	8.5	25	37	.62	5⅛	7⅞	12½	5½
25G7S	75	11	16	7.5	12.5	37.5	52	.80	6⅝	7⅞	12½	7
25G9S	100	14	21	10	16.5	50	63	1.1	8⅛	7⅞	12½	8½
25G11S	125	18	27	12.5	21	62.5	74	1.2	9⅝	7⅞	12½	10

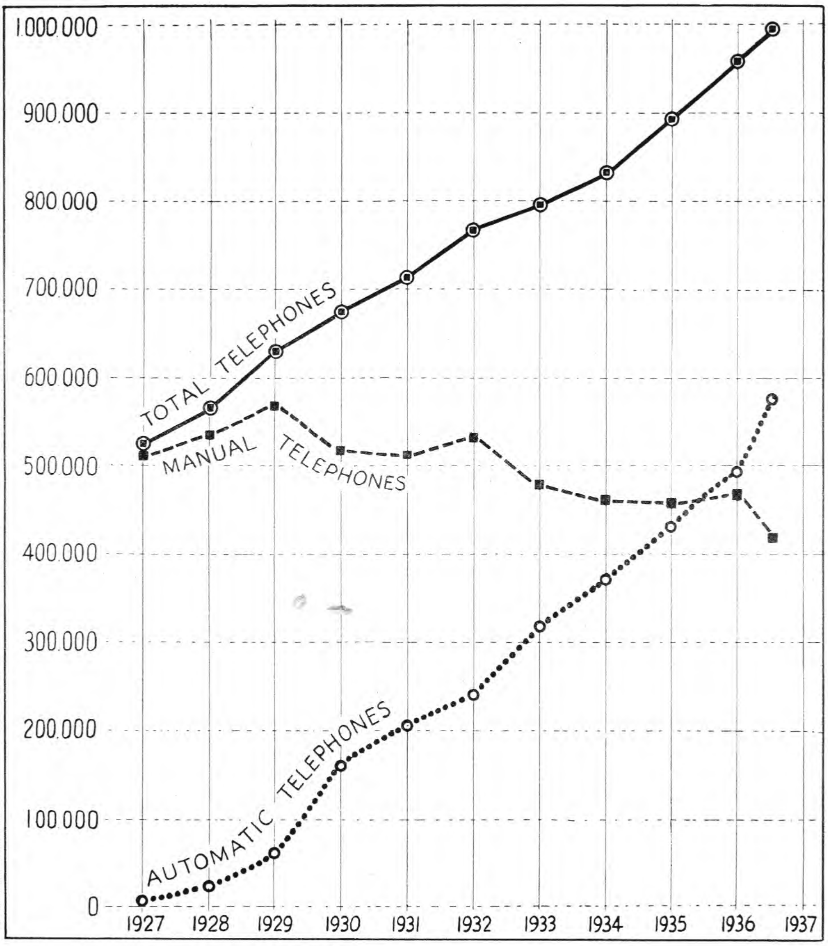
The Plate is the Nerve Centre of any Battery

TUNGSTONE ACCUMULATOR CO., LTD., St. Bride's House, Salisbury Square, E.C.4.
Telephone CENTRAL 8156 (4 lines) & 8189 Telegrams "Typify, Fleet, London" Cables: "Dilutum, London"

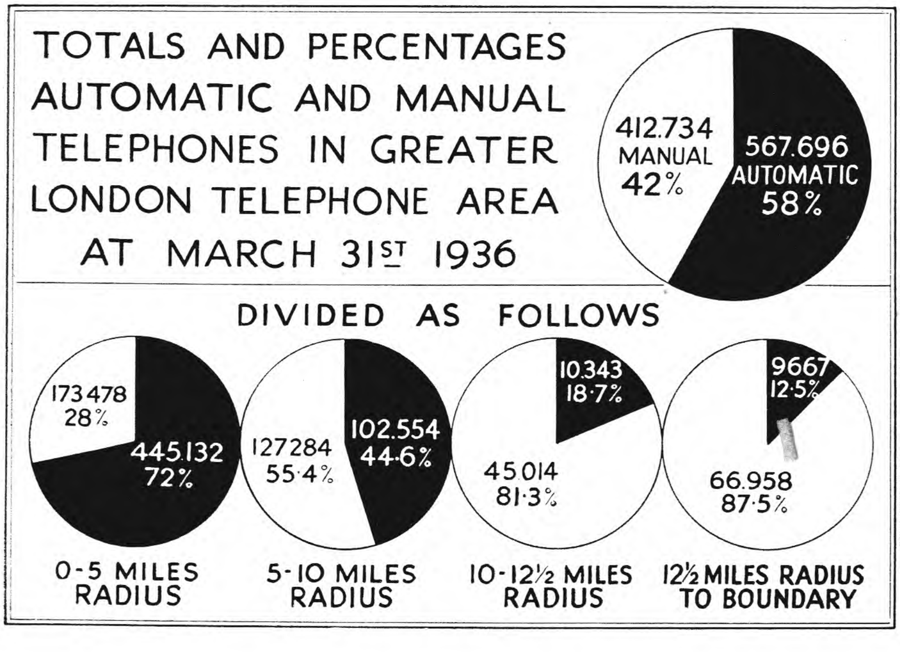
Telephone communications are in the forefront of London's public services. No other utility has made greater advances, or received closer attention from the Administration responsible. The British Post Office introduced automatic telephone service a number of years ago, and has continued the process of automatisation with commendable thoroughness. To achieve such steadily sustained progress standardisation was necessary and the Strowger system was selected as standard for all future use.

London is the greatest city in the world and it is fitting to record that its automatic telephone system has served as an example for many State and other great Telephone Administrations of the world to follow.





USED TO AUTOMATIC TELEPHONY



Statistics by courtesy of British Post Office

INDEX TO ADVERTISERS

Now Ready
New Second Edition of
RADIO ENGINEERING

By FREDERICK EMMONS TERMAN.

Associate Professor of Electrical Engineering, Stanford University.

813 pages, 9 × 6, 471 illustrations. 30/- net

THE new edition of this well-known and widely-used text preserves the same general style and the same method of approach that made the first edition so successful. It has, however, been thoroughly revised and largely rewritten in the light of an improved viewpoint, new developments in the field, and the author's own experience in using the first edition in his classes. Though the length of the book has been increased very little, it now covers considerably more territory as a result of improved organization and presentation.

Features of the New Edition

1. A full treatment of power amplifiers of all types, including Class A, Class AB, Class B, Class C, Linear Amplifiers, etc.
2. The sections on audio-frequency voltage amplifiers have been completely rewritten to take into account the increasing use of pentode tubes for this purpose.
3. Sections dealing with the new developments in broadcast antennas and methods of predicting broadcast coverage, including the use of Sommerfeld analysis, are also given, as well as material enabling the prediction of ultra-high frequency field strength.
4. The section on radio receivers has been completely rewritten and the typical examples described have all been changed in order to cover latest practices.
5. Material has been added on the alignment problem of all-wave receivers, all-wave antenna systems, etc.
6. There is included a discussion of the feed-back amplifier, both as applied to audio-frequency amplifiers and to broadcast transmitters.
7. The section on antennas now includes not only the newer developments in broadcast antenna, but also a consideration of such matters as mutual impedance between antennas and voltage induced in parasitic antennas.
8. There is a complete treatment of vacuum tube characteristics based upon the power series methods.
9. A complete set of problems is provided for each chapter.

Chapter Headings

The Elements of a System of Radio Communication
Circuit Constants
Properties of Resonant Circuits
Fundamental Properties of Vacuum Tubes
Vacuum-Tube Amplifiers
Vacuum-Tube Amplifiers (*continued*)
Power Amplifiers
Vacuum-Tube Oscillators
Modulation
Vacuum-Tube Detectors
Sources of Power for Operating Vacuum Tubes
Radio Transmitters
Radio Receivers
Propagation of Waves
Antennas
Radio Aids to Navigation
Television
Sound and Sound Equipment
Appendix A
Index

McGraw-Hill Publishing Co., Ltd.
ALDWYCH HOUSE LONDON, W.C.2

LATEST EXAMINATION SUCCESSES

Since the B.I.E.T. was founded ten years ago, we have specialised in preparing candidates for leading Technical Examinations, and our success may be gauged from the following remarkable results :

FOUR 1st PLACES

In the Probationary Inspectors and Assistant Superintendent of Traffic Examinations held in 1932-1935, B.I.E.T. candidates obtained **Four First Places.**

FIRST TWO PLACES

In the recent Limited Competition Examination for Assistant Superintendents of Traffic, the candidates placed **First and Second** *on the List of Successes were trained by the B.I.E.T.*

145 SUCCESSES

In the Probationary Inspectors and Assistant Superintendents of Traffic Examinations held in 1934 and 1935, **145 B.I.E.T. candidates passed the Examinations.**

We teach successfully by correspondence and definitely guarantee—

"NO PASS—NO FEE"

You are advised to send for a copy of our General Prospectus "ENGINEERING OPPORTUNITIES." This Hand-book contains 268 pages of most useful information. It also contains particulars of all leading Engineering Examinations, including

Probationary Inspectors (*Open and Limited Competitions*).
Probationary Assistant Engineers (*Limited Competition*).
Assistant Superintendent of Traffic (*Open and Limited Competitions*).
City and Guilds, Special G.P.O. Examination, I.E.E., B.Sc., A.M.I.C.E., London Matric., etc., etc.

The Hand-book also outlines "up-to-the-minute" courses of Home-Study in *all branches* of Engineering.

Special Courses are offered in **Telegraphy, Manual Telephony, Automatic Telephony, Telephone Transmission, Electrical Technology, Wireless and High Frequency Radio Communication, Alternating Currents, etc., etc.**

Our 268 pages Hand-book should be on your Bookshelf. It will be gladly sent on request, FREE and without obligation. (*Please state subject or Examination of most interest.*)

British Institute of Engineering Technology
369 Shakespeare House,
17, 18 & 19 Stratford Place, Oxford Street,
London, W.1

Fit

"TripleX" Regd

-and be safe

THE

G.P.O.

DO

THE "TRIPLEX" SAFETY GLASS CO. LTD
1 ALBEMARLE STREET · LONDON · W 1

IT PAYS TO READ TELEPHONY

This statement is endorsed by hundreds of telephone men who frequently find one article " worth the year's subscription price," as many have phrased it. One manager of a large telephone system writes us in detail regarding the value of TELEPHONY and concludes his letter with this paragraph :

> " In the foregoing we have attempted to tell you why we feel it is a good investment to have our employees read and study TELEPHONY. In addition to this, the articles in TELEPHONY of a managerial nature are of an inestimable value."

Subscription price : $5.00 U.S. money, for 52 worthwhile issues.

TELEPHONY

Address : Odhams Press, Ltd., Technical Book Dept., 85 Long Acre, London, W.C.2 (Telephone : Temple Bar 2468) for a sample copy of TELEPHONY, or write direct to :
TELEPHONY PUBLISHING CORPORATION,
608 S. Dearborn Street, Chicago, Ill., U.S.A.

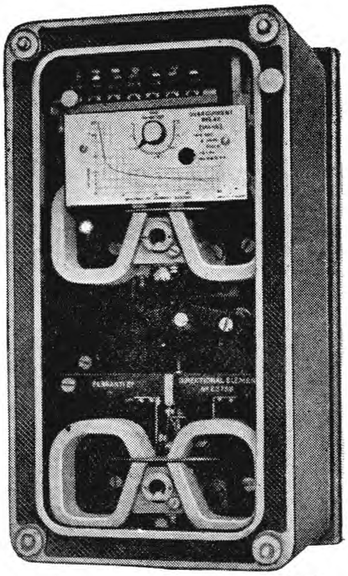
Ferranti

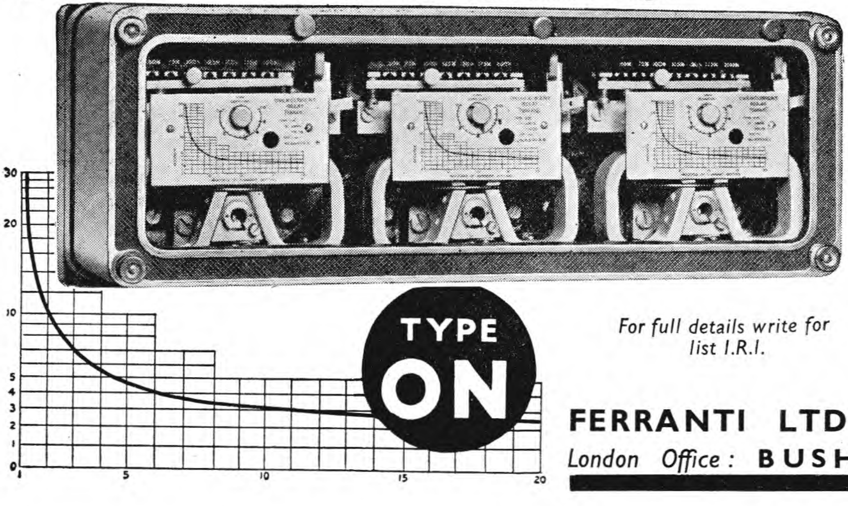
A.C. OVERCURRENT RELAYS

OVERCURRENT DIRECTIONAL ▸

TYPE OD

Specify Ferranti relays for the protection of your system.
These relays have an adjustable inverse and definite minimum time limit characteristic. They are applicable both for overcurrent and earth leakage protection on A.C. circuits. Low consumption of only 2.0 V.A on the 100% setting imposes a very small burden on the current transformers.
High torque ensures good setting values and freedom from sticking. Heavy gauge windings withstand the severest duties. Two powerful damping magnets on each element. Contacts are exceptionally robust.
Type O.D. Relays remain truly directional down to 1% of normal voltage.


FI 25a



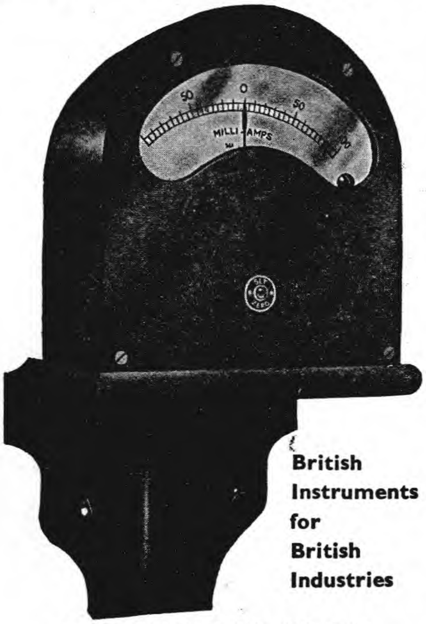
TYPE ON

For full details write for list I.R.I.

◂ OVERCURRENT NON-DIRECTIONAL

The automatic plug setting board is easily visible. Insulated tapping plug provided. Flag indicator on each element reset by hand from outside the case.
Type O.N. Relays are available in single, double and triple pole cases for horizontal or vertical mounting.

FERRANTI LTD., HOLLINWOOD, LANCS.
London Office : **BUSH HOUSE, ALDWYCH, W.C.2**



Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and