W. J. Harris,

MILITARY BOOKS

Published by Authority

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE
By HARRISON and SONS, 45-47, St. Martin's Lane, W.C.,
Printers in Ordinary to His Majesty.

To be purchased, either directly or through any Bookseller, from
WYMAN and SONS, Limited, 29, Breams Buildings, Fetter Lane, E.C. and
54, St. Mary Street, Cardiff; or
H.M. STATIONERY OFFICE (Scottish Branch), 23, Forth Street, Edinburgh; or
E. PONSONBY, Limited, 116, Grafton Street, Dublin;
or from the Agencies in the British Colonies and Dependencies,
the United States of America and other Foreign Countries of
T. FISHER UNWIN, Limited, London, W.C.

(The prices in brackets are those at which the books are obtainable, post free, by Officers, Non-Commissioned Officers, and Men, in the manner prescribed by Appendix XXIII. of the King's Regulations and Orders for the Army, 1912. Applications should be made on Army Form L. 1372, and addressed to the Secretary, War Office, S.W.)

ABYSSINIA. Expedition to. 2 vols. and maps. 1870. Half Mor., £5 5*s.* Cloth, £4 4*s.*

AFRICA. Continent of. Geology of. Notes on. 1906. 3*s.* (2*s.* 4*d.*)

AMHARIC LANGUAGE. Short Manual of the. With Vocabulary. 1909. 5*s.* (3*s.* 6*d.*)

ANIMAL MANAGEMENT. 1908. 1*s.* 6*d.* (1*s.* 4*d.*)

ARABIC GRAMMAR. Two parts. 1887. (*Sold to Officers only*). 10*s.* (10*s.* 6*d.*)

ARMOURERS. Instructions for, in the care, repair, browning, &c., of Small Arms, Machine Guns, "Parapet" Carriages, and for the care of Bicycles. 1912. 1*s.* 6*d.* (1*s.* 4*d.*)

Ditto. Amendments. Aug. 1912; Aug. 1914. Each 1*d.* (1*d.*)

ARMY CIRCULARS AND ARMY ORDERS issued before Dec. 31, 1892, which are still in force and required for reference. Reprint of. May 1896. 3*d.* (3*d.*)

ARMY ORDERS. Monthly. Each 3*d.* (3*d.*)

ARMY ORDERS. Covers for. 9*d.* (9*d.*)

ARMY ENTRANCE Regulations:—

R.M. Academy. Admission to, and for First Appointments therefrom to the Royal Artillery and Royal Engineers, during the period of the War. 1915. Provisional. 1*d.* (1*d.*)

R.M. College. Admission to, and for First Appointments therefrom to the Regular Army, during the period of the War. 1915. Provisional. 1*d.* (1*d.*)

Military Forces of the Self-governing Dominions and Crown Colonies. Officers of the. 1912. 1*d.* (1*d.*)

Militia and Imperial Yeomanry. Officers of. 1907. 1*d.* (1*d.*)

Special Reserve of Officers, the Malta Militia, the Bermuda Militia, Channel Islands Militia, and Territorial Force. Officers of the. 1912. 1*d.* (1*d.*)

University Candidates. 1912. 1*d.* (1*d.*)

Warrant Officers and N.C.O. of the Regular Army. Combatant Commissions as Second Lieutenants. 1914. Provisional. 1*d.* (1*d.*)

See also Commission; Medical Corps; Special Reserve; Territorial Force; Veterinary Corps.

ARMY LIST. The Quarterly (*not issued in* October, 1914). Each 15*s.* (10*s.* 9*d.*)

ARMY PAY, Appointment, Promotion, and Non-Effective Pay. Royal Warrant, 1914. 6*d.* (7*d.*)

ARMY ALLOWANCES Regulations. 1914. 6*d.* (6*d.*)

ARMY REVIEW. Quarterly. July 1911 to Oct. 1914. 1*s.* (Up to July 1914, 1*s.*; Oct. 1914, 11*d.*) (*Publication suspended*)

(B 11775) Wt. 44745—484 7½M 2/16 H & S

(As to prices in brackets, see top of page 2.)

ARMY SERVICE CORPS:—
- Regimental Standing Orders. 1911. 6*d.* (6*d.*): Amendments 1*d.* (1*d.*); Memorandum No. 25. 1*d.* (1*d.*)
- Training. Part I. 1909. (Reprinted, with Amendments. 1915) 9*d.* (9*d.*)
  - Ditto. Part II. Supplies. 1909. (Reprinted, 1914, with new Appendix XII.) 1*s.* 3*d.* (1*s.* 1*d.*)
  - Ditto. Part III. Transport. 1911. (Reprinted, with Amendments to April 1915). 9*d.* (9*d.*)
  - Ditto. Part IV. Mechanical Transport. (*Out of print*)

ARTIFICERS. Military. Handbook. 10th edition. 1915. 9*d.*

ARTILLERY AT THE PICARDY MANŒUVRES in 1910. Translated from the French. 2*s.* 6*d.* (2*s.*)

ARTILLERY. Royal:—
- Officers' Mess Management. (*See* Ordnance College.)
- Practice. Instructions:—
  - Garrison. Coast Defences. Seawards. 1914–15. 3*d.* (3*d.*)
  - Garrison. Siege and Movable Armament. 1914. 3*d.* (3*d.*)
  - Horse, Field, and Heavy. 1914. 6*d.* (5*d.*)
- Standing Orders for:—
  - Brigade of Mounted Artillery. 1*d.* (1*d.*)
  - Lieut.-Colonel's Command, R.G.A. (Coast and Siege). 1*d.* (1*d.*)
- Training:—
  - Field. 1914. 9*d.* (9*d.*)
  - Ditto. Examples of Ranging (to supplement those given in Sec. 227). 2*d.* (2*d.*)
  - Garrison—
    - Vol. I. 1914. 6*d.* (6*d.*)
    - Vol. II. (Siege). 1911. (Reprinted, with Amendments. 1914). 9*d.* (8*d.*)
    - Vol. III. 1911. (Reprinted, with Amendments, 1914). 1*s.* (11*d.*)

ARTILLERY COLLEGE. Reports upon the 14th to 18th Senior Classes. Each 1*s.* (9*d.*) (*See also* Ordnance College).

ARTILLERY, FIELD. The Tactics of. (*Von Schell*). Translated. 1909. 1*s.* (10*d.*)

ARTILLERY INSTRUMENTS. Handbook of. 1914. 1*s.* 6*d.* (1*s.* 4*d.*)
- Ditto. Amendments. 1*d.* (1*d.*)
- Ditto. Addendum to. 2*d.* (2*d.*)
- Ditto. Appendix. Dec. 1915 (Periscopes, &c.): and Amendments to p. 111 of the Handbook. 1*d* (1*d.*)

ARTILLERY MUSEUM in the Rotunda, Woolwich. Official Catalogue. 1906. (*Sold at the Rotunda.* 1*s.* 6*d.*)

ARTILLERY AND RIFLE RANGES ACT, 1885, and MILITARY LANDS ACTS, 1892 to 1903. Byelaws under:—
- Aldeburgh, 1896; Ash (Aldershot Camp), 1887; Finborough, 1901; Hythe, 1894; Inchkeith Battery, 1896; Kinghorniness, 1896; Landguard, 1887; Lydd—Dungeness, 1895; Middlewick, 1890; Millbrook, 1888; Orchard Portman, 1896; Scarborough, 1902; Scraps Gate, 1886; Shoeburyness, 1895; Southwold, 1896; Strensall, 1900; Wash, 1891; Whitehaven Battery (Cumberland), 1896. Each 1*d.* (1*d.*)
- Purfleet, 1911. 1*s.* (9*d.*)
- Salisbury Plain, 1900. 4*d.* (4*d.*)

ARTILLERY STORE ACCOUNTS AND THE SUPERVISION OF R.G.A. SUB-DISTRICTS. Notes on. 1914. 1*s.* (10*d.*)

ARTILLERY STORE ACCOUNTS AND THE CARE AND PRESERVATION OF EQUIPMENT OF ROYAL ARTILLERY. HORSE, FIELD, AND HEAVY BATTERIES. Notes on. Sept. 1914. 6*d* (5*d.*)

AUSTRIA. CAMPAIGN OF 1866 AGAINST. (*See* GERMANY).

BARRACKS. Care of. Instruction in. 1901. 9*d.* (7*d.*)

BASHFORTH CHRONOGRAPH. Experiments with, to determine the resistance of the air to the motion of projectiles. Report on. 1870. 1*s.* (9*d.*)

BAYONET FIGHTING. Instruction with Service Rifle and Bayonet, 1915. 1*d.* (1*d.*); Amendments. (*In the press*)

BAYONET FIGHTING FOR COMPETITIONS. Instruction in. 1*d.* (1*d.*)

BERMUDA MILITIA ARTILLERY. Regulations. 1914. 9*d.* (7*d.*)

BICYCLES. Military. Handbook on. 1911. (Reprinted, with Amendments, 1914). 1*d.* (1*d.*)

BRITISH MINOR EXPEDITIONS, 1746 to 1814. 1884. 2*s.* 6*d.* (1*s.* 11*d.*)

(As to prices in brackets, see top of page 2.)

CADET UNITS. (*See* Territorial Force).

CAMEL CORPS TRAINING. Provisional. 1913. 8*d.* (7*d.*)

CAPE OF GOOD HOPE. Reconnaissance Survey of the, 1903-1911. Report on the. 1*s.* 6*d.* (1*s.* 1*d.*)

CAVALERIE. Translated from the French of Captain Loir. (*In the press*).

CAVALRY OF THE LINE. PEACE ORGANIZATION OF THE: and Arrangements for Mobilization consequent on the establishment of Cavalry Depôts. (Special A.O., July 19, 1909.) 1*d.* (1*d.*)

CAVALRY SCHOOL, NETHERAVON. Standing Orders. 1911. 2*d.* (2*d.*)

CAVALRY TRAINING. 1912. (Reprinted, with Amendments, 1915.) 1*s.* (11*d.*)

CEREMONIAL. 1912. 3*d.* (4*d.*); Provisional Amendments. June 1914. 1*d.* (1*d.*)

CHEMISTRY. PRACTICAL. Quantitative and Qualitative. A Course of. 5*s.* (3*s.* 8*d.*)

CHEMISTS OF THE RESEARCH DEPARTMENT. Rules and Regulations. 1*d.* (1*d.*)

CHIROPODY. Manual of. 2*d.* (2*d.*)

CIVIL EMPLOYMENT FOR EX-SOLDIERS Guide to. 1913. 2*d.* (2*d.*)

CIVIL EMPLOYMENT REGULATIONS. 1913. 1*d.* (1*d.*)

CIVIL POWER. DUTIES IN AID OF THE. Special A.O., Dec. 17, 1908. (Amendments to "King's Regulations" and to "Manual of Military Law"). 1*d.* (1*d.*)

CLOTHING AND NECESSARIES (including Materials). Priced Vocabulary of. 1915. Provisional. 1*s.* (11*d.*); Amendments, Jan. 1916. 1*d.* (1*d.*)

CLOTHING Regulations:—

Part I. Regular Forces (excluding the Special Reserve). 1914. 6*d.* (6*d.*)

Part II. Special Reserve. 1914. 3*d.* (3*d.*)

Part III. Mobilization, Field Service, and Demobilization. 1908. 3*d.* (3*d.*)

Amendments to Parts I., II., and III. Nov. 1909; April, Oct. 1910; March, April, Sept., Nov. 1911; Feb., May, July, Sept. 1912; April, July 1913. Each 1*d.* (1*d.*)

COLCHESTER GARRISON. Standing Orders. 1913. 9*d.* (7*d.*)

COMMAND, ALDERSHOT. Standing Orders. 1914. 2*s.* 3*d.* (1*s.* 9*d.*) (*Out of print*)

COMMAND. THE ART OF. By Colonel von Spohn. Translated. 1*d.* (1*d.*)

COMMAND. WESTERN. Standing Orders Jan. 1910. (Reprinted, with Amendments, 1915). 6*d.* (5*d.*)

COMMANDS, Military, and Staff in the United Kingdom. Reorganization of. (Special A.O., Jan. 6, 1905, with alterations to date. Issued with Special A.O., Nov. 11, 1907). 3*d.* (3*d.*)

COMMISSION IN H.M. REGULAR ARMY (from 1st April, 1912). Short Guide to the various ways of obtaining a; &c., &c. April 1912. 2*d.* (2*d.*) (*See also* Army Entrance; Medical Corps; Special Reserve; Territorial Force; Veterinary Corps.

COMPANY TRAINING. Notes on. For the use of the Special Reserve Territorial Force, and newly-raised Units of the Regular Army. Sept. 1914. 1*d.* (1*d.*)

CONVEYANCE OF TROOPS AND ISSUE OF TRAVELLING WARRANTS. Instructions. 1910. 2*d.* (2*d.*)

COOKING. Military. Manual of. 6*d.* (5*d.*)

COOKING AND DIETARY. Military. Manual of. Mobilization. 1915. 2*d.* (2*d.*)

CREWS OF WAR DEPARTMENT VESSELS AND BOATS AT HOME STATIONS. Regulations for the Appointment, Pay, and Promotion of. 1911. 2*d.* (2*d.*)

CYCLIST TRAINING. Provisional. 1914. 3*d.* (3*d.*)

DIVISION ORDERS. Extracts from. 1880. 2*s.* 6*d.* (1*s.* 9*d.*)

DRAINAGE MANUAL. For the use of Royal Engineer Officers, and other persons employed on the Construction and Maintenance of Drainage Works in connection with War Department Buildings in the United Kingdom or in similar climates. Revised edition, 1907. (Reprinted 1915). 6*s.* (4*s.* 4*d.*)

DRAWING PLATES. Military—

Attack of Dufor's Countermines or 2nd plate of Mines; Carnot's First System; Detached Forts; Concealed Defences, 1, 2, 3, 4; Printing Plate, A, B, C, &c.; Detail Plate, No. 1; Do., No. 2; Neighbourhood of Woolwich; Village and Surrounding Ground. Each 2*d.* (2*d.*)

Attack of Fortress—Preliminary Operations; Do., Distant Attack; Do., Close Attack; Neighbourhood of Metz. Each 3*d.* (3*d.*)

(As to prices in brackets, see top of page 2.)

Drawing Plates. Military—*continued.*
Woods and Villages. 6 plates. Each 6*d.* (5*d.*)
Neighbourhood of Woolwich. Southern Side. 1*s.* 6*d.* (1*s.* 1*d.*)

DRESS REGULATIONS. 1911. 2*s.* 6*d.* (2*s.*) *(Out of print)*
Ditto. Amendments, March, Aug. 1912. Each 1*d.* (1*d.*); Aug. 1913. 2*d.* (2*d.*)

DRUM AND FLUTE DUTY for the Infantry, with Instructions for the Training of Drummers and Flautists. 1887. 2*s.* (1*s.* 6*d.*)

DYNAMICS. Notes on. (*See* Ordnance College).

EGYPT. BRITISH FORCE IN. Standing Orders. 1912. 1*s.* (10*d.*)

EGYPT. CAMPAIGN OF 1882 IN. Military History. With Case of Maps. Condensed Edition. 1908. 3*s.* 6*d.* (2*s.* 8*d.*)

ELECTRICAL COMMUNICATIONS. FIXED. Instructions as to. 1912. 4*d.* (4*d.*)

ELECTRICITY AND MAGNETISM. Text Book for use of the Cadets at the R.M. Academy. 1911. 2*s.* 6*d.* (2*s.*) *(Under revision)*

ELECTRICITY. Notes on. 1915. 1*s.* (11*d.*)

ELECTRIC LIGHT APPARATUS. DEFENCE. Instructions for the Working of. 1915. 1*d.* (1*d.*)

ELECTRIC LIGHTING. Military. Vol. I. 1*s.* (11*d.*); Vol. II. 1909. (Reprinted, with Amendments, 1915). 1*s.* 6*d.* (1*s.* 4*d.*); Vol. III. 1*s.* (11*d.*)

ENCOUNTER. THE BATTLE OF. By Hans von Kiesling. Part I. Practical. Translated. 1*s.* 6*d.* (1*s.* 3*d.*)

ENGINEER SERVICES Regulations. Peace:—
Part I. 1910. (Reprinted with Amendments published up to May 1, 1915.) 1*s.* (11*d.*)
Part II. 1911. Technical Treatises. (Reprinted, with Amendments to May 1. 1915). 9*d.* (8*d.*)

ENGINEER TRAINING. 1912. (Reprinted, with Amendments, 1914.) 6*d.* (6*d.*)

ENGINEERING. Field. Manual of. 1911. 9*d.* (9*d.*)

ENGINEERING. Military:—
Part I. Field Defences. 1908. 1*s.* 6*d.* (1*s.* 3*d.*)
Part II. Attack and Defence of Fortresses. 1910. 9*d.* (8*d.*)
Part III*a.* Military Bridging.—General Principles and Materials. 1913. 1*s.* (11*d.*)
Ditto. Ditto.—Ditto. Index to. 1*d.* (1*d.*)
Part III*b.* Ditto.—Bridges. 1*s.* 3*d.* (1*s.* 2*d.*)
Part IV. Mining and Demolitions. 1910. (Reprinted, 1915, with Amendments to 1912 inclusive). 1*s.* (11*d.*)
Part V. Miscellaneous. 1914. 1*s.* (11*d.*)
Part VI. Military Railways. 1898. *(Out of print)*

EQUIPMENT. INFANTRY. Pattern 1908 Web. 1913. 2*d.* (2*d.*)

EQUIPMENT Regulations:—
Part 1. 1912. (Reprinted, with Amendments published in Army Orders up to Aug. 31, 1914). 1*s.* (11*d.*)
Part 2. Details:—
Section.
I. Infantry. (Regular Army.) 1913. 6*d.* (5*d.*)
I*a.* Mounted Infantry. 1912. 6*d.* (5*d.*)
II. Cavalry. (Regular Army.) 1914. 3*d.* (3*d.*)
III. Army Service Corps. (Regular Army.) 1913. 6*d.* (5*d.*)
IV., IV*a.*, and IV*b.* Army Ordnance Corps. Army Pay Corps. Army Veterinary Corps. (Regular Army.) 1914. 2*d.* (2*d.*)
V. Royal Army Medical Corps. (Regular Army.) 1914. 2*d.* (2*d.*)
VI.-IX. R.M. Academy; R.M. and Staff Colleges; Garrison Staff and Schools of Instruction; Military Prisons, Detention Barracks and Military Provost Staff Corps. (Regular Army.) 1914. 2*d.* (2*d.*)
X*a.* Engineer. General. Fortress Survey, Railway, and Depôt Units. Peace and War. (Regular Army.) 1914. 2*d.* (3*d.*)
X*b.* Field Troop. (Regular Army.) 1912. 2*d.* (2*d.*
X*c.* Field Company. (Regular Army.) 1914. 2*d.* (2*d.*)
X*d.* Divisional Signal Company (Regular Army.) 1914. 2*d.* (2*d.*)
X*e.* Signal Company (Wireless). (Regular Army.) 1912. 2*d.* (2*d.*)

(As to prices in brackets, see top of page 2.)

Equipment Regulations—*continued.*

Section.

- X*f*. Headquarters Signal Units. (Regular Army.) 1914. 2*d*. (2*d*.)
- X*g*. Signal Company (Cable). (Regular Army.) 1912. 2*d*. (2*d*.)
- X*h*. Signal Squadron. (Regular Army.) 1914. 2*d*. (2*d*.)
- X*j*. Signal Troop with Cavalry Brigade. (Regular Army.) 1912. 2*d*. (2*d*.)
- X*k*. Signal Troop with a Cavalry Brigade not allotted to a Cavalry Division. (Regular Army.) 1914. 2*d*. (2*d*.)
- X*l*. Signal Company (South Africa). (Regular Army.) 1912. 2*d*. (2*d*.)
- X*m*. Bridging Train. (Regular Army.) 1912. 2*d*. (2*d*.)
- X*n*. Field Squadron. (Regular Army.) 1914. 2*d*. (2*d*.)
- XI*a* Horse Artillery. Q.F. 13-pr. (Regular Army.) 1913. 9*d*. (8*d*.)
- XI*b* Field Artillery. Q.F. 18-pr. (Regular Army.) 1914. 9*d*. (8*d*.)
- XI*c*. Ditto. Q.F. 4·5-in. Howitzer. (Regular Army.) 1913. (Reprinted, with Amendments up to Aug. 1, 1914). 9*d*. (8*d*.)
- XI*d*. Reserve Brigades with Q.F. 18-pr. Equipment, Horse and Field Artillery, Staff and Depôts, Riding Establishment, School of Gunnery (Horse and Field), and Mounted Band. (Regular Army.) 1914. 6*d*. (6*d*.)
- XI*e*. Mountain Artillery with B.L. 2·75-in. Equipment. Mountain Battery and Ammunition Column. Mule Transport. Provisional. (Regular Army.) 1914. 6*d*. (5*d*.)
- XII*a*. Royal Garrison Artillery. (Regular Army.) 1914. 2*s*. 6*d*. (1*s*. 11*d*.)
- XII*b*. Royal Garrison Artillery, Siege Artillery, Movable Armament, and Machine Guns in Armaments. 1913. 1*s*. (10*d*.)
- XII*c*. Heavy Artillery. B.L. 60-pr. (Regular Army.) 1913. 9*d*. (8*d*.)
- XIV. Cavalry School, Netheravon. (Regular Army.) 1914. 2*d*. (2*d*.)
- XV. Camel Corps School, Egypt. (Regular Army.) 1914. 2*d*. (2*d*.)
- XVI. Special Reserve. 1913. 4*d*. (4*d*.)
- XVII. Officers Training Corps. 1912. 3*d*. (3*d*.)

Practice Batteries and Drill Guns (Fixed Mountings) of the Royal Garrison Artillery. (Part 2, Sections XII*a*. and XVI., and Part 3.) 1909. **1*s*.** 6*d*. (1*s*. 2*d*.)

Part 3 Territorial Force. 1914. 6*d*. (6*d*.)
Ditto. Details:—
Sec. IX. Artillery. 1912. 1*s*. (9*d*.)
Ditto. Amendments, April 1912; Feb. 1914. Each 1*d*. (1*d*.)
Sec. X. Engineer. 1912. 3*d*. (3*d*.)

Amendments to Part 2. Feb., April, July (two issues), Aug. 1914. Each 1*d*. (1*d*.)

Amendments to Parts 1, 2, and 3. Nov. 1913. 1*d*. (1*d*.)

Amendments to Parts 1, 2, and 3. March, July 1913; April, Aug. 1914. Each 2*d*. (2*d*.)

EUROPEAN WAR, 1914-16. Despatches (Naval and Military) relating to Operations in the War:—

- I. Sept., Oct., and Nov. 1914. With List of Honours and Rewards Conferred. With Sketch Map. 2*d*. (3*d*.)
- II. Nov. 1914 to June 1915. With Names of Officers mentioned, and Awards of the Victoria Cross. 6*d*. (7*d*.)
- III. July to Oct. 1915. *(In preparation)*
- IV. Dec. 11, 1915. From General Sir Ian Hamilton, G.C.B., describing the Operations in the Gallipoli Peninsula, including the Landing at Suvla Bay. 2*d*. (2*d*.)

EXAMINATION PAPERS:—

Qualifying Certificates. Sept. 1905; **March 1906**; Sept. 1909; **March, Sept. 1910**; March, Sept. 1911; March 1912. Each 6*d*. (5*d*.)

(As to prices in brackets, see top of page 2.)

Examination Papers—*continued*

Entrance: R.M. Academy, R.M. College, Qualifying Test for Commissions. Supplementary First Appointments in the Royal Marines. June–July 1912. 1*s.* (11*d.*)

Entrance: R.M. Academy. R.M. College. Qualifying Test for Commissions Nov. 1912; Nov.–Dec. 1913. Each 1*s.* (11*d.*)

Entrance: R.M. Academy, R.M. College, Qualifying Test for Commissions. Supplementary First Appointments in the Royal Marines. Appointments in the Indian Police Force. Appointments in the Police Forces of the Straits Settlements and the Federated Malay States. Cadetships in the Royal Navy (Special Entry). June–July 1914. 1*s.* (11*d.*)

Entrance: R.M. Academy, R.M. College, Indian Army College. Supplementary First Appointments in the Royal Marines. Appointments in the India Police Force. Appointments in the Police Force of Ceylon. Cadetships in the Royal Navy (Special Entry). June–July 1915. 1*s.* (11*d.*)

Freehand Drawing at the Army Entrance Examination of Nov. 1913. Specimen Paper to illustrate the kind of questions that will be set in. 6*d.* (5*d.*)

R.M. Academy, Fourth Class; R.M. College, Fourth, Third and Second Divisions. July, Dec. 1904; June 1905. Each 1*s.*

R.M. Academy, Fourth Class; R.M. College, Senior Division. Dec. 1905; June, Dec. 1906; July, Dec. 1907. Each 1*s.*

Staff College. Admission. Aug. 1907; Aug. 1909; July 1911; June–July, 1912; June–July 1913. Each 1*s.* (6*d.*)

Regular Forces, Canadian Permanent Forces, Special Reserve of Officers. Territorial Force, and Colonial Military Forces. May, Nov. 1906; May, Nov. 1908. Each 1*s.* (11*d.*)

Ditto. May 1909. 9*d.* (8*d.*)

Officers for Promotion. Dec. 1912; May, Dec. 1913; April 1914. Each 1*s.* (6*d*)

Militia. Imperial Yeomanry, and University Candidates. March, Sept. 1904; Sept. 1905; Oct. 1906. Each 1*s.*

Special Reserve, Militia, Territorial Force, and University Candidates. Oct. 1911; March, Oct. 1912; March. Oct. 1913. Each 1*s.* (6*d.*)

Special Reserve, Militia, Territorial Force, Non-Commissioned Officers, and University Candidates. March 1911. 1*s.* (6*d.*)

Officers Training Corps:—

Cadets of the Senior Division. Certificate A. Dec. 1908. 6*d.* (5*d.*)

Cadets of the Junior and Senior Divisions. Certificates A and B. Spring of 1909; May, Nov. 1911; March, Nov. 1912; March, Nov. 1913; March 1914. Each 6*d.* (6*d.*)

Foreign Languages. Modern. July 1906; July 1908; April, July 1909; Jan., June, Oct. 1910; Jan., June 1911; June 1912; June 1913; June 1914. Each 1*s.* (6*d.*)

EXPLOSIVES. Service. Treatise on. 1907. 1*s.* 6*d.* (1*s.* 2*d.*)

FIELD ALMANAC. 1916. 1*d.* (1*d.*)

FIELD SERVICE MANUALS:—

Ammunition Column. Divisional. New Armies. 1915. 3*d.* (3*d.*)

Artillery. Field. Brigade. Q.F. 18-pr. 1915. 3*d.* (3*d.*)

Ditto. Ditto. (Howitzer) Brigade. 5-inch B.L. 1908. 3*d.* (3*d.*)

Ditto. Heavy (B.L. 60-pr.) Battery and Ammunition Column. Expeditionary Force. 1910. 3*d.* (3*d.*) *(Under revision)*

Ditto. Horse. Brigade. 13-pr. Q.F. 1908. 3*d.* (3*d.*) *(Under revision)*

Ditto. Ditto. Appendix to. R.H.A. Battery and Mounted Brigade Ammunition Column. 1*d.* (1*d.*)

Cavalry Regiment. Expeditionary Force. 1913. 3*d.* (3*d.*) *(Under revision*

Engineers. Balloon Company. Expeditionary Force. 1910. 3*d.* (3*d.*)

Ditto. Bridging Train. Expeditionary Force. 1915. 3*d.* (3*d.*)

Ditto. Field Company. Expeditionary Force. 1915. 3*d.* (3*d.*)

Ditto. Field Squadron. Expeditionary Force. 1914. 3*d.* (3*d.*)

Ditto. Works Company. Expeditionary Force. 1910. 3*d.* (3*d.*)

Headquarters Units. Expeditionary Force. 1911. 3*d.* (3*d.*)

Infantry Battalion. Expeditionary Force. 1914. 3*d.* (3*d.*)

Infantry (Mounted) Battalion. Expeditionary Force. 1913. 3*d.* (3*d.*)

Medical Service. Army. Expeditionary Force. 1914. 3*d.* (3*d.*)

(As to prices in brackets, see top of page 2.)

Field Service Manuals—*continued.*

Signal Service. Signal Company (Air Line). Expeditionary Force. 1913. 3*d.* (3*d.*)
Ditto. Ditto. (Cable). Expeditionary Force. 1913. 3*d* (3*d.*)
Ditto. Ditto. (Divisional). Expeditionary Force. 1915. 3*d.* (3*d.*)
Ditto. Ditto. (Lines of Communication). Expeditionary Force. 1914. 3*d.* (3*d.*)

FIELD SERVICE POCKET BOOK. 1914. 1*s.* (11*d.*)

FIELD SERVICE REGULATIONS:—

Part I. Operations 1909. (Reprinted, with Amendments, 1914). 6*d.* (6*d.*)
Part II. Organization and Administration. 1909. (Reprinted, with Amendments to Oct. 1914). 1*s.* (10*d.*)
Ditto. Amendments, April 1915. 1*d.* (1*d.*)

FINANCIAL INSTRUCTIONS IN RELATION TO ARMY ACCOUNTS. 1910. (Reprinted, with Amendments to Sept. 1, 1914.) 4*d.* (4*d.*)

FLYING CORPS. ROYAL. Training Manual:—

Part I. Provisional. 1914. 1*s.* (10*d.*)
Ditto. Amendments. Jan. 1915. 1*d.* (1*d.*)
Part II. Military Wing. Provisional. 1914. 3*d.* (4*d.*)

FOREIGN LANGUAGES. STUDY OF. Regulations. 1913. 2*d.* (2*d.*)

FORTIFICATION PERMANENT. For the Imperial Military Training Establishments and for the Instruction of Officers of all Arms of the Austro-Hungarian Army. 7th Edition. Translated. 4*s.* (2*s.* 11*d.*)

FRANCO-GERMAN WAR, 1870-71. Translated from the German Official Account:—

First Part—History of the War to the Downfall of the Empire—

Vol. 1 (Secns. 1 to 5). Outbreak of Hostilities to Battle of Gravelotte. (*Out of print*)
Vol. 2 (Secns. 6 to 9). Battle of Gravelotte to Downfall of the Empire. (*Out of print*)

Second Part—History of the War against the Republic—

Vol. 1 (Secns. 10 to 13). Investment of Paris to Re-occupation of Orleans by the Germans. £1 6*s.* (18*s.* 6*d.*)
Vol. 2 (Secns. 14 to 18). Events in Northern France from end of Nov. In North-west from beginning of Dec. Siege of Paris from commencement of Dec. to the Armistice. Operations in the South-east from middle of Nov. to middle of Jan. £1 6*s.* (19*s.*)
Vol. 3 (Secns. 19 and 20). Events in South-east France from middle of Jan. to Termination of Hostilities. Rearward Communications. The Armistice. Homeward March and Occupation. Retrospect. £1 11*s.* 6*d.* (£1 2*s.* 3*d.*)

Also separately, Sections in paper covers, and Plans unmounted:—

Sec.
1. Events in July. Plan. 3*s* (2*s.* 2*d.*)
2. Events to Eve of Battles of Wörth and Spicheren. 3rd edition. (*Out of print*)
3. Battles of Wörth and Spicheren. 3rd edition. (*Out of print*)
4. Advance of Third Army to the Moselle, &c. 2nd edition. (*Out of print*)
5. Operations near Metz on 15th, 16th, and 17th August. Battle of Vionville—Mars la Tour. 2nd edition. (*Out of print*)
6. Battle of Gravelotte—St. Privat. (*Out of print*)
7. Advance of Third Army and of Army of the Meuse against Army of Chalons. (*Out of print*)
8. Battle of Sedan. (*Out of print*)
9. Proceedings on German Coast and before Fortresses in Alsace and Lorraine. Battle of Noisseville. General Review of War up to September. 4*s.* 6*d.* (3*s.* 4*d.*)
10. Investment of Paris. Capture of Toul and Strassburg. 6*s.* (4*s.* 6*d.*)
11. Events before Paris, and at other points of Theatre of War in Western France until end of October. 5*s.* 3*d.* (3*s.* 11*d.*)
12. Last Engagements with French Army of the Rhine. Occurrences after fall of Strassburg and Metz to middle of November. 4*s.* 6*d.* (3*s.* 5*d.*)

Franco-German War—*continued.*

Sec.

13. Occurrences on Theatre of War in Central France up to Re-occupation of Orleans by the Germans. 6*s.* (4*s.* 6*d.*)
14. Measures for Investment of Paris up to middle of December. 4*s.* (3*s.*)
15. Measures for Protecting the Investment of Paris and Occurrences before French Capital to commencement of 1871. 2*s.* 6*d.* (1*s.* 11*d.*)
16. Proceedings of Second Army from commencement of 1871 until the Armistice. 3*s.* 6*d.* (2*s.* 8*d.*)
17. Proceedings of First Army from commencement of 1871 until the Armistice. 3*s.* (2*s.* 3*d.*)
18. Occurrences on South-eastern Theatre of War up to middle of January, 1871. Events before Paris from commencement of 1871 to the Armistice. 8*s.* (6*s.*)
19. Occurrences on South-eastern Theatre of War from middle of January 1871. Proceedings in rear of German Army and in Coast Provinces, from Nov. 1870 until the Armistice. 13*s.* 6*d.* (9*s.* 8*d.*)
20. General Retrospect of War from beginning of Sept. 1870 to Cessation of Hostilities. Armistice and Peace Preliminaries. Return of German Army and Peace of Frankfort. The Occupation. The Telegraph, Post, Supply of Ammunition, Commissariat, Hospital Service, Divine Service, Military Justice, Recruitment, and Home Garrisons. Results. 5*s.* (3*s.* 9*d.*)

Analytical Index. 1*s.* 6*d.* (1*s.* 1*d.*)

Plans—

4. Battle of Colombey-Nouilly. 3*d.* (3*d.*)
5A. Battle of Vionville—Mars la Tour. Position of Contending Forces at Noon. 3*d.* (3*d.*)
5B. Battle of Vionville—Mars la Tour. Position of Contending Forces from 4 to 5 p.m. 3*d.* (3*d.*)
9A. Battle of Sedan. Position of Contending Forces towards Noon. 3*d.* (3*d.*)
9B. Battle of Sedan. Position of the Germans in the afternoon shortly before the end of the struggle. 3*d.* (3*d.*)

(*See also* SIEGE OPERATIONS.)

FRENCH WORDS AND PHRASES with English Pronunciation, Short Vocabulary of. Notes on French Measures. Abbreviations and Terms used on French Maps, with English Equivalents. 1*d.* (1*d.*)

GERMAN ARMY:—

Cavalry. Drill Regulations. 1909. 3*d.* (3*d.*)
Field Service Regulations. 1908. 1*s.* (10*d.*)
Foot Artillery. Drill Regulations. Part IV. The Fight. 1909. 3*d.* (3*d.*)
Manœuvres Regulations. 1908. 3*d.* (3*d.*)

GERMANY. The Campaign of 1866 in. With 22 Plans in portfolio. 1872. (Reprinted 1907.) 6*s.* (4*s.* 10*d.*)
Ditto. Moltke's Projects for. 1*s.* (10*d.*)
Ditto. Moltke's Correspondence during the. Précis. With 4 Plans. 1*s.* (10*d.*)

GUERNSEY AND ALDERNEY ROYAL MILITIA. Regulations. With the Militia Laws relating to the Islands. Provisional. 3*s.* (2*s.* 2*d.*)

GUNS. Drill for. (*And see* **GUNS.** Handbooks for):—

60-pr. B.L. 1912. (Reprinted, with Amendments, 1915). 1*d.* (1*d.*) (*Under revision*)
18-pr. Q.F. 1914. 1*d.* (1*d.*) (*Under revision*); Amendments, April 1915. ½*d.* (½*d.*)
15-pr. B.L. 1914. 1*d.* (1*d.*)
15-pr. B.L.C. 1914 1*d.* (1*d.*)
15-pr. Q.F. 1915. 1*d.* (1*d.*) (*In the press*)
13-pr. Q.F. 1914. 1*d.* (1*d.*); Amendments, April 1915. ½*d.* (½*d.*)
12-pr. 12-cwt. Q.F. Land Service. 1914. 1*d.* (1*d.*)
12-inch B.L. Howitzer. Mark I. (E.O.C.) 1915. (Reprinted with corrections). 1*d.* (1*d.*)
10-pr. B.L. 1914. 1*d.* (1*d.*)
9·2-inch B.L. Mark IX., on Mark IV. Mounting. Land Service. 1914. 1*d.* (1*d.*)
9·2-inch B.L. "C" Mark IX., on Marks V^{A}. and V^{B}. Mountings. Land Service. 1914. 1*d.* (1*d.*)
9·2-inch B.L. Marks X., X^{v}., and X*., on Mark V. Mounting. Land Service. 1914. 1*d.* (1*d.*)

As to prices in brackets, see top of page 2.)

Guns. Drill for—*continued.*
6-inch B.L. Marks VII. and VIIV. Land Service. 1914. 1*d.* (1*d.*)
6-inch B.L. Howitzer. 1912. (Reprinted, with Amendments to Dec. 1914). 1*d.* (1*d.*)
6-inch Q.F. Land Service. 1914. 1*d.* (1*d.*)
5-inch B.L. Howitzer. 1915. 1*d* (1*d.*)
4·7-inch Q.F. on Travelling Carriages. 1912. 1*d.* (1*d.*)
4·7-inch Q.F. Fixed Armament. Land Service. 1914. 1*d.* (1*d.*)
4·7-inch Q.F. Heavy Batteries. 1915. 1*d.* (1*d.*)
4·5-inch Q.F. Howitzer. 1914. (Reprinted, with Amendments, 1915). 1*d.* (1*d.*)
4-inch Q.F. Land Service. 1914. 1*d.* (1*d.*)
2·95-inch Q F. 1914. 1*d.* (1*d.*)

GUNS. Handbooks for. (*And see* **GUNS.** Drill for):—
60-pr. B.L. Land Service. 1913. 1915 (Reprinted). 1*s.* 6*d.* (1*s.* 3*d.*)
Ditto. Amendments. 2*d.* (2*d.*)
18-pr. Q.F. Land Service. 1913. (Reprinted, with Amendments, 1914). 1*s.* (11*d.*) (*Under revision*)
Ditto. Amendments, 1*d.* (1*d.*); August 1915, 2*d.* (2*d.*)
15-pr. B.L. Marks II. to IV., and Carriages, Marks II.* and IV., and Wagon, and Limber. Mark IV. Field Batteries. 1914. Provisional. 1*s.* (10*d.*)
15-pr. B.L.C. Marks I., II., II.*, and IV., with Mark I. Carriage, and Marks I., I*a*, I*b*, and I*c*. Limbers and Wagons. Land Service. 1912. 1*s.* (10*d.*)
15-pr. Q.F. Land Service. 1914. 1*s.* 6*d.* (1*s.* 2*d.*)
13-pr. Q.F. Land Service. 1913. (Reprinted, with Amendments, 1914). 1*s.* 3*d.* (1*s.* 1*d.*); Amendments, 1*d.* (1*d.*).
10-pr. Jointed B.L. Mule Equipment. 1914. 1*s.* 6*d.* (1*s.* 2*d.*)
9·45-inch B.L. Howitzer. 1906. (Reprinted, with Amendments, 1915). 9*d.* (8*d.*)
9·2-inch B.L. Mark IX., "C" Mark IX., and Marks X., X^v., and X.* Land Service. 1912. 1*s.* (11*d.*)
8-inch R.M.L. Howitzer of 70 cwt. For Movable Armament and Armament of Works. Land Service. 1901. (Reprinted 1915). 2*s.* (*In the press*)
6-inch B.L. and B.L.C. Guns, Mountings, &c. 1904. 1*s.* 6*d.* (1*s.* 4*d.*)
6-inch B.L. Marks VII. and VIIV. Land Service. 1911. 9*d.* (8*d.*)
6-inch B.L. Marks VII. and VIIV., on Travelling Carriage. Land Service. 1915. 2*s.* (*In the press*)
6-inch B.L. 30 cwt. Howitzer. Marks I. and I*. 1915. 1*s.* 6*d.* (1*s.* 2*d.*)
6-inch Q.F. Land Service. 1903. 1*s.* (10*d.*)
6-inch "B" Q.F. Land Service. 1911. 1*s.* (10*d.*)
5·4-inch B.L. Howitzer. Mark I. 1902. 1*s.* 6*d.* (1*s.* 2*d.*)
5-inch B.L. Marks I.—V. 1904. 9*d.* (9*d.*)
5-inch B.L. Marks IV.—V. Land Service. 1903. 1*s.* 6*d.* (1*s.* 2*d.*)
5-inch B.L. Howitzer. 1915. 1*s.* (11*d.*)
4·7-inch Q.F. Fixed Armaments. Land Service. 1904. 1*s.* (11*d.*)
4·7-inch Q.F.B., on Travelling Carriages. Land Service. 1910. (Reprinted, with Amendments, 1914). 9*d.* (8*d.*) (*Under revision*)
4·5-inch Q.F. Howitzer. Land Service. 1915. 1*s.* (*In the press*)
2·95-inch Q.F. Mule Equipment and Man Transport Equipment. 1914. 2*s.* (1*s.* 6*d.*)
·303-inch and ·303-inch Converted Maxim Machine (Magazine Rifle Chamber), mounted on Carriages, M.G., Infantry, Parapet, Tripod and Cone Mountings. 1911. (Reprinted, with Amendments, 1915). 9*d.* (9*d.*)
·303-inch Vickers Machine (Magazine Rifle Chamber), on Tripod Mounting, Mark IV. 1914 6*d.* (6*d.*): Amendments, June 1915. 1*d.* (1*d.*)
·303-inch Lewis Machine (Magazine Rifle Chamber). Part I. 1915. Provisional. 4*d.*

HISTORICAL RECORDS OF THE BRITISH ARMY:—
Horse Guards. 5*s.* (3*s.* 7*d.*)
Dragoon Guards, 3rd, 4th, 5th, 6th, and 7th. Each 4*s.* (3*s.*)
Dragoons, 1st, 3rd, 7th, 14th and 16th. Each 4*s.* (3*s.*)
Ditto. 12th and 13th. Each 3*s.* (2*s.* 3*d.*)
Marine Corps. 3*s.* (2*s.* 2*d.*)
Foot. 6th, 7th, 8th, 10th, 11th, 13th, 15th, 16th, 17th, 18th, 19th, 20th, 21st, 22nd, 34th, 36th, 39th, 46th, 53rd, 67th, 71st, 72nd, 73rd 74th, 86th 87th, and 92nd. Each 4*s.* (3*s.*)
Do. 14th, 56th, 61st, 70th, and 88th. Each 3*s.* (2*s.* 3*d.*)

40
W.O.
2277

INSTRUCTION

IN

ARMY TELEGRAPHY AND TELEPHONY.

VOL. I.—INSTRUMENTS.

Reprinted, with corrections, 1914.

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S
STATIONERY OFFICE
BY EYRE AND SPOTTISWOODE, LTD., EAST HARDING STREET, E.C.,
PRINTERS TO THE KING'S MOST EXCELLENT MAJESTY.

To be purchased, either directly or through any Bookseller, from
WYMAN AND SONS, LTD., 29, BREAMS BUILDINGS, FETTER LANE, E.C., and
54, ST. MARY STREET, CARDIFF; or
H.M. STATIONERY OFFICE (SCOTTISH BRANCH), 23, FORTH STREET, EDINBURGH; or
E. PONSONBY, LTD., 116, GRAFTON STREET, DUBLIN;
or from the Agencies in the British Colonies and Dependencies,
the United States of America and other Foreign Countries of
T. FISHER UNWIN, LTD., LONDON, W.C.

1916.

Price One Shilling and Sixpence.

THESE Instructions are issued by Command of the Army Council for the guidance of all concerned.

Instruments other than service patterns, and their use, have been described only when they are likely to be of use for military purposes. The Chapter on theory is intended more as a guide to assist Officers and N.C.Os in giving instruction, than as a text-book. For further information on the theory of electricity "Text-book on Electricity and Magnetism, for use at the R.M. Academy," and "Elementary Lessons in Electricity and Magnetism" (by S. P. Thompson) are recommended; and for further information on other points dealt with, "Telegraphy" (by T. E. Herbert, 1906) and "Telephone Handbook" (by Poole, 1906).

R. H. Brade

WAR OFFICE,
17*th December*, 1914.

CONTENTS.

s (33) 31277 (24644) Wt. 44745 7500 1/16 E. & S. (S) A 2

PLATE OF CONVENTIONAL SIGNS.


CELL (LONG THIN LINE +^{ve} PLATE, SHORT THICK LINE −^{ve} PLATE)


OR

BATTERY

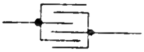

RESISTANCE COIL (NON INDUCTIVELY WOUND)


RESISTANCE COIL, INDUCTIVELY WOUND

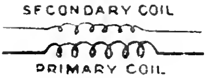

OR

GALVANOMETER


OR

OR

CONDENSER.


TELEPHONE RECEIVER.



INDUCTION COIL


GENERATOR


MICROPHONE.


EARTH CONNECTION


MAGNETO BELL


BATTERY RINGING BELL

To Face p 7

INSTRUCTION IN ARMY TELEGRAPHY AND TELEPHONY.

CHAPTER I.

ELEMENTARY THEORY.

Effects of electric current.

1. When a current of electricity flows in a conductor, certain phenomena are observable, the three principal ones being :—

(*a*) The conductor is heated (thermal effect).

(*b*) A magnetic needle placed in the vicinity of the conductor is affected (magnetic effect).

(*c*) If the current passes through a suitable liquid, called an electrolyte (such as dilute acids or metallic salts in solution), the electrolyte is decomposed (chemical effect).

Conditions necessary for flow of electric current.

2. In order that an electric current may flow, two conditions are necessary, viz. :—

(*a*) There must be a complete conducting path for the current to flow along.

(*b*) There must be in that path an electrical pressure, termed electromotive force (or, shortly, E.M.F.).

Water analogy.

3. For beginners, who have no conception of electric currents, the analogy of water flowing in pipes will assist in forming a working idea of what happens in an electric circuit, and of the laws which govern the flow of an electric current; this analogy will be used to illustrate the laws and effects given below.

Consider a closed circuit of pipes full of water (Fig. 1), then,

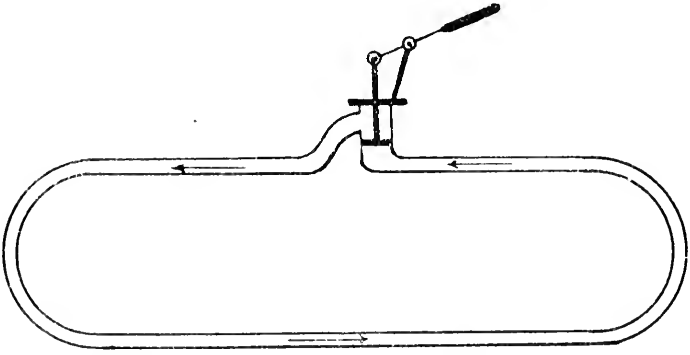


FIG. 1.

if the water is to be made to flow in the pipes, the following conditions are necessary :—

(*a*) The pipes must not be blocked at any point, *i.e.*, the path must be complete.

(*b*) There must be a pump of some sort at some part of the circuit (there may be more than one) to force the water to flow.*

Sources of Electromotive Force.

Sources of current.

4. The "electromotive force" necessary to produce a current can be obtained from—

(*a*) Primary batteries of one or more cells, either "wet" or "dry."

(*b*) Accumulators (or secondary cells).

(*c*) Generators, driven by hand or power.

In (*a*) and (*b*) chemical energy is converted into electrical energy, and in (*c*) mechanical energy is converted to electrical energy.

For telegraph work and the speaking portions of telephones, primary batteries are generally used, and in the field they are always used.

Secondary batteries (accumulators) are used in large civil telegraph offices and telephone exchanges.

Generators driven by steam or oil engines, &c., are used for producing large currents for lighting and power purposes, and for "charging" accumulators; small hand generators are used for ringing bells in telephone work.

The cell or generator corresponds to the pump in the water circuit, and one or more are used in each circuit, according to circumstances.

Simple primary cell.

5. The simple cell consists of two dissimilar metals immersed in an acid solution. The metals first used were zinc and copper, and the plates in a cell are often referred to as zinc and copper, even though they may be actually constructed of other materials. If the zinc and copper are joined together by a "conductor" outside the containing vessel, a current will flow in the conductor and through the cell (Fig. 2).

Details of cells in use, and their peculiarities will be considered in Chapter II.

Direction of current and E.M.F.

6. If the pump in the water circuit be reversed, the water will flow in the reverse direction, and the same thing occurs with the electric current, as may be shown by the magnetic effect mentioned above; if a magnetic needle be placed near

---

* The case of water flowing from a higher point to a lower one can only give a temporary current, as the water will only flow till the cistern at the higher point is empty, and, if the current is then to be continued, a second pipe with a pump is necessary to continue the supply of water, when we get back to the closed circuit with a pump, see also para. 24.

the conductor, it will be found that the direction in which it moves depends on which end of the conductor is joined to the zinc and which to the copper.

Conventionally it has been agreed that the current flows from the copper to the zinc *outside* the cell, and from the zinc to the copper inside the cell. The copper or corresponding plate is usually called the positive (+ve) and the zinc the negative (−ve) plate or "pole" of the cell.

Strength of current.

7. The current of water flowing in a pipe can obviously vary in strength; the larger the pipe, the shorter its length and the stronger the pump, the more water will flow past any point in a given time, *i.e.*, the larger the current. Note that the current of water could be measured as so many gallons per second, but not merely in gallons.

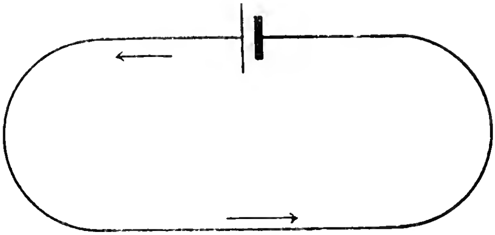


FIG. 2.

The strength of the electric current can also be varied, and consequently the magnitude of the effects it produces. This variation can be shown by the amount of the deflection produced on a given magnetic needle, or the amount of chemical action produced in a given time when the current flows through an electrolyte. In both cases the greater the current the greater the effect, other things remaining the same.*

The strength of the electric current depends on two things—the amount of the E.M.F. and the "resistance" of the circuit.

Simple Circuits.

Resistance.

8. When water flows through pipes the friction of the water against the sides of the pipes offers a certain amount of resistance to the current, this resistance depending on (among other things) the size of the pipe, and the smoothness of its surface; if the pipe is closed by a piece of metal, this metal offers an infinite resistance, or, in other words, the current cannot flow.

---

* The rate of chemical action is exactly proportional to the strength of the current producing it. The amount of the deflection of the magnetic needle depends also on other things.

Similarly, all materials offer greater or less resistance to the electric current.

Conductors and insulators.

9. Those materials which offer comparatively little resistance to an electric current are called conductors, and those which offer a very high resistance are called insulators, or non-conductors.

Metals, their alloys, carbon, and electrolytes* are all conductors.

The conductors most used in telegraph work are copper, bronze, and iron.

Other materials are all more or less non-conductors, and the insulating or non-conducting materials chiefly used in telegraph work are glass, porcelain, shellac, indiarubber, ebonite, silk, cotton, paper, air, &c.

It should be noted that air is an insulator, but that any porous material, such as paper, is a bad insulator when *damp*. A porcelain or ebonite insulator to carry a bare telegraph wire is made in the shape of an inverted cup, to keep a portion of the surface dry, and the porcelain is glazed to keep out moisture.

Insulating materials are used to confine the current to its proper path, and may be compared to the sides of a pipe carrying water.

Factors governing resistance.

10. The resistance of a piece of material depends on :—

(*a*) The nature of the material.
(*b*) Its length.
(*c*) Its cross-section (*i.e.*, breadth and thickness).
(*d*) Its temperature.

Note.—It does not in the least depend on the strength of the current flowing through it.

Laws of resistance.

11. For a given material it is found that :—

(i) The resistance varies directly as the length, *i.e.*, if you *double* the length of a piece of wire you *double* its resistance.
(ii) The resistance varies inversely as the cross-sectional area, *i.e.*, if you *halve* the cross-sectional area of a wire of given length you *double* its resistance.

The effect of temperature on resistance is so small that for telegraph purposes it may be disregarded.

The above laws holds equally with conductors and insulators, but to show the difference between them it may be stated that if the resistance of a piece of copper is one millionth of a unit (*see* below), the resistance of a similar piece of ebonite would be about 20,000 million million units.

---

* Electrolytes are water containing acids or dissolved salts.

12. To enable practical electrical measurements to be taken it is necessary to lay down certain standards to which various amounts can be referred, just in the same way that we measure length in yards, or water in gallons. The yard and gallon are termed "units" of length and volume respectively. Units.

The chief units used in electrical measurements are :—

Unit of E.M.F.	The volt (v).
Unit of resistance	The ohm (ω).
Unit of current	The ampere (a).
Unit of quantity	The coulomb.
Unit of capacity	The farad.
Unit of power	The watt.

The actual values of these units, based on theoretical principles which need not be considered here, have been determined scientifically with great accuracy.

The methods of reproducing these standards for practical measuring work, and the methods of measuring electrical quantities are given in Chapter XX. The following examples will give some idea of the values of these units :—

The E.M.F. of one Daniell cell is just over 1 volt, and that of a Leclanché cell just over 1½ volts, the E.M.F. of the service generator used for search-light work is about 80 volts.

The resistance of a mile of copper wire used for telegraph lines and weighing 100 lbs. to the mile, is 8·7 ohms. The resistance of a mile of 3-strand bronze wire used by the field telegraph units, is 12 ohms.

The ampere is the current produced by an E.M.F. of 1 volt through a resistance of 1 ohm. The current used in a 16-candle power 60-volt electric lamp, as used in search-light emplacements, &c., is about 1 ampere. The current used in an ordinary telegraph line is about $\frac{1}{50}$ of an ampere or less.

The coulomb is the quantity of electricity which flows past a given point in a circuit when a current of 1 ampere flows for 1 second.

These units are inconveniently large, or small, for some purposes, and the following prefixes are used to designate multiples and submultiples :—

Meg, means a million, *e.g.*, megohm is a million ohms.

Kilo, means a thousand, *e.g.*, a kilowatt is a thousand watts (=about 1 and $\frac{1}{3}$ horse power).

Milli, means a thousandth of a, *e.g.*, a milliampere is 1/1,000 of an ampere.

Micro, means a millionth of a, *e.g.*, a microfarad is 1/1,000,000 of a farad.

13. The relationship* between amperes, volts, and ohms is expressed in Ohm's law, viz. :— Ohm's law.

---

* The relationship expressed by Ohm's law and considered here is not applicable to alternating currents (sometimes used for electric lighting, &c.),

$$\text{Current (in amperes)} = \frac{\text{E.M.F. (in volts)}}{\text{Total resistance (in ohms)}};$$

or, shortly,
$$C = \frac{E}{R}.$$

This equation may also, of course, be expressed

$$R = \frac{E}{C}, \quad \text{or} \quad E = CR.$$

Note that R represents the total resistance of the circuit, which may be the sum of several resistances, such as instruments, wires, and the battery resistance.

This law simply states that the current is proportional to the E.M.F., and inversely proportional to the total resistance; in other words, if we double the E.M.F. (leaving the resistance the same) we double the current; if we double the resistance (leaving the E.M.F. the same) we halve the current; if we double both E.M.F. and resistance we leave the current unaltered.

Note that the E.M.F. has direction, and that if we add another cell to increase the E.M.F. we must connect it the right way or its E.M.F. will oppose the original E.M.F., and decrease instead of increasing the current.

Water analogy.

14. In the case of water in a pipe the same sort of thing applies, only the relation is not so simple; it is, however, obvious that if the pump is worked harder—*i.e.*, the propelling force is increased, more water will flow in a given time, or if the pipe is made smaller, or partially blocked (resistance increased), less current will flow. If two pumps are working together more water will flow, provided they assist each other, but if two similar pumps are worked in opposite directions no water will flow at all.

Divided Circuits.

Water analogy.

15. If instead of one pipe we have for a portion of the circuit two similar pipes, as between A and B, Fig. 3, the water will divide, and flow equally in both pipes, and the resistance will be less than if only one pipe was there. If the branches were unequal more water will flow in the larger one, and if the one is very small it will not have much effect whether it is there or not. Note that if a second path is added, *however small*, it cannot *increase* the total resistance, but must diminish it, even if only slightly.

---

or to rapidly vibrating currents such as are used in telephony and "vibrating" telegraph instruments. In these cases account has to be taken of the "capacity" and "self-induction" of the circuit, and the "frequency" of the vibrating or alternating current; the detailed relationships in these cases are too complicated for consideration here, but the general effects observed will be mentioned later (para. 60, *et seq.*).

The same effect is observed in an electrical circuit; if two or more similar paths are provided the current divides equally, and the combined resistance of n similar branches is $\frac{1}{n}$ the resistance of any one branch. If the paths are dissimilar, the current will divide in the ratios of the "conductivities" of the separate branches, and the total conductivity is equal to the sum of the conductivities of the separate branches. The conductivity of a portion of a circuit is the reciprocal of its resistance, *i.e.*, if its resistance is R its conductivity is $\frac{1}{R}$.

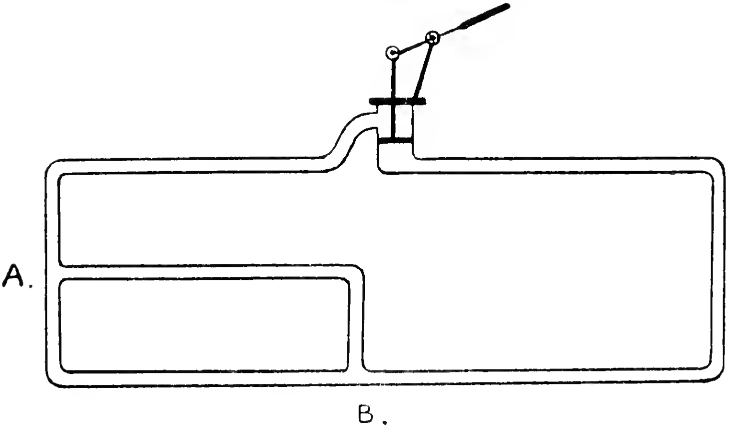


FIG. 3.

Calculations for divided circuits.

16. Consider the circuit represented in Fig 4. The current divides at A into four paths, whose respective resistances are R_1, R_2, R_3, and R_4.

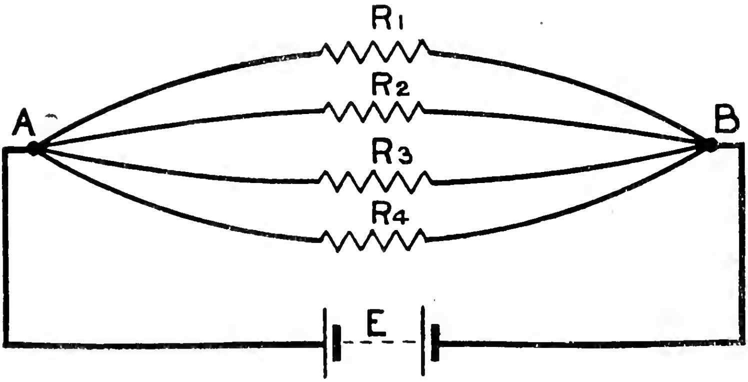


FIG. 4.

Let R stand for combined resistance. Then, remembering that conductivity $= \frac{1}{R}$, we have $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$.

If all the branches are of equal resistance, we get

$$\frac{1}{R} = \frac{4}{R_1} \quad \text{and} \quad R = \frac{R_1}{4},$$

or, in words, the combined resistance of n equal branches is $\frac{1}{n}$th of their individual resistance.

The case of two branches occurs frequently in practice. Here

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{and} \quad R = \frac{R_1 \times R_2}{R_1 + R_2}.$$

If E be the E.M.F. of the battery, and the resistance of the leads and internal resistance of battery be ignored, the current flowing $C = \frac{E}{R}$, where R is the combined resistance of R_1, R_2, R_3, R_4, and the proportion of the total current flowing in each branch will be $C \times \frac{R}{R_1}$, $C \times \frac{R}{R_2}$, $C \times \frac{R}{R_3}$, $C \times \frac{R}{R_4}$, respectively.

The student should apply different numerical values to the above symbols and work out a few exercises in divided circuits for himself.

It should be noted that—

(*a*) The combined resistance of a number of branches is always less than that of any individual branch.

(*b*) When, of two branches, one has a very high resistance and the other a very small one, the combined resistance will be nearly equal to the latter.

Shunts.

17. A practical example of the application of the above principles is to be found in the calculation of "shunts." Supposing it is desired to reduce the current passing through a

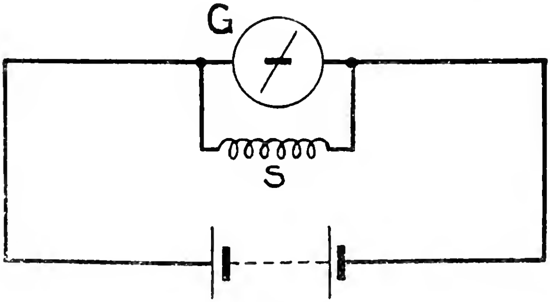


FIG 5.

galvanometer, this can be done by joining it in "parallel" with a resistance (Fig. 5.) Now what must be the value of this resistance in order that $\frac{1}{n}$th of the *total* current may pass through the galvanometer, whose resistance is G ?

Since $\frac{1}{n}$th of the total current is to pass through G, the $\frac{n-1}{n}$th must pass through S. Therefore

$$\frac{\text{Conductivity of galvo.}}{\text{Conductivity of shunt}} = \frac{\frac{1}{n}}{\frac{n-1}{n}} = \frac{1}{n-1},$$

but

$$\frac{\text{Conductivity of galvo.}}{\text{Conductivity of shunt}} = \frac{\frac{1}{G}}{\frac{1}{S}} = \frac{S}{G};$$

therefore $S = \frac{G}{n-1}$ and the combined resistance of S and G equals $\frac{G}{n}$.

If values 10, 100, 1000 be successively applied to n, and the value of G be 1000 ω, the corresponding values of S would be $\frac{1000}{9}$ ω, $\frac{1000}{99}$ ω, and $\frac{1000}{999}$ ω, and the combined resistance of S and G, 100 ω, 10 ω, and 1 ω.

Earth Returns.

18. The earth is largely used as a conductor for telegraph purposes ; it has such a large cross-section that its resistance is in practice very small, provided the connection between the earth and the rest of the circuit is good.

The advantages in telegraph work of using an "earth return," instead of a second wire, to complete the circuit, are that only half the length of wire is necessary, and the resistance of the circuit is largely reduced.

Earth returns are, however, not suitable for telephone work, when good speaking is required over long distances, but can be used for short distances, especially in the country, well away from other wires carrying electric currents ; they are often so used for military work in the field when a complete metallic circuit would require more time and material than is available.

Water analogy.

19. If in the case of water in pipes, we have, instead of a complete circle of pipes, one long pipe, each end of which is inserted in a large lake of water, the water will flow through

the pipe in the same way (when the pump is working), but the effect on the lake will be so small as to be negligible—this is the equivalent of an earth return (Fig 6).

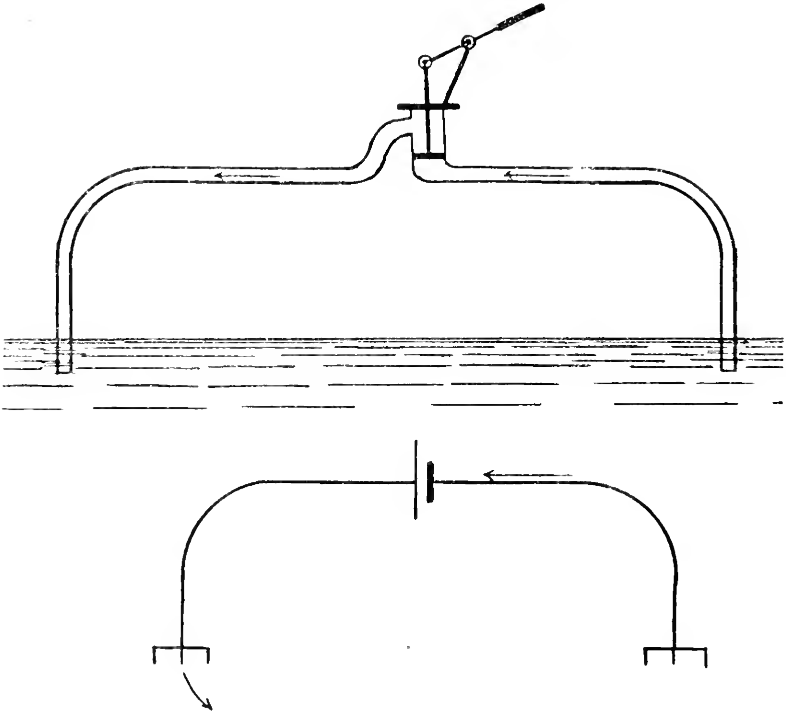


FIG. 6.

20. The action of shunts and divided circuits assists in making clear the result of defective insulation, and line leakage, &c.

Line leakage.

The term insulation resistance means the electrical resistance through the insulating medium in use, *e.g.*, in the case of a circuit with an earth return, between the line and earth. As it is this resistance that keeps the current in its proper path, it should, of course, be as high as possible. This resistance corresponds to the resistance through the sides of a pipe carrying water, though in this case the resistance is so great that no water will pass through unless there are leaks in the pipe or its joints.

Water analogy.

21. Consider the case of an electric circuit carried on poles with an earth return and the equivalent water circuit. The insulation of the circuit depends on the insulation of its

supports, the air being nearly a perfect insulation, and at each support a very small portion of the current leaks away, especially during wet weather, and the same thing would occur in the pipe circuit if the joints were defective. The more numerous the supports the greater the leakage would be, and the lower the insulation resistance of the line, the insulation resistance of the line being inversely proportional to its length. (*See* Fig. 7.)

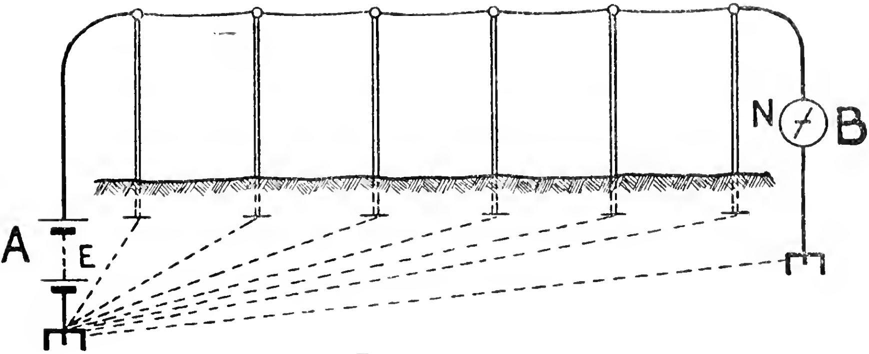


FIG. 7.

"Earthy" line.

22. If the insulation resistance falls very low, *i.e.*, if the leaks become large, the line is said to be "earthy," and if the line becomes too earthy, communication is impossible. If the pipe has a large hole in it, this is equivalent to the line making electrical connection to earth, the line is said to be "dead earth," and it will be seen that all, or practically all, the water, or electric current, will flow through the hole or earth fault, back to the pump or battery, and none will go through the instrument at the far end of the line.

Note that if a line is earthy its resistance as measured from one end is less than if the insulation is perfect, and consequently *more* current will flow from the battery, but *less* will reach the instrument at the other end.

A complete investigation of the effects of line leakage, &c., is too complicated for inclusion here.

Short circuit.

23. An instrument, or portion of a circuit, is said to be short-circuited when an alternative path for the current is provided round the instrument, and when this path has such a low resistance that practically all the current flows round this path, and little or none through the instrument; a "dead earth" is an example of short circuiting.

Fall of Potential.

Water analogy.

24. So far we have only considered a complete circuit with a cell or pump creating a difference of pressure between its two sides, and although a complete circuit is necessary in order to maintain an electric current, it is of importance to consider also parts of the circuit. If a current is flowing in any portion of a circuit there must be a difference of pressure between the ends of this portion. This can be illustrated by the following water analogy (*see* Fig. 8). A is a tank of water filled to the level B and *kept* filled to that level. From the bottom of the tank runs a level pipe, C D, of uniform section. At intervals along this pipe are inserted vertical tubes, open at the top, as at E, F, G, H. The height of the water in these tubes shows the pressure, or head, of the water at the points E, F, &c. If the pipe be closed at D, so that no current flows, it will be found that the water stands at the same level in the tank and in all the pipes, the top of the water being on the horizontal line B L, showing that the pressure is the same all along the pipe C D. If we now fully open the pipe at D so that a current flows, the water in the vertical tubes will fall until a steady condition is reached. When this happens there will be no pressure at D, the pressure at the points E, F, &c., will

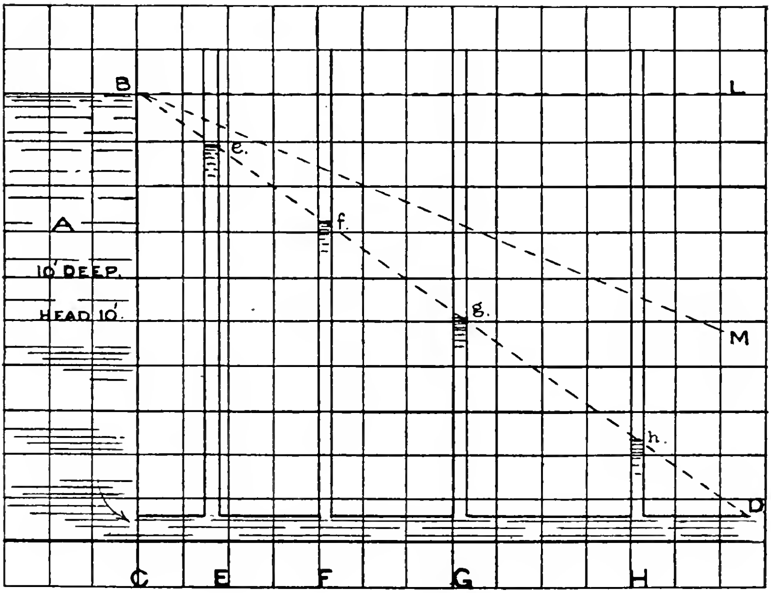


FIG. 8.

fall, and it will be found that the top of the water in the tubes will lie on a straight line B D, showing that there is a gradual fall in the pressure, depending on the length of the pipe. The difference of pressure between any two points is shown by the difference in level of the water in the tubes at those points.

If the pipe is partially closed at D so that the current is reduced, the top of the water in the vertical tubes will still lie on a straight line, but on some line B M, and it will be found that the greater the current the nearer B M gets to B D, and the less the current the nearer B M gets to B L. In other words, the smaller the current, the less the difference of pressure between any two given points, but as long as a current flows at all there must be *some* difference of pressure between any two points in the circuit.

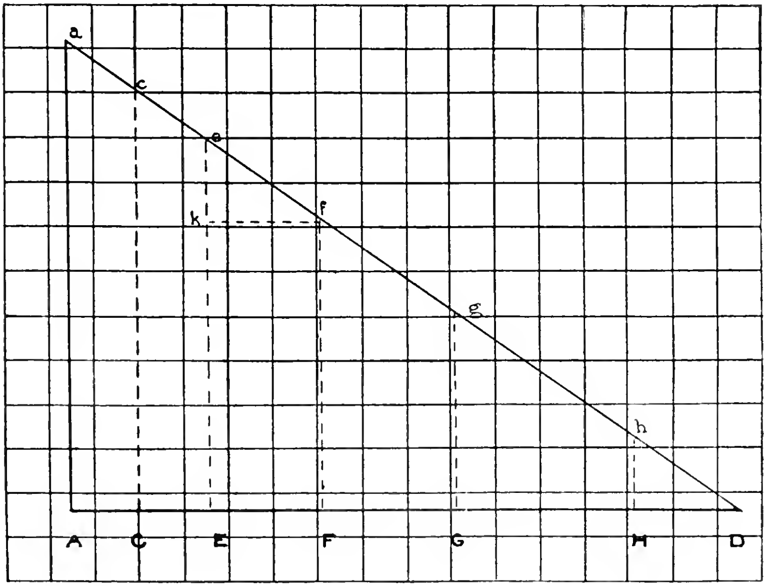


FIG. 9.

Electrical circuit.

25. The same fall in pressure occurs in an electrical circuit when a current is flowing. This pressure is generally called "potential," and is measured in volts, which correspond to the feet "head" used in measuring water pressure. This can be represented graphically in the same manner as the fall in water pressure. In Fig. 9 A D represents the whole resistance of the circuit, A is the point of maximum potential (which is in the cell close to the zinc plate), and D is the point of lowest potential (which is the zinc terminal of the cell). A C is the

resistance of the cell itself, C E, E F, &c., of other portions of the circuit. Aa represents the E.M.F. of the cell, and aD the rate of fall of potential in the circuit. The length of the vertical lines through each of the points C, E, &c., gives the potential at that point, and the difference of potential between any two points is represented by the difference in the lengths of the verticals drawn from them.

The current flowing in the circuit is $\frac{\text{E.M.F.}}{\text{resistance}}$, or $\frac{a\text{A}}{\text{AD}}$ (as aA and AD are drawn to scale), and since aAD and ekf are similar triangles,

$$\frac{a\text{A}}{\text{AD}} = \frac{ek}{kf},$$

but ek represents the difference of potential, and kf the resistance between the points E and F, hence

Current $= \frac{\text{difference of potential}}{\text{resistance}}$ for any two points in a circuit.

Hence we can say that in any portion of a circuit where a current of C amperes is flowing, and whose resistance is R ohms, a difference of potential of V volts will exist at the ends of the portion, where $C = \frac{V}{R}$, or $V = CR$. This difference of potential V is the pressure lost in forcing the current, C, through a resistance, R.

If in Fig. 9, AC represents the internal resistance of the cell, then C will represent the +ve terminal (as already stated D is the −ve terminal). The difference of potential at the terminals of the cell will therefore be represented by Cc, and it will be seen that this must always be less than the E.M.F. of the cell as long as a current (however small) be flowing. If, however, the line aD be nearly parallel to AD, *i.e.*, if the external resistance CD be large compared with the internal resistance AC, the difference of potential at the terminals of the cell will be very nearly equal to the E.M.F. of the cell.

The term electromotive force is generally reserved for the maximum potential difference created by a cell or generator, as shown by Aa in Fig. 9. When we say that an E.M.F. exists in a portion of a circuit we mean that an actual source of pressure, such as a cell, exists in that portion of the circuit. An E.M.F. may exist when no current is flowing.

Heating Effect of Current.

26. Although the heating effect of current is of immense importance in electric lighting, &c., the only cases in practical telegraphy in which it has to be considered are those in which large batteries of low resistance are being used. If such a battery be connected through coils of fine wire of not very high

resistance, the current may be large enough to heat the coil sufficiently to fuse it, or to damage the insulation. Care should therefore be taken never to use a battery much more powerful than is necessary for the work in hand, and special care must be taken when using delicate testing instruments, as their accuracy may be affected by a comparatively small rise in temperature.

As a good rough rule, the maximum current that may be passed through a copper conductor with a cross-sectional area of 1 square inch is 1,000 amperes, and for other sizes in proportion.

Rise in temperature of conductor.

27. The amount of heat produced in a conductor is proportional to the work done by the current in overcoming the resistance of the circuit, in fact the whole of the energy in an ordinary circuit is expended in heating the conductor. The work done is proportional to QV where Q is the quantity of electricity that has passed, and V the difference of potential through which it has passed. The rise in temperature of the conductor, which is the important point, depends on the *rate* at which heat is produced by the current, on the rate at which the conductor can cool, and on the material of which the conductor is made. The rate at which heat is produced is proportional to $\frac{QV}{t}$, where t is the time taken for the quantity Q to pass, this can also be written CV or C^2R, where C is the current flowing, and R the resistance through which it has flowed. The rate at which the conductor cools depends on its nature, its shape and its surroundings.

Magnetic Effect of Current.

28. It has been pointed out that a conductor carrying a current affects a magnetic needle in its vicinity; in other words, a current produces a magnetic effect. This effect is of very great importance, as on it depends the action of every telegraph and telephone instrument.

Magnets.

29. To understand the magnetic action of a current it is necessary to explain the properties of a simple magnet.

If a bar of steel be magnetized, and then suspended so as to move freely in a horizontal plane, it will always set itself pointing approximately north and south—this is the ordinary compass needle—and if the end pointing north be marked, it will be found that it is always the same end that points north. If a second magnet be taken, and the north-seeking end marked and brought near the first magnet, it will be found that the two north-seeking ends repel each other, the two south-seeking ends repel each other, and either north-seeking end will attract either south-seeking end. It will also be found that either end will attract any piece of iron brought near it.

These properties reveal magnetic forces starting in, or near, the ends of a magnet; these ends are called the poles. The end of the bar which points north is termed the north-seeking, or more commonly, though less correctly, the "north" pole of the magnet.

Induced magnetism.

30. If a rod of soft iron is brought near a permanent magnet it will also behave like a magnet, the end near the north pole of the magnet becoming a south pole and *vice versâ*. If the rod of soft iron be placed near (say) the north pole of a permanent magnet, a north pole appears at the far end of the soft iron. In these cases the soft iron is said to be magnetized by "induction." Its magnetic properties disappear at once if it is taken away from the magnet. The difference between the behaviour of soft iron and steel is that the latter is the harder to magnetize, but retains its magnetism when the magnetizing force is removed, while the latter loses almost the whole of its magnetism at once.

Magnetic field.

31. Any space where these magnetic forces act is termed a magnetic field, and this magnetic field at any point has *direction* and *intensity*, or strength. The direction at any point is given by the direction in which a compass needle will point, and the force holding it in that position depends on the strength of the field. There is a magnetic field due to the earth, its direction being approximately north and south, with an inclination to the horizontal which varies at different places.

Lines of force.

32. To obtain a picture of a magnetic field, the space where magnetic forces act is considered as mapped out into "lines of magnetic force" (hereafter called "lines of force"). These lines give the direction of the magnetic force, and form continuous closed lines or loops. There is, of course, one such line through every point in a magnetic field ; but to get an idea of the strength of the field, it is assumed that (conventionally) the number of lines in a given area (at right angles to the lines) is proportioned to the strength of the field. Thus we say that if the lines of force are close together the field is strong.

Field due to magnets.

33. The lines of force of a bar magnet issue from the north pole, curve round to the south pole, and return to the north pole inside the magnet. The lines are densest, *i.e.*, the field is strongest, near the pole. The lines of force can be illustrated by placing a magnet on a table, cover it with a stiff piece of paper, and scattering iron filings over the latter ; on gently tapping the paper the filings will set themselves along the lines of force.

If a piece of soft iron is placed in a magnetic field, it becomes magnetized. The lines of force flow through iron much more readily than through other materials, or air, and therefore concentrate themselves in the iron, the total number of lines being also increased by the presence of iron in the field. Thus by moving iron in a magnetic field the lines of force are also moved, even though the cause of the lines remains the same and does not move. The lines of force due to one or two systems of magnets, as given by filings, are shown in Fig. 10.

Field due to a current.

34. An electric current flowing along a conductor produces a magnetic field, and the lines of force of this field form closed loops round the conductor; in a long straight conductor the loops are circles round it with the conductor in the centre. The field ceases to exist when the current ceases to flow. The force due to a current in such a conductor is distributed over the whole length of the wire, and thus though the total force may be large, the force per unit length is usually very small.

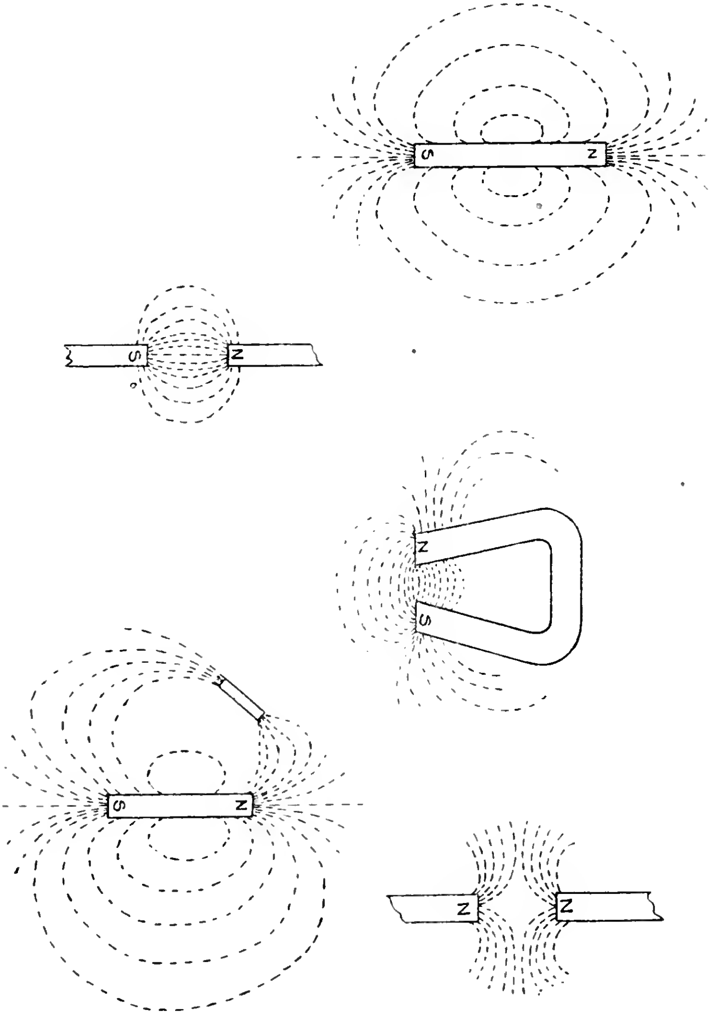


FIG. 10.

This can be shown by placing a wire above a compass needle and pointing along it (*i.e.*, the wire must be lying north and south). If a current be now passed along the wire the needle will be deflected and will try to place itself at right angles to the wire, *i.e.*, along the lines of force. The magnetism due to the earth will oppose this deflection, and the amount of the deflection will depend on the relative strengths of the two fields. The direction of the deflection depends on the direction of the current and may be determined by the following rule: "Imagine yourself swimming along the wire in the direction of the current and facing the needle, the north pole of the magnet will be deflected to your *left*" (Fig. 11). If the wire be bent round so as to pass round the needle (Fig. 12) it will be seen from the above rule that the portions AB and CD of the wire will tend to deflect the needle in the same direction, hence the two portions of the circuit assist each other and the effect is increased. Similarly, if the wire is wrapped several times round the needle, *i.e.*, if the needle be inserted in a coil, the effect is still more increased (Fig. 13). This is the principle on which the ordinary galvanometers are constructed.

Solenoid.

35. If the wire is wound into a close helix, called a solenoid, the lines of force thread the helix as shown by the dotted lines in Fig. 14, and the helix has all the properties of a bar magnet. It is found that the "polarity" of this coil depends on the direction of the current flowing in it; if the direction of the current is reversed, the end of the coil that was north-seeking becomes south-seeking.

Electro-magnet.

36. If a bar of soft iron is inserted in the coil, the magnetic effect is enormously increased. This bar of soft iron becomes a powerful magnet when a current flows, but practically ceases to be a magnet when the current stops. Such a piece of iron with a coil wound round it is called an electro-magnet.

This arrangement is the basis of a large number of telegraph and telephone instruments, in which an electro-magnet alternately attracts, and ceases to attract (or repels) a moveable piece of iron or steel called the "armature."

The pull exercised by a magnet on a piece of iron can be increased by bending it into such a shape that the two "poles" are close together. Such a magnet is often called a "horseshoe" magnet. The iron inside the coil of an electro-magnet is called the "core," frequently two straight electro-magnets are combined to make a horseshoe magnet by joining two adjacent ends of the cores by a piece of soft iron called the "yoke."

Strength of electro-magnet.

37. The exact force exerted by an electro-magnet on a piece of iron at a given distance depends on so many things, such as the exact shape of the magnet, the quality of the iron, &c., that it cannot easily be calculated; but it has been found that if the shape, &c., are the same, and the space filled by the coil is the same, the force is practically proportional to the strength of the

current and the number of turns of wire, *i.e.*, to the "ampere-turns." Thus, if one electro-magnet has 100 turns of wire with 10 amperes flowing in it, and another 10,000 turns of finer wire with only $\frac{1}{10}$th ampere flowing, the magnetic force is the same.

FIG. 11.

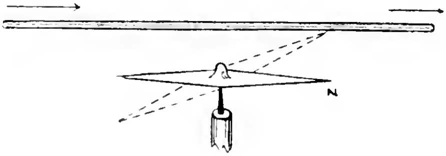


FIG. 12.

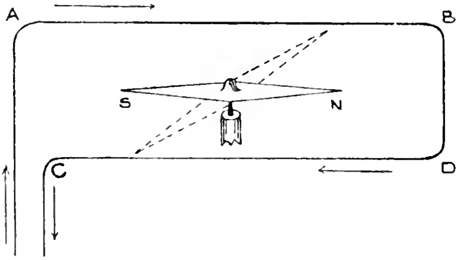


FIG. 13.

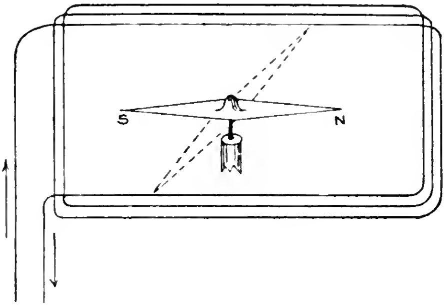
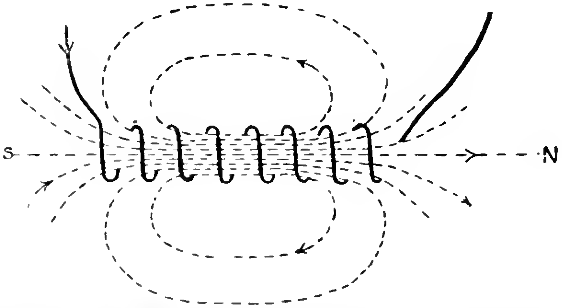


FIG. 14.



It matters very little whether the turns of wire are all on one coil, or whether they are on several, and the position of the coils on the core also matters little.

Residual magnetism.

38. If the ends of the core are bent round so that they touch, or if they are joined by a piece of iron, the core will retain practically all its magnetism, even though the current cease to flow. If, however, there be even a very small gap in the continuity of the iron, the magnetism disappears very rapidly when the current ceases. The magnetism remaining in the iron when the current ceases is called the "residual" magnetism.

It is, therefore, important, in all instruments with an electro-magnet and moving armature, that the armature does not actually touch the cores of the magnet, or it will probably stick when the current ceases. Some instruments are fitted with a brass pin or stud at the end of the core to prevent this.

The more nearly complete the iron "magnetic circuit," the stronger will be the effect of a given current in a given coil round it, but it will take longer for the electro-magnet to be magnetized and demagnetized, in fact the greater will be the "self induction" (*see* para. 54). For rapid work, therefore, there must be gaps in the iron circuit, even though some of the sensitiveness of the instrument is thereby lost.

The cores of electro-magnets are often made either of a split tube of soft iron, or of bundles of iron wire, the object in both cases being to allow them to magnetize and demagnetize quickly. The reasons why this assists the rapidity of the action need not be explained here.

Water analogy.

39. Water flowing in a pipe has nothing analagous to a magnetic effect, but the use of the magnetic effect of a current is to do work by moving an armature or galvanometer needle, and this effect can be produced by the water.

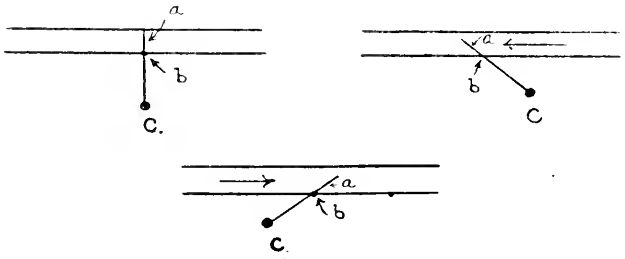


FIG. 15.

If a valve *a* (*see* Fig. 15), pivoted at *b*, with a weight *c* attached, is placed in the pipe, and a current flows in the pipe as shown by the arrow, the valve will be opened by the current, and the weight raised. This is equivalent to the deflecting of a magnetic needle by an electric current, and is the effect produced in a galvanometer, or in moving the "armature" of a sounder or other telegraph instrument. Note that the movement of the weight indicates the direction of the current, and the greater the current the further will the weight be lifted, also that when the current ceases the weight falls back.

Chemical Effect.

Electrolytic action.

40. If two copper plates be inserted in a vessel containing a solution of copper sulphate, and a current passed through, it will be found that the plate at which the current enters will be gradually dissolved away, while copper will be deposited on the other plate. If the plate at which the current enters be made of carbon or platinum, the plate will not be dissolved, but the copper sulphate will be decomposed, and the copper deposited on the plate at which the current leaves, while sulphuric acid will be formed in the cell. This is called electrolytic action.

A similar effect is observed with most other compounds, the metal always appearing at the plate at which the current leaves the cell.

This effect is used for electro-plating, &c., and also forms a method of measuring current, the amount of metal deposited being proportional to the quantity of electricity passed through the cell. A current of 1 ampere flowing for 1 second (*i.e.*, one coulomb of electricity) will deposit ·0003281 gramme (1,000 grammes are about 2·2 lbs.) of copper from a solution of copper sulphate, or ·001118 gramme of silver from a solution of silver nitrate. An instrument for measuring current by this method is called a "voltameter."

Batteries utilise what may be called the inverse of this chemical action for producing a current.

Effect on cables.

41. The only case where this chemical action affects telegraph working is when working on, or testing, underground or submarine cables. If there is a slight fault in the insulation, making earth, and a current is passed from the conductor to earth, any moisture present will be decomposed, and oxygen will be freed at the surface of the conductor. This will oxidise the surface of the conductor, and, as oxide of copper is an insulator, this raises the resistance of the fault. If, on the other hand, the current flows from the earth to the conductor, this oxide is reduced, and the resistance of the fault is lowered. For this reason the –ve of the battery should be connected to line when testing covered wire or cables for insulation; otherwise the existence of small faults may not be apparent.

Capacity and Condensers.

Capacity.

42. So far we have been considering simple straightforward currents of electricity, corresponding to the flow of water in

pipes with rigid walls; but a circuit has, under certain conditions, important properties in addition to that of resistance, one of which is known as "capacity."

Water analogy.

43. An idea of capacity can be obtained by its water analogy. Suppose a closed tank is inserted in the conducting pipe, and that an elastic bag is tied on to the entering pipe as shown in Fig. 16, so as to close the pipe, the pipes and tank being full of water. If water be now pumped in at A the bag will stretch, and water will enter it, but at the same time an equal quantity of water will be forced out at B, but no water will pass from A to B. The amount of water that will flow into the bag depends on the size and nature of the bag and the difference of pressure between A and B; the amount of water that is forced into the bag at some standard pressure might be called its "capacity." If the circuit be blocked at either A or B, no water can be forced in at A, and if after the bag is expanded the circuit be blocked at either A or B, no water can flow, and the bag will remain expanded. If A and B be then connected the bag will contract, and water will flow out from A and in at B until the pressures at A and B are again equalised.

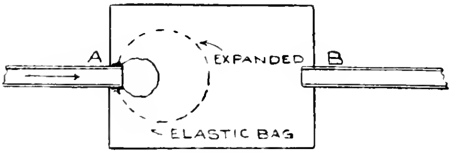


FIG. 16.

Condenser.

44. The corresponding electrical contrivance is called a "condenser," and consists, generally speaking, of two conductors separated by a layer of insulating material, and its action is precisely similar to that of the elastic bag described above.

If too great a pressure be exerted between A and B (Fig. 16) the bag will burst; similarly, if too great a difference of potential be applied to the two conductors of an electrical condenser, the current will spark across, and the condenser will be damaged.

Effect of condenser in a line.

45. If a condenser be inserted in a line as shown in Fig. 16, a gradually decreasing current will flow until the condenser is fully charged and will then cease, but if the condenser be inserted as shown in Fig. 17 at A, there will be a rush of current through A till the condenser is charged, while the current will flow round B in the usual manner. When the condenser is fully charged the current flows round by B as if no condenser existed. If the pump now stops, the water will be forced out from A upwards and in towards A from below, providing there be a path connecting the two sides of A.

Unit capacity.

46. It is found that the amount of electricity that can pass into a condenser is exactly proportional to the electrical pressure at its terminals and the "capacity" of the condenser—the latter depending on its shape, size, and the materials of which it is made.

The unit capacity is defined as that capacity which will hold a charge of one coulomb when the difference of pressure between the terminals is one volt, and is called a farad. A condenser of this capacity would be of enormous size, condensers in use are measured in microfarads, *i.e.*, in millionths of a farad. The condenser used in telegraphy (for duplex working) has a capacity of $7\frac{1}{4}$ microfarads.

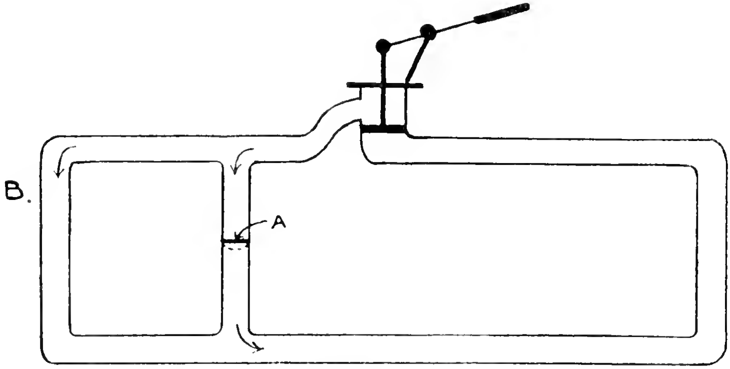


FIG. 17.

Construction of condenser.

47. An electrical condenser always consists of two conductors placed close together and separated by an insulator. The larger the surfaces of the conductor, and the closer they are, the larger the capacity. Service condensers are made of alternate layers of tin foil and paraffined paper or mica, every alternate layer of foil being connected together and to one terminal.

Capacity of a line.

48. In practice, every line has a certain capacity, the wire and the earth forming the two conductors. It is, however, only when the line is long, or the wire close to earth, as in cables, that the capacity is appreciable.

The capacity between aerial wires and earth is about ·014 microfarad per mile, but between underground wires and earth about ·3 microfarad per mile.

Effect of line capacity.

49. The effect of capacity in a line is that when the circuit is first completed there is an extra rush of current, and when the circuit is broken this current will flow out again, and though the current flowing from the battery is at first greater than the normal, the current arriving at the far end is smaller. The practical results of these effects on telegraph working are shown in Chapters V, para. 3, and VII, para. 10.

Induction and Induction Coils.

Induction (electro-magnetic).

50. It is found that, when a conductor is moved in a magnetic field, so as to cut lines of force (*see* para. 32), an E.M.F. is "induced" in the conductor, and, if the conductor be part of a closed circuit, a current will flow in it. This is the principle of the electric generator. The direction of the induced current depends on the direction of the lines of force and the direction of motion of the conductor. The following rule gives the direction of the induced E.M.F.:—"Hold the thumb, first finger, and the remaining fingers of the *right hand* at right angles to each other, as in Fig. 18; point the first finger in the direction of motion of the conductor, and the remaining fingers in the direction of the lines of force, then the thumb will point in the direction of the E.M.F." It is not necessary that the conductor actually move: the same result is obtained if the lines of force move, the essential being that lines of force cut (or pass across) the conductor. The magnitude of the E.M.F. depends on the number of lines of force cut per second.

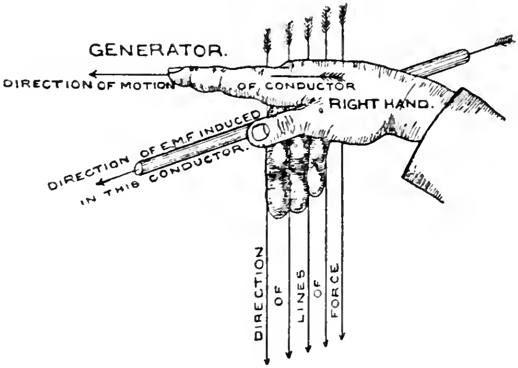


FIG. 18.

If a rectangle of wire be placed in a magnetic field, as shown in Fig. 19, and then rotated about an axis 00 in the direction shown by the arrow at A, the portion AB will cut the lines of force in a downward direction during the first half revolution, and, if the lines of force are in the direction shown by the arrow heads, an E.M.F. will be induced in the direction A to B. At the same time the portion CD will be cutting the lines in an upward direction, and an E.M.F. will be induced in it in the direction C to D. If the rectangle be closed, a current will flow in the direction ABCD, the E.M.Fs in the two portions AB and CB assisting each other. During the second half revolution the portion AB is moving upwards, and the E.M.F. induced is in the direction B to A, and the direction of the current is now BADC, the portion CD assisting as before. The portions AD and BC do not cut the lines of force, and have therefore no effect on the E.M.F.

Thus we see that an alternating current is induced in the wire as it revolves, the direction of the current reversing every half-revolution. If the rectangle of wire be opened at one point and the ends joined by sliding contacts to an external circuit, the current will flow along this circuit. If more turns be taken round the rectangle, the E.M.F. produced will be correspondingly greater. This is the principle of the "generator."

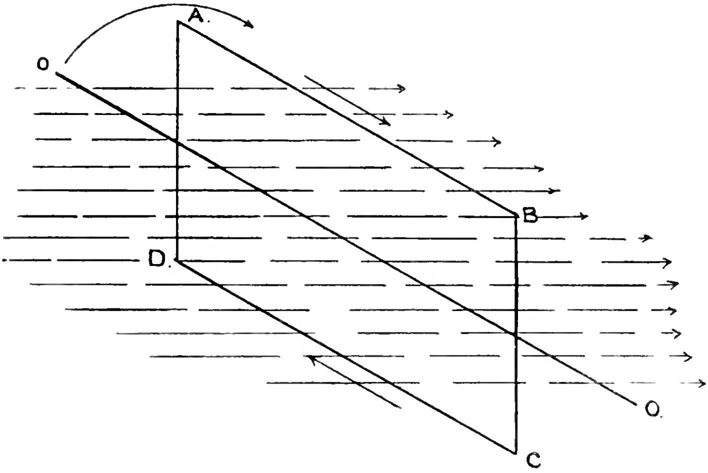


FIG. 19.

Mutual induction.

51. We have seen (para. 34) that when a current flows along a conductor, lines of force exist round it, and as long as the current remains steady the lines do so also. If the current stops, starts, or alters its value, the lines shrink into nothing, spring into existence, or move. Hence, if two wires run along near each other, and a current starts in one, its lines of force cut the other, and a current is induced in it (*i.e.*, if it forms portion of a closed circuit).

Effect of mutual induction.

52. In telegraphy, these induced currents are so small that they do not matter, but a telephone receiver (Chapter X) is such a delicate instrument that it is affected by these currents, and if a telephone wire runs for any distance close to a telegraph wire, a noise is heard in the receiver every time the current starts or stops in the telegraph circuit, and this may very seriously interfere with the speaking. If two telephone wires run together for a long distance, a similar interference takes place, and, as the telephone currents are continually altering their values, the lines of force are continually moving, and a

person listening to a receiver inserted in the second line may even hear the whole of the conversation carried on in the first wire.

It is largely owing to this that earth returns cannot be used for telephone work (*see* para. 18). The overhearing is got over by using metallic circuits and arranging that the induction in the one wire is neutralised by the induction in the return wire. The way this is done in practice is explained in Vol. II.

Induction coil.

53. If the two wires are placed very close together for a considerable length, as can be done by winding them together into a coil, the induced current can be made much larger, and, if the coil has an iron core, the effect is still further largely increased—this is the induction coil as used in telephone work (*see* para. 63 and Chapter X).

Self induction.

54. When a current flowing in a circuit stops, the lines of magnetic force shrink into nothing, and in so doing cut the circuit and induce an E.M.F. in it. The amount of the E.M.F. depends on the current flowing and on the shape of the circuit. If the conductor is wound into a coil, each line of force will cut the circuit in many places, and a larger effect will be produced; if the coil has an iron core, there will be many more lines of force and a correspondingly greater effect when the current is stopped. The direction of the E.M.F. caused by self induction always tends to keep the current flowing, and if the circuit has a high "coefficient of self-induction," *e.g.*, if it contains electro-magnets, this E.M.F. will cause a spark across the contacts when the circuit is broken. This spark may be reduced, or entirely prevented by connecting a condenser across the break in the circuit, or by shunting any electro-magnets in the circuit by a high non-inductive resistance (*e.g.*, the shunt coil in the later Post Office sounders. Chapter III, para. 10).

A similar effect is produced when the current starts in the circuit, the E.M.F. due to self induction opposing the E.M.F. of the circuit, thus preventing the current from reaching its full value at once.*

Water analogy.

55. Self induction in an electrical circuit is analogous to inertia in a water circuit. If water be flowing rapidly in a pipe, and the tap be suddenly turned off, the water is stopped with a jerk, and we get the effect known as a "water hammer," which may burst the pipe.

Winding coils.

56. We see above that an ordinary coil (Fig. 20), especially if wound on an iron core, has high self induction, and if also entirely enclosed in iron the effect will be even still greater. When self induction is required in a circuit (as in "choking" coils, *see* Chapter XV), the core is often made of soft iron

---

* The true form of Ohm's law when a circuit contains self induction is $C = \frac{E}{R}(1 - e^{-\frac{R}{L}t})$, where $e = 2{\cdot}718...$, L = the coefficient of self induction, and t time.

wires, which were bent round outside the coil, the ends meeting outside, or else the coil is enclosed in an iron case.

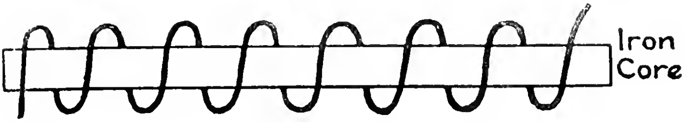


FIG. 20.—Inductive Winding.

Non-inductive winding.

57. If two wires carrying equal currents, but in opposite directions, are laid close together, the lines of force of the one will practically neutralise those of the other, with the result that there will be no lines of force and no inductive effect. Hence to wind a coil so as to get no self-induction, the wire is bent double and wound as shown in Fig 21, and no iron is used. This is called "non-inductive" winding, and is used for resistance coils, &c.

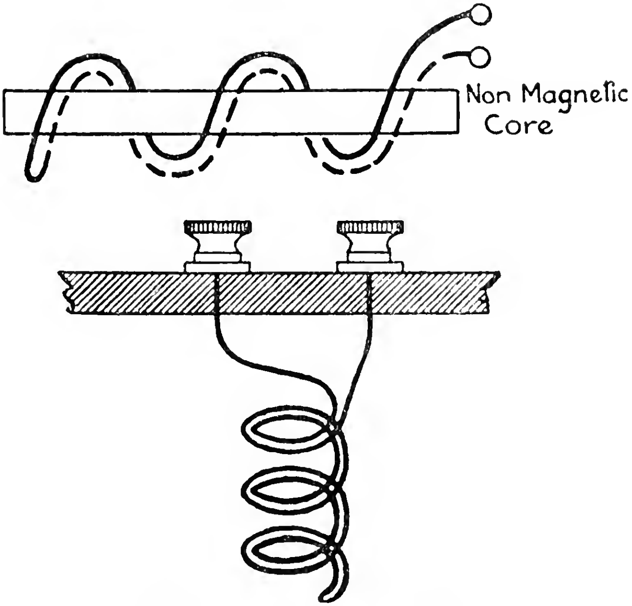


FIG. 21.—Non-Inductive Windings.

Note that lines of force from an external source will cut each half of the winding equally, but in opposite directions, and thus create in the coil two equal and opposite E.M.Fs which will cancel each other.

Differential winding.

58. If an electro-magnet is wound, as shown in Fig. 22, with two separate windings, AB and CD, the windings being of the same size wire, and wound together so that they are of the same length, resistance, number of turns, and mean distance from the core, the magnet is said to be differentially wound. In this case a current in AB will have exactly the same magnetic effect as an equal current in CD, and two equal currents, one flowing from A to B, and the other from D to C, will have equal and opposite effects, and if both flow at once the net magnetic effect will be nil.

This winding is adopted in many telegraph instruments as it is required for duplex working (Chap. VII).

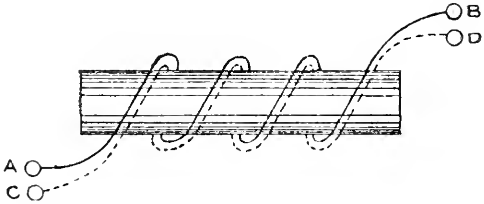


FIG. 22.

Shielding coils.

59. The outer iron covering mentioned above also acts as a shield, lines of force pass very readily along inside iron, and consequently very few lines from an inside source will pass out of the iron into the air outside. Similarly, lines from outside will not readily pass inside. This shielding effect has an importance in telephone exchange work.

Vibrating Currents.

Vibrating currents

60. We have so far been considering currents that rise to their full value very rapidly and then remain steady for a comparatively long time—these are the currents used in ordinary telegraphy. As we have seen, they will not pass through a condenser, and self-induction has only a slight retarding effect.

In telephone working, and telegraph work on the "vibrator" system, which are described in Chapters X to XVI, the currents used are continually altering in value, or even changing direction, the vibrations being at the rate of several hundred a second.

Effect of self-induction on vibrating currents.

61. As stated in para. 54, the self-induction prevents the current from rising quickly to its proper value, and consequently if the E.M.F. producing it has ceased before the current has time to grow, little of it will have passed. This is what happens with rapidly vibrating currents, and a coil having high self-induction acts as if it had a very high resistance to a vibrating current, even though its true resistance (to a steady current) is low. By this means we can produce a

circuit offering a comparatively low resistance to a steady current, but an extremely high resistance * to a rapidly vibrating or alternating current.

This can be illustrated in the water analogy by placing a weighted valve in the pipe as in Fig. 15. In this case the valve will open freely to allow a steady current to pass through, but will offer considerable resistance to spurts of current.

Effect of capacity on alternating currents.

62. If a "condenser" be joined up in "series" in a circuit, as shown in Fig. 23, a steady pressure only displaces the diaphragm or bag (in the case of water) slightly, and the current is stopped ; if, however, the water surges backwards and forwards in the pipe, the diaphragm A is set vibrating, as shown by the dotted lines, and if the condenser is of sufficient capacity, the vibrating current passes freely through it.

Water. Electrical.

FIG. 23.

By the use of a condenser we can, therefore, produce a circuit offering little opposition to the passage of a vibrating current, but offering an enormous resistance to a steady current.

Induction coils.

63. As stated in para. 51, if two wires run side by side for any distance, and the current in the one varies its strength, a current is induced in the other. If the current in the one is continually varying, there will be a similarly varying current induced in the other. If the two conductors are both wound into coils on the same iron core, the result is an "induction coil" (para. 53), and the two wires are known as the primary and secondary coils, a varying current in the primary producing a varying current in the secondary.

If the primary coil has a few turns of thick wire, and therefore a low resistance, a low E.M.F. will produce a large current in it, and consequently many lines of force (the number of lines of force is nearly proportional to the ampere-turns). If the secondary has many turns of fine wire, these lines of force will cut it many times, and consequently induce an E.M.F. which may be much greater than the E.M.F. in the primary circuit. In this case the current will be much smaller, owing to the greater resistance, but if the secondary circuit has already a high resistance this does not matter.

---

* Resistance used in this sense should strictly be called "impedence," and depends on the true resistance, the self-induction, and the frequency of the vibrations.

The importance of the induction coil for telephone work is shown in Chap. X.

It is important to note that an induction coil cannot create current, or energy.

Work and power.

64. It should here be noted that Ohm's law in its simplest form ($C = \frac{E}{R}$) is only true when the whole of the energy in the circuit is being utilized in heating the conductors.

The work done in a circuit = QE when Q is the *quantity* of electricity which has passed through the circuit and E is the E.M.F. in the circuit, or for a portion of the circuit with a difference of potential V at its ends, the work done = QV.

The power (or rate of doing work) $= \frac{QV}{t}$ where t is the time it takes for Q units to flow, or power (W) = CV. This is always true. When the whole power is expended in heating the conductors, V = CR hence $W = C^2R$. When a current starts to flow in a circuit containing electro-magnets, the current does not at once take up its value of $\frac{V}{R}$ (*see* para. 54), consequently V is greater than CR, consequently CV is greater than C^2R. In this case C^2R is the power used in heating the conductors and the rest of the power is used in energising the magnets, and moving the armatures, &c.

The unit of work, in this system of units, is the "joule," and the unit of power the "watt;" a watt is a "joule per second," and 746 watts are equal to one horse-power.

CHAPTER II.

BATTERIES.

Action of Primary Cell.

Simple cell.

1. As stated in Chapter I, a source of E.M.F. is required to produce an electric current, and this source of E.M.F. is frequently a "primary" cell (sometimes called a voltaic cell). In its simplest form this consists of a plate of zinc, and a plate of copper immersed in dilute sulphuric acid. If the two plates are joined by a conductor outside the cell a current will flow.

The energy required to produce the current is furnished by the chemical action of the acid on the zinc, the latter being gradually dissolved and zinc sulphate formed in the solution. The copper is not in any way acted on, and merely acts as a conductor connecting the external circuit to the liquid.

Polarization.

2. When a current flows through the cell and the zinc is being dissolved, hydrogen gas is liberated at the copper plate, and gradually coats it with a thin film of gas. This has two effects on the cell, it introduces a high resistance into the cell, and action between the hydrogen and the copper creates an E.M.F. in an opposite direction to the proper E.M.F. of the cell. In other words, the resistance of the cell is increased, and the E.M.F. lowered. Both these effects reduce the current flowing, and in the simple cell the result of this "polarization," as it is called, is to make the current produced fall off very quickly, so much so, in fact, that the simple cell is useless for telegraph work.

The polarization is got rid of by adding something which will combine with the hydrogen as soon as it is formed ; there are various ways of doing this which will be described later.

Local action.

3. If the zinc of the simple cell were pure no action would take place between the zinc and the liquid unless a current were flowing through the cell. In practice, however, the zinc contains impurities, and these set up "local action," the impurities act as the other plate of a small cell, and a current is set up in the cell which consumes the zinc to no useful purpose. Local action can be largely reduced by "amalgamating" the zinc, *i.e.*, by coating it with mercury ; it is, however, always present in cells containing an acid liquid, but disappears almost entirely when other liquids (*e.g.*, salammoniac solution) are used.

E.M.F. of cells.

4. It has been found that the E.M.F. of a cell depends merely on the materials of which it is made * (or which have formed in it during use) and is entirely independent of its size, shape, &c.

The cells in general use in telegraphy have E.M.Fs of between 1 and 2 volts, depending entirely on the class of cell, *e.g.*, Daniell cells 1·07 volts, Leclanché cells and dry cells 1·5 volts.

Resistance of cells.

5. Although the E.M.F. of a cell depends only on its materials, the resistance depends also on its size and shape. The larger the cell, and the closer together the plates the smaller its resistance. A large cell has also more active material and hence lasts longer without renewal.

The resistance of cells is important in many cases, as a high resistance cell can only furnish a small current. For example, if a cell has an E.M.F. of 1 volt, and an internal resistance of 20 ohms it can only furnish a current of $\frac{1}{20}$ ampère when it is short circuited, and $\frac{1}{25}$ ampère through an external resistance of 5 ohms, while a cell with the same E.M.F. and a resistance of 1 ohm would furnish $\frac{1}{6}$ ampère through the same external resistance, or over four times as much current.

Cells used in telegraphy have a resistance varying from 0·1 ohm to 10 ohms, or more. (See table at end of chapter.)

Daniell Cells.

6. Daniell cells are of various forms. They all consist of a zinc plate immersed in a solution of zinc sulphate ($ZnSO_4$),† and a copper plate immersed in a solution of copper sulphate ($CuSO_4$). The liquids are kept from mixing either by gravity or by the use of a "porous pot." The copper sulphate acts by combining with the hydrogen that is liberated on the copper plate, forming sulphuric acid (H_2SO_4) and depositing copper on the copper plate. This entirely prevents "polarization."

The zinc gradually dissolves in the zinc sulphate solution, forming more zinc sulphate, till the solution becomes concentrated, when crystals are deposited. When this happens the solution must be removed, and water added.

Porous pot.

7. The porous pot is made of unglazed porous earthenware, and suffices to keep the liquids apart to a very large extent, particularly when a current is flowing. The current is able to pass through it. In time the liquid will mix in spite of the porous pot, and this occurs more rapidly when the cell is not furnishing a current; when this mixing of the liquids occurs copper will be deposited on the zinc plate, and the cell must then be washed out and renewed.

---

* The temperature has also a slight effect, but this is negligible for telegraph work

† Cells having dilute sulphuric acid instead of zinc sulphate are also called Daniell cells, but are seldom used in telegraphy.

Post Office patterns.

8. The Post Office patterns consist of a teak box divided into partitions forming five or more cells (see Fig. 1). The zinc is in the form of a thick plate, and is surrounded by a dilute solution of zinc sulphate. The copper is a thin plate and is placed in the porous pot, surrounded by a concentrated solution of copper sulphate, and a few crystals of the latter are placed in the pot to keep the solution up to strength. The porous pot is coated with paraffin wax round the top and one side to prevent, as far as possible, the liquids mixing or "creeping;" the uncoated side of the pot must be next the zinc plate.

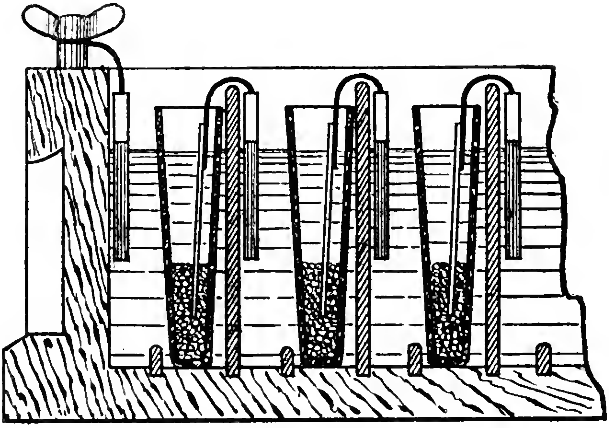


FIG. 1.—Daniell Battery (Post Office pattern).

In making up the cell it is usual to fill the portion containing the zinc with water, and then short circuit the cell for 24 hours. After that time sufficient zinc sulphate will have formed for the cell to work properly. The E.M.F. is just over 1 volt per cell and the resistance from 2 ohms upwards. If the resistance rises above about 5 ohms per cell, the cell wants cleaning and remaking up. There is now no service pattern of Daniell cell suitable for telegraph or telephone purposes.

Characteristics.

9. The Daniell cell has a comparatively low E.M.F., high resistance, does not polarize, but the liquids mix when not in use. It is consequently well suited to heavy continuous work on telegraph circuits, but is not suitable for use in the field or for telephone work, as it is not portable, deteriorates when not in use, and requires considerable attention.

Minotto cell.

10. The Minotto cell is largely used in India, where the materials, being in demand for trade purposes, are readily obtainable, and may be met with elsewhere. It is illustrated in Fig. 2, and consists of a vessel, at the bottom of which is placed a copper disc, forming the positive plate of the cell. Above this are packed crystals of copper sulphate; above this

again, but separated by a felt disc, sawdust or sand is placed, then another felt disc, and then a disc of zinc, fitted with a binding screw. An insulated wire passing through the cell makes electrical connection with the copper plate. The cell is completed by adding zinc sulphate solution until the sawdust, felt, &c., are thoroughly saturated. This cell has an E.M.F. of about 1 volt, but its internal resistance is very high, being seldom less than 12 ohms. The cell has all the above-mentioned characteristics of the Daniell cell, except that, as it has little free liquid, it is fairly portable.

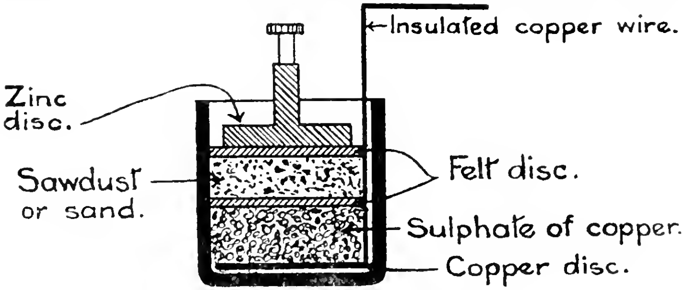


FIG. 2.—Minotto Cell.

Leclanché Cells.

11. The cells in most common use, in and out of the service, are of the Leclanché type. In these cells the plates are of zinc and carbon, and immersed in a solution of ammonium chloride (NH_4Cl), commonly called salammoniac. The carbon is surrounded by manganese dioxide (MnO_2), which combines with the hydrogen which is liberated at the carbon plate.

The carbon plate or rod has a lead head cast round the top to attach the terminal for connecting the line wire. The top of the carbon and the lead are coated with paint or tar varnish to prevent the liquid getting between the carbon and the lead, and crystallising out. If this happens the resistance is largely increased, and if it is found to have occurred the carbon must be renewed. The top of the jar, in open type cells, is also coated with tar varnish or paraffin wax, to prevent the liquid rising by capillary action and crystallising out.

Characteristics.

12. The E.M.F. of Leclanché cells is about 1·5 or slightly more, when freshly made up. The manganese dioxide does not combine instantaneously with the hydrogen liberated at the carbon plate, and consequently the cell polarizes rapidly when furnishing much current; when the cell ceases to furnish a current the hydrogen is absorbed, and the cell recovers. There is practically no local action, and the cells (except "dry" cells) do not deteriorate when not in use. They have usually

a low resistance. Leclanché cells are consequently very suitable for telephone work; and, as they can be made portable, for all field work and for telegraph work.

Porous pot form.

13. In the porous pot form (see Fig. 3) the manganese dioxide is mixed with crushed carbon, and is enclosed with the carbon plate in a porous pot. The pot is sealed up, except for a small vent hole. This form is useful for minor telegraph circuits and bell installations. There is no service pattern of this type.

LECLANCHÉ CELLS.

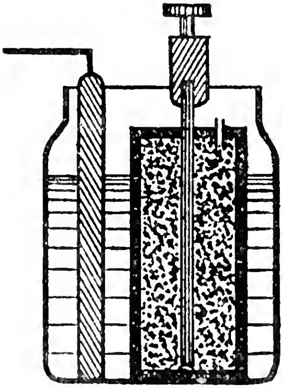


FIG. 3.—Porous Pot Form.

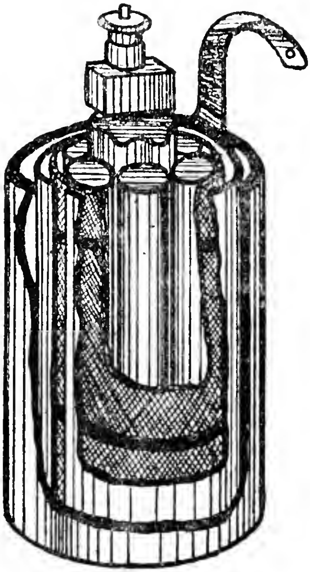


FIG. 4.—Agglomerate Block Form.

Agglomerate block form.

14. In the agglomerate block form the manganese dioxide is mixed with an equal weight of crushed carbon, moulded into a block or rod, with shellac as an agglomerant. The blocks are placed round the carbon rod or plate, and held there by india-rubber bands, and sometimes by a canvas wrapping as well. The following service cells are of this type.

Leclanché "A," Mk. III.

15. Cells, electric, Leclanché A, Mark III.—The cell is of ebonite, rectangular, $7\frac{3}{4} \times 5\frac{1}{2} \times 2\frac{7}{10}$ inches, the zinc plate is bent round to fit the inside of the cell. The carbon plate is in the centre and surrounded by six flat agglomerate blocks held on by two indiarubber bands. The cell is sealed with bitumen and plaster of paris; two holes are left in the sealing, which are closed by corks, having a cane core. The cell when issued is packed with salammoniac, and is made ready for use

by filling with water. Internal resistance about ·3 ohm. Used by the R.A. for firing batteries.

Leclanché "C."

16. Cells, electric, Leclanché "C."—The cell is of stoneware, circular in plan, 5½ inches diameter by 13 inches high, open at the top. The zinc plate is bent into a cylinder, and lines the cell. The carbon is a rod, grooved to take the agglomerate blocks, which are in the shape of rods. There are 12 agglomerate blocks in all, two in each groove, held in place by a canvas wrapping and four indiarubber bands. Internal resistance about ·15 ohm. The height over all is 15 inches. Used by the R.A. for range dials, &c.

Leclanché "F."

17. Cells, electric, Leclanché "F."—The cell is of ebonite, circular in plan, 4¼ inches diameter by 7¼ inches high, sealed in the same manner as "A" Mark III. The zinc, carbon, and agglomerate blocks are arranged as in "C" cells, except that there are only six blocks, and the cell is packed with salammoniac, similarly to "A" Mark III. Internal resistance about ·2 ohm. The height over all is 9½ inches. Used for railway signalling and permanent telephones.

Leclanché "G."

18. Cells, electric, Leclanché "G" are similar to "C" cells, except they are only 9 inches high over all (height of cell 7⅛ inches), and have only six agglomerate blocks and two indiarubber bands. Internal resistance about ·15 ohm. Used for permanent telephones, and electric light dials, &c. (See Fig. 4.)

Leclanché "J."

19. Cells, electric, Leclanché "J."—The cell is of glass, with a zinc rod, and carbon plate and two flat agglomerate blocks. The internal resistance is ·6 to 1 ohm, and the over all dimensions 3 × 3 × 6¾ inches. The indiarubber bands for securing the agglomerate blocks have loops for the zinc rods to pass through, thus keeping the latter separate from the carbon plate, &c. This is a very common commercial pattern. Used for garrison telephones and telegraphs.

Dry cells.

20. Dry cells are Leclanché cells in which the salammoniac solution is made into a paste with some absorbent material. As a rule, the zinc plate forms the case of the cell, and the carbon rod is in the centre (see Fig. 5). Most commercial forms, and the service Mark I cells, have a piece of insulated wire connected to the zinc, and a terminal on the carbon. The Mark II service cells have two terminals, the centre one being the carbon and the one on the edge being the zinc. They are issued with a piece of connecting wire each; care must be taken not to connect the two terminals of one cell. These cells are very portable, but deteriorate in store, particularly in hot climates. When exhausted they cannot be replenished, but have to be replaced. They are used for all work in the field, and for all portable telephones.

Service sizes.

21. Dry cells are made in several shapes and sizes; those used in the service are mostly of the "Obach" make, and are as follows :—

Cells, dry, "A."—$7\frac{3}{8}$ inches high × $3\frac{3}{8}$ inches diameter, for use with telephone sets, portable, "A," &c. Resistance about ·15 ohm.

Cells, dry, "O."—$6\frac{1}{2}$ inches high × $2\frac{13}{16}$ inches square, for use with field telegraphs. Resistance about ·22 ohm.

Cells, dry, "P."—$5\frac{15}{16}$ inches high × $2\frac{1}{4}$ inches square, for use with telephone sets, portable, "B" and "C." Resistance about ·22 ohm.

Cells, dry, "S."—$4\frac{1}{2}$ inches high × $1\frac{1}{2}$ inches square, for use with telephone sets, portable, "D, Mark II." Resistance about ·5 ohm.

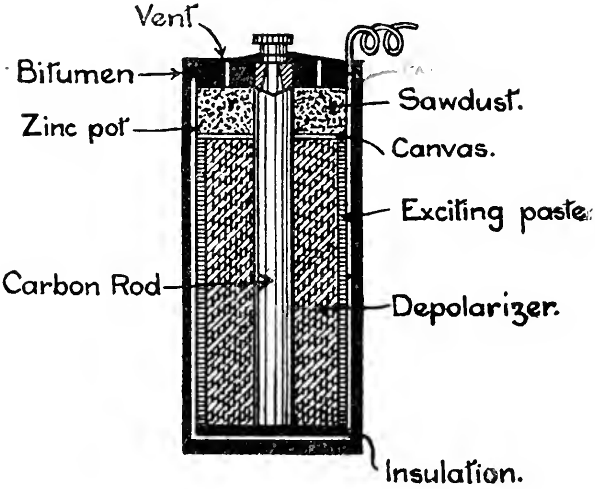


FIG. 5.—Obach-dry cell.

Bichromate Cell.

Bichromate cell.

22. This type of cells is extensively employed in the Postal Telegraph Department, but does not form part of service equipments.

The elements are zinc (amalgamated) and carbon, with chromic acid as the depolarising agent.

The zinc with a small quantity of mercury stands in a very weak solution of sulphuric acid; the carbon in a similar but stronger solution to which potassium bichromate is added. These sections are separated by a porous pot of somewhat dense texture.

The depolarising agent is formed by the admixture of bichromate of potash and sulphuric acid; amalgamation of the zinc is maintained by capillary action.

The form of cell most commonly employed is shown in Fig. 6. It is specially suited to long distance working and for quadruplex and automatic telegraphy.

When in action, the zinc is attacked by the sulphuric acid and sulphate of zinc is formed. The liberated hydrogen on reaching the outer cell combines with the oxygen of the chromic acid, forming water and chromium, the latter of which tends to deposit chrome-alum crystals on the carbon plate.

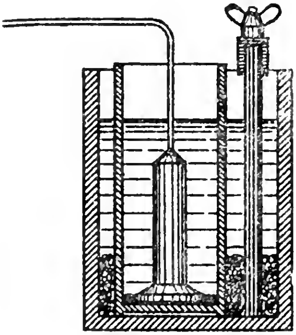


FIG 6.—Bichromate cell.

Its E.M.F. is approximately 2 volts, and the internal resistance of the quart size averages 2 ohms.

Its value for the purposes named is due to the high E.M.F. combined with comparatively low internal resistance.

It possesses the disadvantage of being subject to polarisation if worked on circuits of low resistance, and like all two fluid cells requires attention, whether in actual use or not.

Batteries.

Cells in series. 23. A single cell seldom suffices for practical purposes, and two or more cells must be used, joined up to form a battery. For ordinary working, cells are joined up in "series," *i.e.*, the negative or zinc terminal of one cell is joined to the positive of the next and so on. In this case the E.M.F. and resistance of the battery is the sum of the E.M.Fs and resistances of the individual cells, *e.g.*, if 10 dry cells, each of 1·53 volts and ·25 ohms, are joined in series, the E.M.F. of the battery is 15·3 volts and its resistance 2·5 ohms.

The current furnished (see Chapter I, para. 13) equals

$$\frac{\text{E.M.F. of battery}}{\text{Resistance of external circuit} + \text{resistance of battery}},$$

and in ordinary telegraph working the resistance of the line and instruments is seldom less than several hundred ohms, and is, therefore, large compared with the battery resistance; consequently, the current is nearly proportional to the number of cells joined up in series.

In cases where the external resistance is low compared with the battery resistance, adding cells in series has a very small effect on the current. Suppose the external resistance were 1 ohm and the cells available were Daniell cells with E.M.F. of 1 volt and resistance of 5 ohms, then the current with one cell would be $\frac{1}{6}$ ampere, while with 10 cells it would be $\frac{10}{51}$ ampere, or less than $\frac{1}{5}$ ampere.

Cells in parallel.

24. In such cases, if a larger current is required, it is better to join up the cells in "parallel," *i.e.*, connect all the positive terminals together and all the negative terminals together, and we then get the E.M.F. of one cell only, but the internal resistance is lowered, as in the case of divided circuits (Chapter I, para. 15), that is, if 10 similar cells are joined in parallel, the combined resistance is one-tenth that of one cell. Taking the same example of external circuit, 1 ohm resistance, and cells of 1 volt and 5 ohms each, if the 10 cells are joined up in parallel, the E.M.F. is 1 volt and battery resistance $\frac{1}{2}$ ohm; hence, the current is $\frac{1}{1 \cdot 5}$ ampere or $\frac{2}{3}$ ampere.

This case would only be used in practice for telephone speaking circuits when only very high resistance cells are available. With service Leclanché cells available for use with ordinary telegraph and telephone instruments, it is never necessary to join cells in parallel.

Formulæ for current furnished by a battery—

C = current in amperes.
e = E.M.F. of one cell.
R = resistance in ohms of external circuit.
r = ,, ,, one cell.

Then with n cells in series,

$$C = \frac{ne}{R + nr};$$

with n cells in parallel,

$$C = \frac{e}{R + \frac{r}{n}}.$$

N.B.—When cells are joined in parallel they must all be of the same type, having the same E.M.F.

Cells in compound.

25. It is unnecessary here to consider the different arrangements of compound circuits. Occasions may however arise in which it is necessary to use cells of objectionably high resistance, and in such a case, and if there is an ample supply of the cells at hand, some relief may be obtained by joining up several rows in parallel, each row consisting of enough cells in series to give the required E.M.F.

If m rows of cells are joined in parallel, each row having n cells in series, the current furnished equals

$$\frac{ne}{R + \frac{nr}{m}}.$$

Service batteries.

26. Some of the service cells are issued in boxes joined up into batteries: their descriptions are as follows; the cells are joined up in series:—

Batteries, Leclanché C, 4-cell. For range finders, &c.
Batteries, Leclanché F, 2-cell } For telephone circuits.
Batteries, Leclanché G, 2-cell }
Batteries, dry, 6-cell } For field telegraph use.
Batteries, dry, 10-cell }

Batteries, Leclanché H, 6-cell and 10-cell were formerly used by field telegraph units, and may be met with; no more are to be provided. The cells are generally similar to cells Leclanche "A," only smaller, being $3\frac{15}{16} \times 2 \times 5\frac{5}{8}$ inches. Resistance ·4 to 1 ohm.

Battery Power required for Telegraph Circuit.

27. To calculate the battery power required it is necessary to know the E.M.F. and internal resistance of the cells used, the resistance of the line* and instruments in the circuit, and the current required to work the instrument. It is best to add 25 per cent. to the calculated result to allow for line leakage, &c. In telegraph work the resistance of the battery can usually be neglected.

A good rough rule is "multiply the resistance of the circuit (line and instruments) by the current required (in *amperes*) and divide the product by the E.M.F. of one cell"; this gives the number of cells required; add 25 per cent. as stated above.

The accurate formula is $n = \frac{CR}{e - Cr}$, but for Leclanché cells the resistance of the cells may be neglected, and with Daniell cells the difference will not often exceed 10 per cent. on ordinary line circuits. A few examples worked out both ways will make this clear.

---

[*] 50 ohms should be added to the line resistance where earths are used, to allow for the resistance of the earth connections.

TABLE I.—Resistance of Line Wire commonly Used.

Wire. Designation.	Description and Use.	Resistance per mile.
Wire, electric.		Ohms.
Z 21	200 lbs. per mile, galvanized iron, permanent lines	27
Z 23	400 lbs. per mile, galvanized iron, permanent lines	13·5
Z 31	100 lbs. per mile, steel 3-strand, field lines ...	50
Z 17	„ „ copper, permanent lines ...	8·5
Z 7	„ „ bronze „ „ ...	12
Z 9	„ „ „ 3-strand, field lines	12
Z 5	70 lbs. bronze, permanent lines	26
Z 3	40 lbs. „ „ „	45·5
Cable, electric,		
C_1	590 lbs. per mile, river crossings, field telegraphs	26
D_5 Mk. II.	80 lbs. per mile, field cable	200
D_5 Mk. III.	. ...	63
D_5 Mk. IV.	85 lbs. „	63
C_4.	1,000 lbs. per mile, 4 core interruption cable	17
D_1.	20 lbs. „ field telephone cable ...	1060
D_3.	40 lbs. „ „ „ ...	325

TABLE II.—Resistance of Telegraph Instruments.

Instrument.	Resistance of Coils in		Minimum Current required to work.
	Series.	Parallel.	
	Ohms.	Ohms.	Amperes.
Galvanometer, single and duplex	100	25	—
Sounder, (P.O. pattern)... ...	20	—	·055
„ translating	40	—	·020
Morse Recorder, Mk. II.	300	75	—
„ „ (galvanometer)	30	—	—
Combined inker (P.O. pattern) ...	300	75	·005
„ „ „ (galvanometer)	30	—	—
Local inker (P.O. pattern) ...	40	—	·069
Relay, Telegraph, Mk. I	400	100	·00113 (coils in series) ·00226 („ parallel)
„ „ Mk. II (P.O. Standard A)	400	100	·00055 („ series) ·0011 („ parallel)
Relay, P.O. Standard B	200	50	
Wheatstone receiver	200	50	·010
Choking coil of separator ...	200	—	—

NOTE.—The currents given are the least the instruments will work with when they are in perfect adjustment; larger currents should be allowed in practice (see Table III).

TABLE III.—Current required for Working Telegraph Circuits.

Type of Circuit.	Line Current allowed in Amperes.
Local circuits...	·1–·12
Single current simplex with relay (coils in series) ...	·015–·02
,, ,, ,, (,, parallel) ...	·03–·04
Double current ,, ,, (,, series) ...	·014–·017
,, ,, ,, (,, parallel) ...	·028–·034
Instrument, telegraph, Morse recording (coils in series)	·015–·020
Wheatstone simplex...	·02–·03

NOTE 1.—For local circuits use 3-6 cells.

NOTE 2.—For duplex circuits the battery power required is about double that required for simplex.

NOTE 3.—For quad working calculate "A" battery as for duplex, and take 2½ times the number for the "B" battery.

NOTE 4.—For Wheatstone working it is usually best to have an E.M.F. of at least 100 volts, if this gives too large a current add resistance to the line to reduce it.

Example. 28. Simplex circuit with two intermediate offices and vibrators with separators. Length of line, 50 miles of Z 9. Batteries available, Dry O :—

Resistance—	Ohms.
3 relays	1,200
4 galvos	400
Earths	50
2 separator coils	400
Line	600
Total	2,650

Current required = 0·017 ampere.

E.M.F. of cells 1·5 volts each, resistance 0·3 ohm each.

Then number of cells by rough rule

$$= \frac{2650 \times 0{\cdot}017}{1{\cdot}5} + 25 \text{ per cent.}$$

$$= \frac{45}{1{\cdot}5} + 25 \text{ per cent.}$$

$$= 30 + 8 = 38.$$

Say four 10-cell batteries.

By calculation it will be seen that with good dry cells and Z 9 wire—

10 cells will work a baseboard simplex through about 8 miles.
20 ,, ,, ,, ,, 70 ,,
30 ,, ,, ,, ,, 130 ,,
40 ,, ,, ,, ,, 195 ,,

and for each intermediate office deduct 50 miles, and if separators are used at the terminals deduct 35 miles. It will also be seen that if the coils of the relays and galvos are placed in parallel 10 cells will work through 14 miles, but 20 will only work through 45 miles.

General Care of Batteries.

General remarks on batteries.

29. It should be remembered that dry cells are subject to deterioration whether in use or not, especially if kept in hot or very dry places, for which reason they should be tested periodically, especially when forming part of a portable instrument. Cells issued from store should receive immediate attention in this respect. The rough testing described in para. 36 is sufficient for cells required for ordinary use. For more accurate testing, see Chap. XX.

Porous pots that have once formed part of a battery should be kept in water, otherwise they are subject to disintegration.

A battery maintenance card should be kept in each battery room, or cupboard, showing dates on which the batteries were made up or replenished, and the results of the periodical tests.

Situation for batteries.

30. The efficiency of a battery and the amount of attention it requires depends largely on strict observation to cleanliness of surroundings and adequate ventilation.

Wet batteries, especially those of the Leclanché type, should be placed in a box with the lid slightly raised, or the box itself perforated near the top. The situation chosen should be free from extremes of temperature. Undue heat subjects the liquids to evaporation, followed by deposition of salts on external surfaces; this tends to short circuit the battery and draw off the liquids. Extreme cold raises the internal resistance and tends to crack porous pots and glass containing-vessels.

It is of equal importance to keep batteries in a dry situation otherwise the terminal screws, commonly attached direct to the box, are in electrical connection through the moist wood. If placed on damp ground or damp supports, the risk of leakage and subsequent exhaustion is intensified.

Accommodation should, therefore, be provided on shelves or wooden supports, and in some instances it may be advisable to connect the instrument leads direct to the terminals of the battery, the zinc being joined by means of a battery wing nut.

At many offices the number and types of batteries employed call for the provision of a special cupboard, the shelves of which may consist of three triangular-shaped battens with the apex upwards supporting the battery boxes. Each shelf is served with a damp-resisting mixture before being painted and is fitted with casing, terminal screws, and circuit cards.

The bottom portion of such cupboards is usually reserved for battery stores, for which reason the lower shelf is of ordinary design. This shelf and the bottom edge of the door are about

6 inches clear of the floor level. The cupboard is usually open at the top and a clearance of about 3 inches is allowed between the doors and the shelves for ventilation purposes. The inside surfaces of the doors, which open from the centre, are usually reserved for battery maintenance cards. A special room is desirable.

The battery room.

31. At the largest offices a specially-designed and well-ventilated battery room is necessary. It should be situated either on the ground floor or in the basement of the building, and as near the instrument room as possible.

The batteries are arranged on a rack supported in some instances on insulators. The rack is fitted with battens, &c., similar to those of the battery cupboard, and is placed in a position clear of the walls to admit of access from all sides.

The residue of some types of batteries is of commercial value, that of the Daniell, for instance, containing a large percentage of copper oxide. For this reason, and with a view to keeping the drains free of chemical deposit, the orifice of the waste-pipe in the cleaning cistern or tank should project about 3 inches above the bottom.

The residue withdrawn from the tank, as well as that obtained direct from the batteries, is placed in a special box for future disposal. The tank is also fitted at the end opposite the waste-pipe with a sloping corrugated board on which the various battery parts are drained during cleaning operations.

The waste-pipe is connected direct to the main drain, not to a branch, so as to minimise the risk of chemical destruction due to the presence of acids.

A good water supply is, of course, essential.

Making up, Refreshing, and Cleaning Batteries.

P.O. Daniells.

32. *To Make up.*—The arrangement of the plates and the porous pots is shown on Fig. 1.

Place the unparaffined surface of the porous pot outwards.

Use about 4 ozs. of copper sulphate crystals for the large size, and 3 ozs. for the small size, and add water or copper sulphate solution till on a level with the top of the zinc plate.

Fill the zinc compartments with water or weak zinc sulphate solution to the top of the zinc plate.

Short circuit the battery for a few hours prior to use.

To Refresh.—Withdraw any superfluous liquid from the porous pots. Replace copper sulphate crystals used up by the action of the battery.

Withdraw about two-thirds of the zinc sulphate solution and replace with water.

Lightly scrape the front surface of the zinc plate to remove any copper deposit.

Examine the battery generally for probable defects.

To Clean.—Withdraw about one-third of the solution from the zinc compartment and place it in a jar containing scraps of zinc.

Pour the contents of the porous pots into another jar.

Scrape the plates quite clean and bright.

Lightly hammer the rivet connecting the strap to the copper so as to ensure perfect electrical contact.

Carefully remove any copper deposit from the surface of the porous pots.

Renew any porous pots which may be cracked or otherwise defective.

Keep the box free from water when washing out the zinc compartments.

Test the zinc compartments occasionally for leakage, by filling each in succession with water and observing the effect both on adjacent compartments and externally.

Replace the zinc and copper sulphate solution previously withdrawn, first diluting the zinc sulphate solution with water.

Leclanché.

33. *To Make up* porous pot and agglomerate block, "open" forms for ordinary purposes use about 3 ozs. of crushed salammoniac for the quart size (other sizes in proportion) with sufficient water to bring the level of the liquid to about two-thirds of the height of the containing vessel when the elements are added.

In situations where a battery is subjected to long periods without attention, and providing the work of the cell is not excessive, use salammoniac solution only.

Salammoniac solution is made by dissolving as much crushed salammoniac in clean water as the latter will take up.

(Solution only should be used in connection with "sealed" batteries.)

When porous pots are employed, pour a small quantity of water or solution through the vent holes in the top.

See that no liquid remains on the terminal screws or ends of the zinc connecting wire.

Wipe the lead head of the carbon, and the neck of the containing vessel, with a rag or piece of waste lightly served with oil.

To Refresh.—Remove any crusted salammoniac from surfaces above the solution.

Restore the level of the liquid by adding a small quantity of crushed salammoniac and water, or solution.

Clean the terminal screws and ends of the zinc connecting wires.

Apply the oiled cloth or waste as when making up.

Examine the battery generally for miscellaneous defects. (The solution should be bright and clear. If cloudy, the battery requires cleaning.)

To Clean.—Scrape the zinc rod or plate quite clean, and repair any exposed portion of the connecting wire, re-amalgamate the zinc if necessary.

Wash each porous pot or carbon, and renew the composition on any portion of the lead cap that may be exposed. If any white deposit is observed between the cap and the carbon, the latter should be renewed.

Renew hard or cracked porous pots, also zincs which are reduced to less than one-half their original size.

See that the surface of the carbon rod or plate is free from oil or any other foreign substance.

Agglomerate blocks should be renewed as soon as they present a very rough or crumbling appearance; any agglomerate blocks or carbons condemned should at once be broken up.

Dry cells.

34. Dry cells are of little use if their E.M.F. falls below 1 volt. Under these conditions they may be converted into wet cells as follows:—

(*a*) Remove the bituminous cover, and add salammoniac solution or salt and water.

(*b*) Remove the cardboard case. Perforate the zinc in several places, and place the cell in a receptacle containing salammoniac solution.

Keep in a cool dry place, whether in use or not.

See that the zinc connecting wire and the carbon terminal screw do not touch.

Bichromate.

35. *To Make up.*—Place 4 ozs. of bichromate in the outer cell, and insert the porous pot containing the zinc rod previously amalgamated.

Place 2 ozs. of mercury in the porous pot.

Fill each vessel with water up to about 2 inches of the top.

Add respectively $\frac{1}{4}$ ozs. and 4 ozs. of sulphuric acid to the inner and outer cells.

To Refresh (outer cell).—Examine the solution by inserting a small strip of white paper. If stained a deep orange colour, no attention is required.

If the paper assumes a bluish tint, withdraw about one-half of the liquid and replace with fresh solution, at the same time add about 2 ozs. of bichromate and remove any chrome-alum crystals.

(Inner cell.)—In conjunction with the foregoing withdraw half of the solution and replace with water.

Add a small amount of mercury if the zinc presents a dull appearance.

To Clean.—The necessity of cleaning the cell is indicated by a bluish solution (notwithstanding the presence of sufficient bichromate of potash), and the zinc becoming black and coated with deposit.

After dismantling the cell, insert the porous pot containing its zinc in an open jar under a tap. The whole of the solution in the pot and the deposit will then be washed away, leaving the mercury for future use.

Thoroughly wash the carbon and the outer jar, and clean the terminals and zinc connecting loops.

The zinc can be used until it is about one-quarter of its original size.

Re-amalgamate the zincs if necessary.

To amalgamate zinc, thoroughly clean the surface in sulphuric acid, and then apply mercury by means of a piece of rag tied to a stick.

Testing batteries.

36. The internal state of the battery may be sufficiently accurately guessed at by noting the deflections produced on the two coils of the quantity and intensity detector, and comparing them with those produced by a battery known to be in good condition. A diminution in the deflection produced on the intensity coil will indicate that the E.M.F. of the battery is failing, while a low reading on the quantity coil, together with a normal one on the intensity coil, would denote a rise in the internal resistance.

A rise in the internal resistance will not perceptibly affect the deflection on the intensity coil, but a diminution of the E.M.F. will equally affect both coils. The state of the latter should, therefore, be ascertained first; and, if found to be affected, an allowance must be made for it in the estimate of the internal resistance.

It is a good plan to keep a lineman's detector specially for battery testing, and the deflections indicated by it, on both coils, by a current from a good Leclanché cell, noted.

Each cell of a battery, in good condition, will give as good a deflection with the quantity coil as the whole battery.

In testing a battery after making it up afresh, each cell should be tested separately, as well as the complete battery, and any cell not giving good results on Q and I coils should be cut out and made up afresh.

In testing Leclanché and dry cells, care should be taken not to short circuit the battery through the Q coil for longer than is necessary, as otherwise the cell will be speedily run down.

Accurate methods of testing are given in Chap. XX, para. 27.

Secondary Batteries.

Secondary cells.

37. Accumulators or secondary cells differ from primary cells in that they must first have an electric current passed through them to effect certain chemical changes in their constituents before they are capable of furnishing electrical energy.

The only pattern likely to be met with in the service are cells in which both plates are made up of lead and lead salts.

These may be divided into two classes; those in which the plates are "formed" and those in which the plates are "pasted."

In the first case finely divided lead plates are charged and discharged repeatedly till they are of the right constituents, and in the latter case certain lead salts made into pellets are inserted in lead grids. In both cases after being used the actions are similar. The cell consists of two plates or sets of plates, one positive and one negative, immersed in dilute sulphuric acid. When charged the positive plate is a red brown, owing to the formation of lead peroxide, while the negative is grey, as it consists of pure lead. On discharge the lead and lead peroxide are turned into lead sulphate, and the electrolyte is weakened by the formation of water. On charging again lead and lead peroxide are once more formed, and the electrolyte is made more concentrated by the reformation of sulphuric acid.

Setting up and charging.

38. To charge secondary cells the positive terminal of the battery is connected to the positive of a source of electrical energy (usually a dynamo) and a charge of sufficient duration is given. It will be noticed that during charging, the current flows through the cells in the opposite direction to the direction of the discharge current.

On setting up a new battery instructions will usually be forwarded by the makers, and these instructions should be adhered to.

In general the cells, if of large size, will be received from the makers with the positive and negative sections in wooden crates. These are unpacked and the sections put into their boxes (usually of glass) with the necessary separatous between the plates. The cells are joined up in series and the electrolyte is prepared. This consists of pure sulphuric acid diluted with pure distilled or boiled rain-water till its sp.g. is 1·200. When this is ready and cool a suitable dynamo is arranged so as to give a voltage of about 2·75 volts per cell charged and its positive terminal is connected to the positive of the cells. Just before charging, the cells are filled up with electrolyte, and the dynamo switch is closed. The first charge must continue unbroken for 12 hours and must go on for 50 hours before any discharge is taken from the cells.

Maintenance.

39. Secondary cells last longest when they are given regular work to do, and are carefully treated and looked after.

The maximum discharge rate as laid down by the makers for each type of cell should not be exceeded. The capacity is stated in "ampere-hours," viz., a cell of 300 ampere-hours capacity would theoretically give 300 amperes for 1 hour or 1 ampere for 300 hours, but above a certain rate of discharge the capacity decreases in practice.

The cells require to be charged regularly according to the work they have to do. Even if not used at all they require charging at intervals of, say, a month. They should never be worked when the voltage is under 1·8 volts per cell, and when the voltage is as low as this they must not be allowed to stand for any length of time before being charged.

The indications of a cell being properly charged are—

(*a*) High E.M.F. as much as 2·5 volts per cell whilst the normal charging current is passing through it.
(*b*) Proper sp.g. of electrolyte (1·2 usually).
(*c*) Gassing from plates till electrolyte appears milky.
(*d*) Healthy colour of the plates, reddish brown for positives and grey for negatives.

When the cells are nearly charged they gas freely, and unless spray plates are used with open cells, some of the electrolyte is carried away out of the cell. The loss of liquid in the cells is usually due to evaporation, and generally is made up by the addition of water, which must be as pure as that originally used.

The gas given off is objectionable, and arrangements must be made for thoroughly ventilating a battery room, and also for protecting metals from corrosion by painting with "anti-sulphuric" enamel. The floor, too, must be made acid proof.

Accumulator troubles.

40. Sulphating is the most common complaint. It is caused, in general, by excessive discharge, by cells being left run down for some time, and generally by rough usage. The symptoms are a whitish deposit or growth on the plates.

The remedy is to give the cells a long charge at less than normal rates. This will generally cause the sulphate to fall off. If it comes off in lumps and scales these must be removed, or else they are liable to bridge over the space between the positive and negative plates and cause a short circuit.

Buckling of plates is generally due to overcharging or over discharging, or else to bad local sulphating.

The cure, when the buckling is serious, is to take out the plates and straighten them between boards.

Short circuiting, due to something bridging over positive and negative plates. This is usually caused by bits of sulphate or by fragments of metal, especially in the pasted types, falling down between the plates. It is generally detected by finding that one cell in a row runs down before the others of that row.

Use of accumulators.

41. Their advantages, as compared with primary cells, are that much greater currents can be taken from them; they are suitable for heavy continuous work, and the materials of which they are composed do not require to be renewed at frequent intervals. On the other hand, they require constant attention, and are not convenient for transport purposes.

They are generally best installed in large batteries, and not in small isolated groups. On account of their exceedingly low resistance, which is, indeed, practically negligible, and the ease with which they can be maintained, accumulators are now largely employed at important telegraph centres in substitution for primary batteries.

The arrangements are somewhat complicated, and a detailed description is outside the scope of this book.

TABLE IV.—Details of Cells.

Description.	Dimensions.		E.M.F.	Resistance.	Weight (Approximate).		Detail.	Use.
	Height over all.	Sides.						
Cells, electric :—	Inches.	Inches.	Volts.	Ohms.	Lb.	oz.		
Leclanché—								
A, Mark III	$8\frac{3}{4}$	$5\frac{11}{20} \times 2\frac{7}{16}$	1·5	0·3	7	0	6-block agglomerate, ebonite, sealed, rectangular	R.A. purposes
C	15	$5\frac{1}{2}$ dia.	1·4	0·15	15	0	12-block agglomerate, stoneware, open, circular	„
F	$9\frac{1}{2}$	$4\frac{1}{2}$ dia.	1·46	0·16 to 0·2	5	14	6-block agglomerate, ebonite, sealed, circular	Railway signalling instruments and garrison telephones
G	$9\frac{1}{2}$	$5\frac{1}{4}$ dia.	1·4	0·15	7	4	6-block agglomerate, stoneware, open, circular	Electric light dials and garrison telephones
H	$5\frac{5}{8}$	$3\frac{15}{16} \times 2$	1·4	0·4 to 1	—	—	4-block agglomerate, ebonite, sealed, rectangular	Field telegraph equipment, obsolescent
J	$6\frac{3}{4}$	3×3	1·5	0·6 to 1	1	14	2-block agglomerate, glass, open, square	Garrison telegraphs
Dry "E"	$5\frac{1}{2}$	$3\frac{5}{16} \times 2\frac{1}{4}$	1·49	11·9 to 12·5	1	11	... ...	Field company equipment
Dry—								
A	$7\frac{3}{8}$	$3\frac{3}{8}$ dia.	1·53	0·15	9	1	Circular	Telephones, portable, A
O	$6\frac{1}{2}$	$2\frac{13}{16} \times 2\frac{13}{16}$		0·22	3	0	Square	Field telegraph equipment
P	$5\frac{15}{16}$	$2\frac{1}{4} \times 2\frac{1}{4}$		0·25	2	0	„	Telephones, portable, B and C
Q	$5\frac{1}{2}$	2×2		0·2	1	6	„	Not in vocabulary
M	$8\frac{1}{8}$	$4\frac{1}{2} \times 4\frac{1}{2}$		0·15	9	10	„	
N	$7\frac{3}{8}$	$3\frac{1}{4} \times 3\frac{1}{4}$		0·15	5	0	„	
R	5	$1\frac{3}{4} \times 1\frac{3}{4}$		0·3	1	0	„	
S	$4\frac{1}{2}$	$1\frac{1}{2} \times 1\frac{1}{2}$		0·5	0	10	„	Telephones, portable, D, Mk. II
T	$3\frac{3}{8}$	$1\frac{1}{4} \times 1\frac{1}{4}$		0·5	0	5	„	Not in vocabulary
U	7	$3\frac{1}{2} \times 2\frac{1}{2}$		0·18	3	12	Rectangular	
W	$7\frac{1}{4}$	$2\frac{7}{8} \times 2\frac{3}{4}$		0·2	4	0	Square	
Minotti—								
Quart	$6\frac{1}{4}$	$4\frac{3}{8}$ dia.	1·07	10 to 20	—	—	Circular	
Pint	$4\frac{1}{2}$	$3\frac{3}{8}$ dia.		20 to 30	—	—	„	
Bichromate—								
Quart	$6\frac{3}{4}$	6 dia.	2·14	2 to 3	5	13	„	
Batteries, Daniell :—				Per cell.				
5-cell, large	6	14×6	1·07	5 to 2	30	0	Rectangular	
6-cell, small	$5\frac{1}{2}$	14×4		8 to 2	25	0	„	

CHAPTER III.

GALVANOMETERS AND SIMPLE TELEGRAPH CIRCUITS.

Morse signals.

1. The general principles on which telegraph instruments work are described in Chapter I.

The following chapters give details of the various telegraph instruments used in the service, or likely to be met with by military telegraphists, their methods of use and adjustments.

Before describing the various telegraph circuits, it is necessary to explain shortly what kind of signals telegraph instruments are designed to transmit. The letters of the alphabet, figures, &c., are represented by various combinations of two different signals known as "dots" and "dashes." The difference between them is usually one of duration, a dash being three times as long as a dot. Between the dots and dashes forming a letter an interval equal to one dot is left; between letters an interval of two dots, and between words of three dots. Whatever the rate at which the signals are sent, the relative length of dots, dashes and intervals must be kept accurate. Dots and dashes may be represented by long and short marks on a tape, as in a recording instrument, - —— representing "A" —— - - - "B" and so on, or, by long or short intervals of time between sounds, as on a "sounder," or by long or short periods of noise, separated by intervals of silence, as in a buzzer.

Galvanometers.

2. Galvanometers are instruments designed to indicate whether or no a current is flowing in a circuit, its direction (in some cases, including those described in this chapter) and to some extent its strength. They are based on the principle described in Chap. I, para. 34, viz., that a compass needle is deflected by a magnetic field due to a current. Their chief use in telegraphy is to detect and localise faults, and one should form part of every telegraph set (except vibrators).

Most telegraph galvanometers consist of a coil of insulated wire fixed with its axis horizontal, in the centre of which is pivoted a small magnetic needle, weighted so as to hang vertically. The coil is divided into two portions, wound on separate bobbins, so that the needle can be suspended between them, and thus be brought into the centre of the magnetic field produced when a current is flowing through them. To the needle is fixed a light pointer, which moves as the needle moves, and shows the amount and direction of its deflection on a graduated dial.

Fig. 1 shows this diagrammatically. The coil AB represents the two bobbins, which being close together act as one; when a current is passing from A to B the dotted lines show the direction of the lines of force. The needle tries to place itself in the direction of the field, and the stronger the current, the stronger the field, and the further the needle will be deflected from its vertical position.

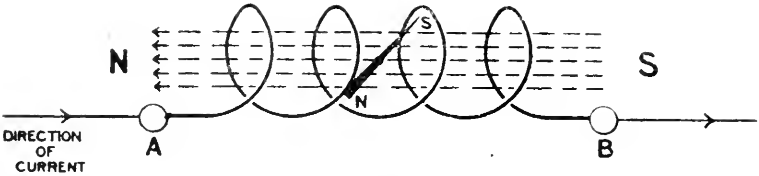


FIG. 1.

The polarity of the needle and the direction of the winding in service galvanometers are so arranged that the pointer moves to the observer's right when a current is flowing from the left to the right terminals of the galvanometer, *i.e.*, the deflection is in the direction of the current (see Fig. 1).

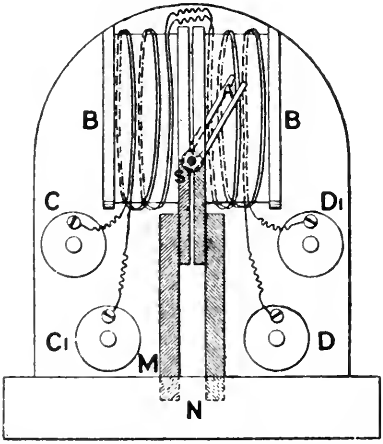


FIG. 2.—Galvanometer, Single and Duplex (with Dial Reversed and Coils shown Diagrammatically).

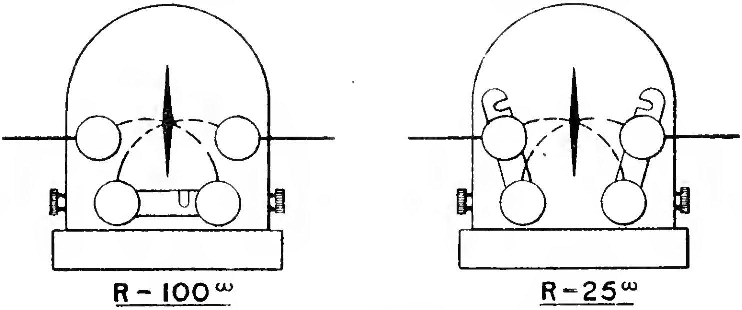
Galvanometer, single and duplex.

3. The pattern most generally used for telegraphy is known as the "galvanometer, single and duplex" (or shortly, the S. and D. galvo.). This form of galvanometer (see Fig. 2) consists of two bobbins BB fixed side by side about $\frac{1}{8}$ of an inch apart. On a horizontal axle between them swings a soft iron needle, A, of U shape, pivoted near the lower end of the U. This needle is magnetised by a pair of permanent magnets, M, placed

below it, and swings with its free end uppermost, being kept in that position partly by the repulsion of the permanent magnets, and partly by the weight of the lower end of the pointer attached to it and swinging in front of the dial.

The bobbins carry two coils of silk-covered wire each having a resistance of 50 ohms. The coils are wound "differentially" (see Chap. I, para. 58), half of each coil on each bobbin; each coil therefore produces the same magnetic effect when the same or equal currents flow in them.

The end of each coil is led to a pair of terminals at the back of the instrument. Brass links are arranged so that the two coils can be connected together in series or in divided circuit (as shown in Fig. 3).



Coils in "series." Coils in "divided.'

FIG. 3.—Galvanometer, Single and Duplex.

The cover of the military instrument is secured by a milled headed screw on either side; the leads are sometimes in error joined to these when connecting up the instrument in circuit.

The method of magnetising the needle described above makes it a strong magnet, and less liable to lose its magnetism than a permanent magnet needle of the same size; but even so the magnetic field produced in the needle by a very strong current round the coils is sometimes greater than that induced by the permanent magnets. If this happens when the needle is swinging, and is over to the left, say, at the moment the current is turned on from C to D (Fig. 2) the field magnetism will reverse that induced in the needle by the permanent magnets, and the needle will remain deflected to the left, indicating the direction of the current incorrectly, and marking also a smaller deflection than if it had deflected to the right. This reversal of polarity lasts, of course, only while the current flows. It is not an uncommon fault on short lines, especially if the permanent magnets of the galvanometer become weak after being a long time in use. The induced magnetism in the needle is then weak, and the repulsion between its free end and the permanent magnets being less, it swings more nearly horizontal. Both these effects make it more liable to have its polarity reversed.

Each coil is wound with silk covered copper wire ·0092 inch diameter (34 S.W.G.) to a resistance of 50 ohms, within 1 per cent., at a temperature of 60° F. A length of silk covered copper wire ·0164 inch diameter (27 S.W.G.) is soldered to each end of each coil, and connecting tabs are soldered to each end.

Up to about 30° the deflection is proportional to the current, and 1 milliampere should give a deflection of about 5°, when it passes through both coils in series. Above 30° the current required to produce a given deflection is greater than ⅕th milliampere per degree, and a current of 20 milliamperes will give a deflection of about 45°.

Post Office pattern.

4. Fig. 4 gives the connections of the P.O. pattern of the same instrument for series or divided. It is known in the Post Office as the "differential galvanometer," and is similar to the military pattern, except that the external case is of different shape (Fig. 4); there are no brass links, and the terminals to which the ends of the coils are connected are differently arranged.

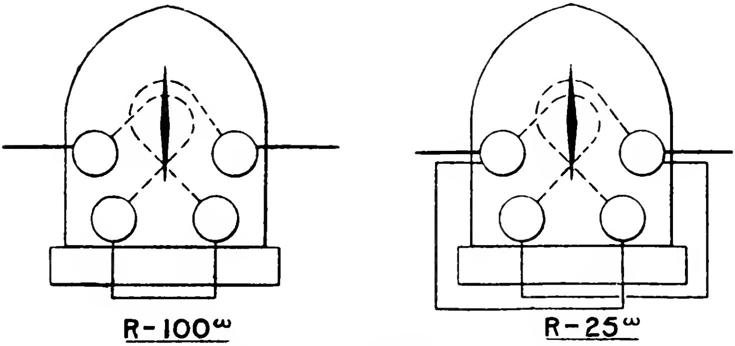


FIG. 4.—Single and Duplex Galvanometer, P.O. Pattern.

The coils are each shunted by a non-inductive resistance of 300 ohms, in order to reduce the self induction of the instrument so as to make it more suitable for high speed working. With both coils in series a current of 20 milliamperes should produce a deflection of 40° to 45°. Up to about 30° the deflection is proportional to the current, 1 milliampere giving a deflection of about 5°.

Detector.

5. The "galvanometer, detector," commonly called the lineman's detector, or Q and I detector (Fig. 5), is another pattern of service galvanometer, used chiefly for testing, and not joined permanently in instrument sets. It is also a two coil galvanometer, the coils being wound one over the other on two bobbins, half of each coil on either bobbin, and the latter mounted close together with their common axis horizontal. The needle is a small steel permanent magnet, moving freely in a vertical plane and pivoted horizontally between the bobbins. It is normally retained in a vertical position by the preponderance of its lower limb and of the lower limb of the pointer fixed to it. In front of the bobbins is a dial, graduated in degrees, over which the pointer swings. The inner coil of the galvanometer has a low resistance (·2 ohm) and few (66) turns, and one end is connected to a terminal marked "Q" on the top of the instrument. The other coil is of higher resistance (100 ohms),

and has a large number of turns (830), and one end is connected to terminal "I." The other ends of the two coils are joined to a common terminal (unlettered) between the other two.

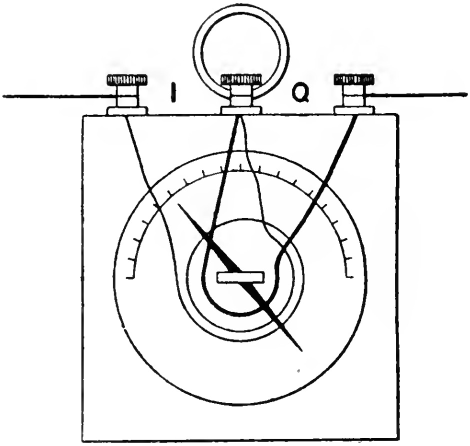


FIG. 5.—Galvanometer, Detector.

"Q" and "I" stand for "quantity" and "intensity," which are misleading terms by which to describe the coils, but have been sanctioned by long usage.

The "Q" coil is wound with silk-covered copper wire of ·048 inch diameter, and its resistance should be ·2 ohm within 3 per cent. at 60° F. The "I" coil is wound with silk-covered copper wire ·006 inch in diameter, and its resistance should be 100 ohms within 5 per cent. at the same temperature.

Up to about 30° the deflection is proportional to the current. A current of 15 milliamperes in the "I" coil should give a deflection of about 45°, and a current of 140 milliamperes in the "Q" coil a deflection of about 40°.

The "intensity" coil is used for localizing faults on lines, and in all cases in which considerable resistance is in circuit with the galvanometer. The "quantity" coil is principally used for battery testing and in cases in which the resistance in circuit (including battery) is under 8 ohms. The methods of using this galvanometer are described in Chapter XIX.

Other galvanometers.

6. There are several other patterns of galvanometers in the service used for testing lines, batteries, and materials. They are not carried by telegraph companies in the field and will be described in the chapters on testing.

Single Current Key.

Key, single current, telegraph equipment.

7. The Morse Key, or "Key, single current telegraph equipment" (Fig. 6), consists of a metallic lever AA, arranged to be operated by the fingers and pivoted near the centre of its

length at B. The movements in either direction are arrested by stops or contacts C and D on either side of the pivot B. On one side the lever is normally held down in contact with the stop by an adjustable spiral spring E; on the other side at the end of the lever is a knob F which is grasped by the fingers. The stop on the lever at D is formed by a screw passing through it by which the amount of play can be regulated. The contact pieces which project from the lever and from corresponding points on the base are terminated with pieces of platinum, the lower contacts being hammered flat to give a good surface for the upper ones to strike upon. Platinum is used because it is not so quickly oxidized by the sparking which takes place at the contacts when the key is in use. This sparking causes oxidation which increases the resistance of the circuit at that point. The contact C is known as the "Front stop," D as the "Back stop" and B as the "Bridge" of the key. Three terminals connected to these points are fixed on the base. Though the design is very simple, it is important for rapid and correct sending that the parts should be of the right proportions so that the key shall be well balanced and work easily, and that the knob be large enough not to cramp the fingers.

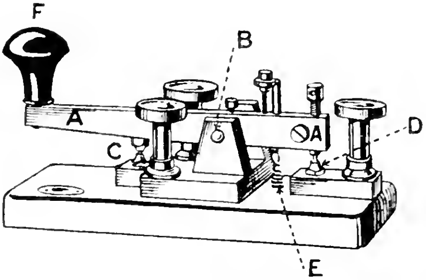


FIG. 6.—Key Single Current, Telegraph Equipment.

Sounders.

Sounder (P.O. pattern).

8. Fig. 7 shows the ordinary pattern of Post Office sounder, sometimes called a "pony" sounder. There are two coils AA wound on soft iron cores and connected in series, the total resistance being 20 ohms, the ends of which are joined to two terminals GG. The cores are made of soft iron tube, split to minimise residual magnetism, and rest on a piece of soft iron H called the yoke, thus forming a horseshoe electro-magnet. A brass lever K is pivoted between two screws E, and is held normally up against the stop C by a spring, the tension of which can be regulated by a milled headed screw F. B is a soft iron armature fixed at right angles to the lever above the cores. When a current flows through the coils the cores become

magnetised, attract the armature and pull down the lever against the pull of the spring. The stop D striking against the brass bracket L prevents the armature touching the cores. If allowed to do so it would stick there when the current ceased instead of being again drawn up against C by the spring. If the current flows for a short time there is a short interval only between the sound of D striking L and K striking C. This signals a dot. A current kept on three times as long makes a longer interval between the sounds and signals a dash.

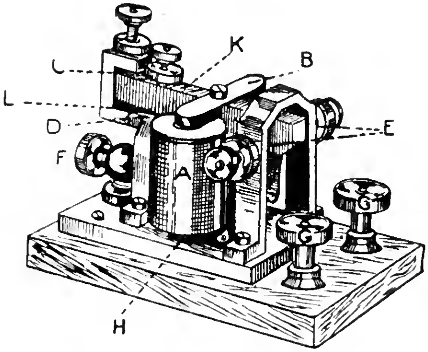


FIG. 7.—Sounder (Post Office Pattern).

Adjustments of sounder.

9. The sounder should be carefully adjusted before working. Before moving any of the adjusting screws E, D, or C, the clamping screws should be loosened; when the adjustments are made, the clamping screws should be tightened up. The first three of the following adjustments can be made before connecting up, the fourth when signals are being sent. They should be made in the order given.

(1) See that the lever K works easily between the pivots at E. These should be screwed up tight enough to prevent any side play in the lever without being too tight to prevent it moving easily up and down. When properly adjusted the screw pivots must be clamped firmly to prevent them shaking loose with the working of the sounder.

(2) Adjust the screw D till the armature when pressed down is just clear of the cores. A thin streak of light should be visible between armature and cores, or armature and nearer core if the two are not quite equidistant. Screw D must then be clamped.

(3) Regulate the play of the lever by means of the screw C. There should be a play of about $\frac{1}{20}$ of an inch between the stops. Then clamp C.

(4) Screw up the milled head F until the required tension of the spring is obtained. It should be such that the armature returns to the upper contact C with the same force as that with

which it is drawn down by the current. It depends, therefore, on the strength of the current received, and this adjustment is best done when the instrument is working. If the tension of spring is to be adjusted when no current is flowing, slack out the spring till the lever rests on the lower stop, then gradually tighten it again till the lever just rises to the top stop. This is the most sensitive adjustment that can be given, *i.e.*, the least possible strength of current will be required to pull the lever down.

If the currents through the coils are very strong it may be an advantage to keep the armature further from the cores by screwing down D and withdrawing C. The smaller the play of the armature the greater the possible speed of signalling, though the clearness of sound is diminished. As a general rule when once a sounder has been put in adjustment nothing should be necessary but a slight alteration in the tension of the spring.

Latest pattern P.O. sounder.

10. In all the latest pattern Post Office sounders a shunt coil of 420 ohms resistance is wound on a bobbin fixed in the base, the ends of the coil being connected to the two terminals. This does not affect the ordinary working of the instrument, as nearly the whole of the current still passes through the coils, which have a resistance of 21 ohms; the total resistance is thus 20 ohms. The objects of the shunt is explained in para. 6, Chapter IV. The latest pattern will work with a current of 55 milliamperes when in perfect order and adjustment.

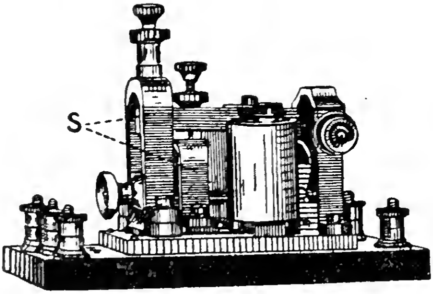
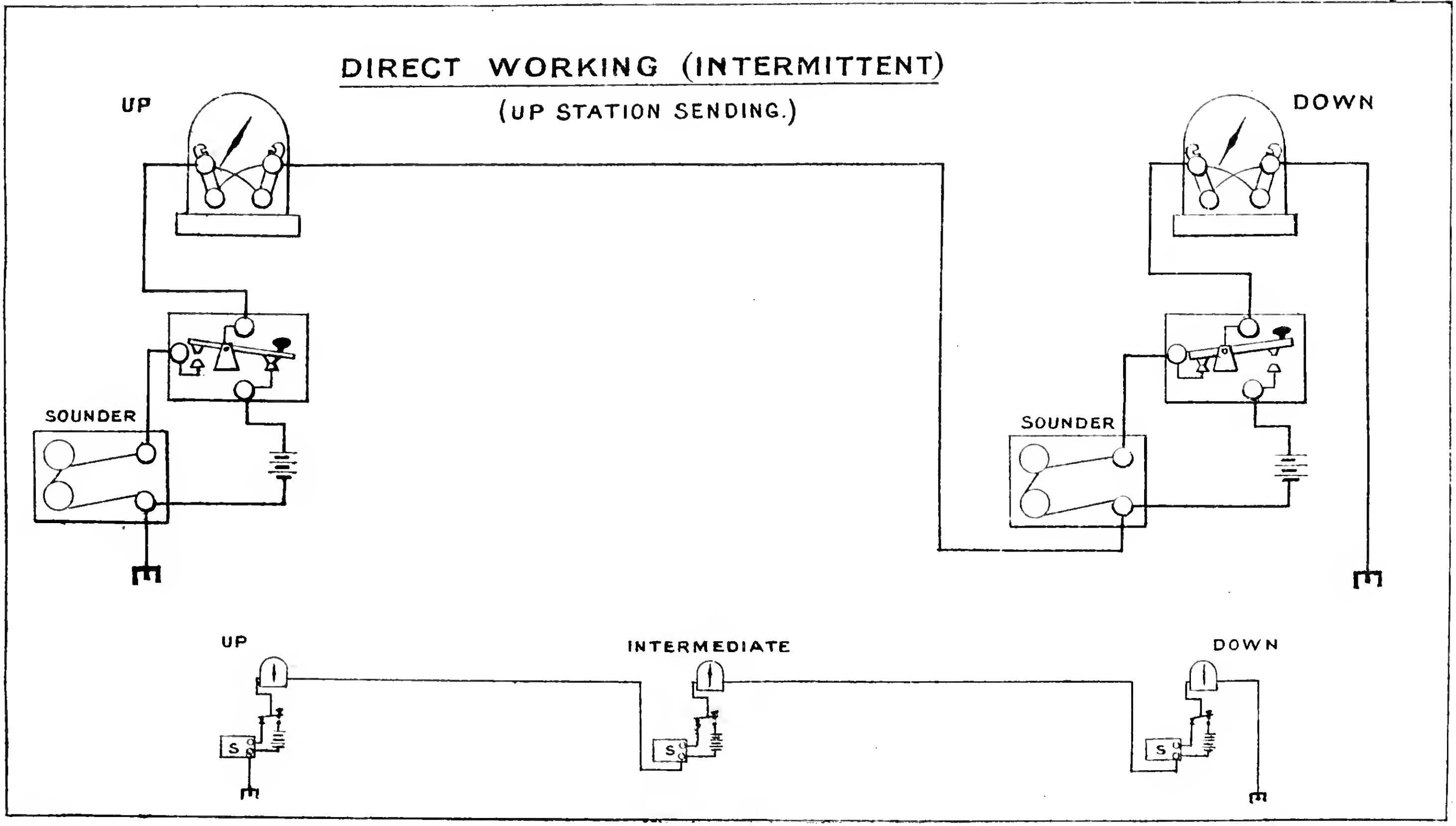


FIG. 8.—Instrument Telegraph, Sounder} Translating.

Service pattern sounder.

11. The service pattern sounder, known as "Instrument telegraph, sounder translating" is shown in Fig. 8. It is constructed on the same principles as the Post Office sounder described above, but its armature lever is furnished with platinum contacts, and the upper and lower contacts are also platinum tipped. These upper and lower contacts are fixed in two stirrup-shaped brackets S on ebonite bases, which insulate the contacts from each other and from the lever. Three terminals, besides the two to which the ends of the coils are brought, are fixed on the base of the instrument. They are

Vol. I. Chap 3. Fig. 9.



DIRECT WORKING (INTERMITTENT)

(UP STATION SENDING.)

H. & C. GRAHAM LTD, LITHRS, LONDON S.E

To face p. 65

marked "S," "T," "M," and connected to top contact, lever, and lower contact respectively. The object of this will be explained in Chapter VI, paras. 3, *et seq.* The resistance of the coils is 40 ohms.

The coils are wound with single silk-covered copper wire ·0108 inch diameter (No. 32 S.W.G.), each coil has a resistance of 20 ohms within 5 per cent. at 60° F. The outer layer consists of No. 25 S.W.G. double silk-covered copper wire. The coils are covered with ebonite $\frac{1}{16}$th in. thick, and are connected up in series, making the resistance of the instrument 40 ohms. The instrument is capable of giving clear and audible signals, at a rate of not less than 20 words a minute, with a current of 20 milliamperes, when in proper adjustment.

Simple Telegraph Circuit.

"Up" and "down" stations.

12. Before describing the connections of telegraph sets, the meaning of "up" and "down" as applied to circuits must be explained. In any circuit one terminal station (the more important usually) is made the "up" station, and the remaining offices are "down" stations with respect to it. The line to the next station is therefore the "down" line. At the next station, however, the line coming from the "up" terminal station is called the "up" line, and that going on to the next office farther from the "up" terminal station is the "down" line, and so on at other stations, the line from the direction of the "up" station being always the "up" line and that leading farther away from it the "down" line.

At any intermediate station all offices between it and the "up" terminal office are "up" stations with respect to it and those in the other direction are "down." At the "up" terminal office the "up" line is put to earth and at the "down" terminal office the "down" line.

As explained below, the current when any station is sending should flow from "up" to "down" along the line.

Direct working (intermittent).

13. The simplest method of connecting up a Morse circuit is shown in Fig. 9. The copper of the battery is joined to front stop of the key and bridge of key to galvanometer. The zinc of battery is joined to one terminal of the sounder, the back stop of the key to the other. The down line (earth at a down station) is joined to the galvanometer, and the up line (earth at an up station) to the sounder and so to the zinc of the battery. The rule to remember is that you send out your current (down the line) from the +ve pole of the battery through your galvanometer, but receive it direct on your sounder.

The object of arranging the circuit in this way is that the current shall always flow in the same direction in the line and therefore through the coils of the sounders or other receiving instruments, whatever station is sending. In this particular system, the receiving instruments (sounders) will work in whichever direction the current flows and two terminal stations might be connected up alike, but in other systems the signals depend on the current flowing in the right direction, and it is better therefore to make the rule apply to all.

The circuit, Fig. 9, should be traced as follows: up station sending—copper to front stop, to bridge, to galvanometer, to line, enters down station at sounder,* through sounder to back stop, to bridge to galvanometer to earth, returns to up station at earth to zinc of the battery.†

This system is called "Direct Working" because the current that works the sounder at the receiving station is obtained directly from the battery at the sending station, and "intermittent" because current only flows during the time a key is pressed down.

Direct working (continuous).

14. There is another method of direct working known as "continuous." The connections are shown in Fig. 10. The front stops of all keys are normally kept down and a continuous current flows when no work is going on, deflecting the galvanometer needles and holding down the armatures. When any station wishes to signal the operator lifts his key, the circuit is broken and the armatures rise. The signals are then sent as in intermittent working, except that the sender's own sounder works as well as those at other stations.

Advantages and disadvantages of "continuous" working.

15. Continuous current working has the following advantages for military work over intermittent working.

(1) Any break in the line is at once notified to all stations by the armatures rising and the deflection going off the galvanometers. In intermittent working the fault would not be observed till the circuit was used or tested.

(2) A battery is not required at every station, it may be all at one station if convenient. This makes it easier to cut in an intermediate station as no battery need be carried (see Fig. 10).

(3) With only a certain number of cells available, more stations can be worked, for one battery does the work for all offices instead of a separate battery being required for each. This single battery must have more cells than any battery at stations working "intermittent" as the resistance of an additional sounder is added to the total resistance of the circuit, but it has much fewer than the total cells at all the intermittent stations together.

(4) There is no difference in the current received at a station when any of the other stations is sending, and the same adjustment of the sounder serves for all. With intermittent working the received current, owing to leakage on the line, varies with the distance of the sending station, and the adjustment of the sounder may have to be altered accordingly. In practice this limits the number of intermediate stations that can be installed on an intermittent circuit.

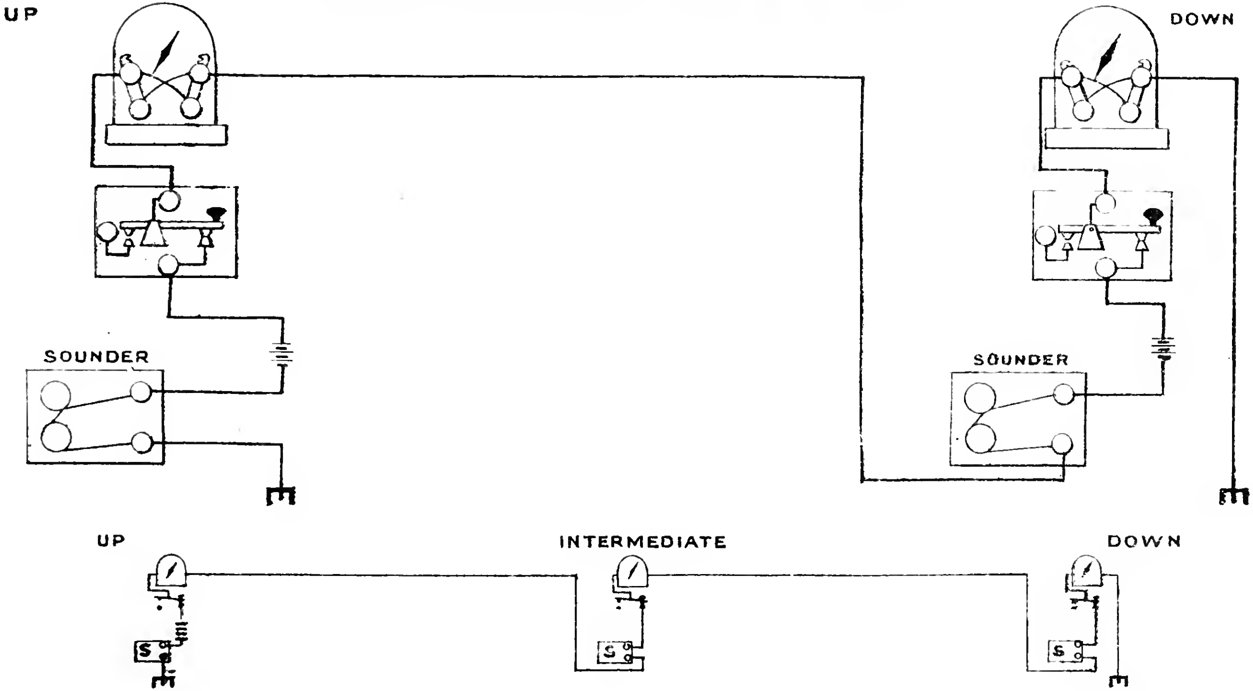
---

* Cannot flow through down battery as front stop is dis.

† Cannot flow through sounder as back stop is dis.

Vol. I. Chap 3. Fig 10.

DIRECT WORKING (CONTINUOUS.)

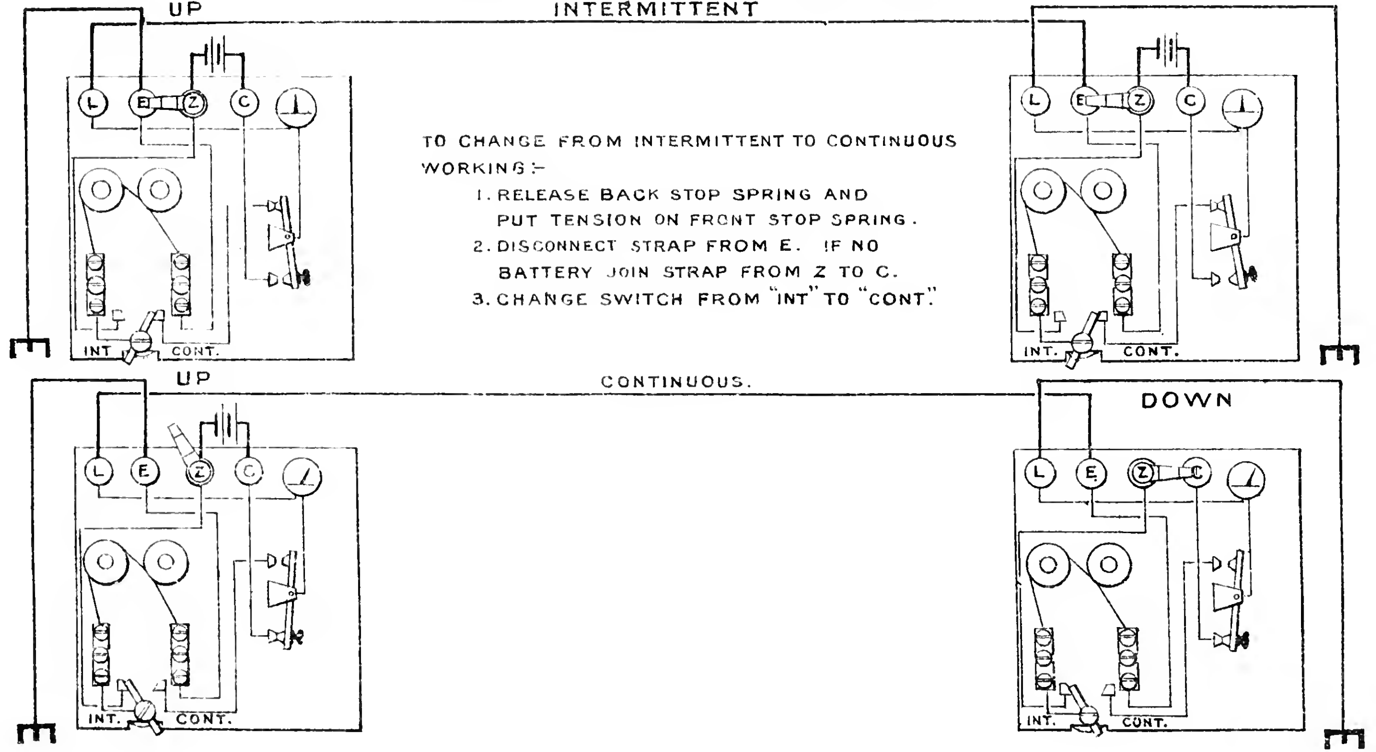


H & C. GRAHAM LTD. LITHRS. LONDON. S.E.

To face p 66.

Vol. I. Chap 3. Fig. 11.

FIELD SOUNDER MARK II.



TO CHANGE FROM INTERMITTENT TO CONTINUOUS WORKING:–

1. RELEASE BACK STOP SPRING AND PUT TENSION ON FRONT STOP SPRING.
2. DISCONNECT STRAP FROM E. IF NO BATTERY JOIN STRAP FROM Z TO C.
3. CHANGE SWITCH FROM "INT" TO "CONT."

1278

To face p. 67

H & C. GRAHAM LTD, LITHRS LONDON. S.E

The disadvantages of the continuous system are:—

(1) The battery is normally working, and therefore becomes exhausted comparatively quickly.

(2) If the battery is at one end of a long line, a fault near that end will prevent any station working, instead of only interrupting communication through the fault, and allowing all stations on one side of the fault to communicate with each other, as is the case with intermittent working.

(3) The "Key, single current" is not suited for this method of working.

For these reasons it is seldom that continuous working would be used in the service.

Military Direct Working Instruments.

Instrument, telegraph, sounder, field, Mark II.

16. Until recently an instrument known as a "Field Sounder" was used in the service. It consisted of sounder, galvanometer, and key grouped on a board with terminals for line, earth and battery connections and arrangements for working intermittent or continuous. Owing to the short distances over which direct working is practicable with the moderate battery power available in the field, this instrument has been given up and is no longer part of the equipment of the Telegraph Companies. Fig. 11 gives, however, a diagram of the connections of the Field Sounder Mark II, joined up for intermittent or continuous working in case the instrument is met with. The field sounder requires a current of about 30 milliamperes. The plan of joining up the instruments of a set permanently on a baseboard, leaving only the external connections to be made when required for use, is adopted in other military sets also.

Morse recorder.

17. Another military instrument designed for direct working is the Morse Recorder or inker, known as the "Instrument, telegraph, Morse recording, Mark II." This instrument is

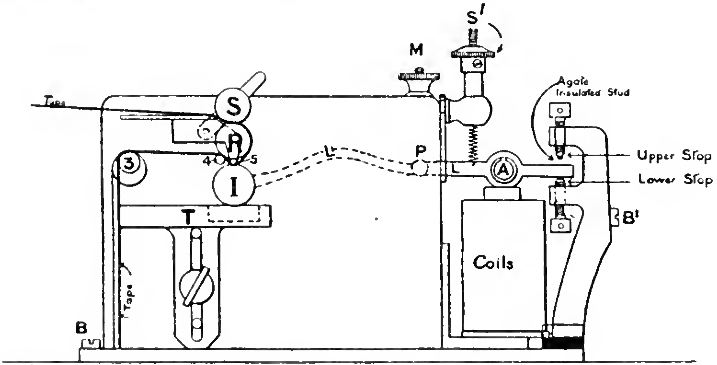


FIG. 12.—Diagrammatic Elevation of Recording Mechanism.

considerably more sensitive than the field sounder, and can therefore be used on comparatively long lines. Instead of being given by the beats of the sounder lever the signals are marked in dots and dashes on a paper tape, otherwise the system of working is the same as when using the sounder. The recording portion (Fig. 12) consists of two coils as in the sounder, with a light armature A carrying a wheel I. The wheel dips normally into an ink trough T and is raised against a tape as the armature is pulled down. The tape is moved forward by clockwork. The extra bulk and weight of the clockwork, its liability to injury from dust, &c., and the comparative uselessness of the instrument if the supply of paper slip fails detract from its value in the field. The baseboard of the recorder (Fig. 13) is fitted with a key and a small galvanometer of 30 ohms resistance, and the connections made for direct working. Four terminals marked L E Z C are provided for connecting "down" line, "up" line, zinc and copper respectively (notice that *earth* is not necessarily connected to E, only at the up station in fact). In addition, arrangements are provided for working "intermittent" or "continuous." These consist of (*a*) two springs on the key with clamping screws, so that either front or back stop can be normally in contact, (*b*) a switch which connects one end of the coils to back stop for "intermittent" or to zinc for "continuous," and (*c*) a strap on terminal Z which is joined across to E for "intermittent" and left open or joined to C for "continuous," according as there is, or is not, a battery at the station.

Two coils of equal resistance and number of turns are wound together on the bobbins, and their ends are brought out to four brass blocks marked U D, Ⓤ Ⓓ respectively. By means of straps the blocks can be joined up to connect the coils in series or in parallel. The resistance of each coil is 150 ohms; if the resistance in the rest of circuit is greater than 150 ohms, a given battery will produce a stronger magnetic pull on the armature with the coils in series; if the rest of the circuit is under 150 ohms the coils should be in divided.*

Two binding screws B and B^1 (Fig. 12) are fixed, one on the brass case and one on the standard which carries the stops. This latter is insulated from the case by an ebonite plate and

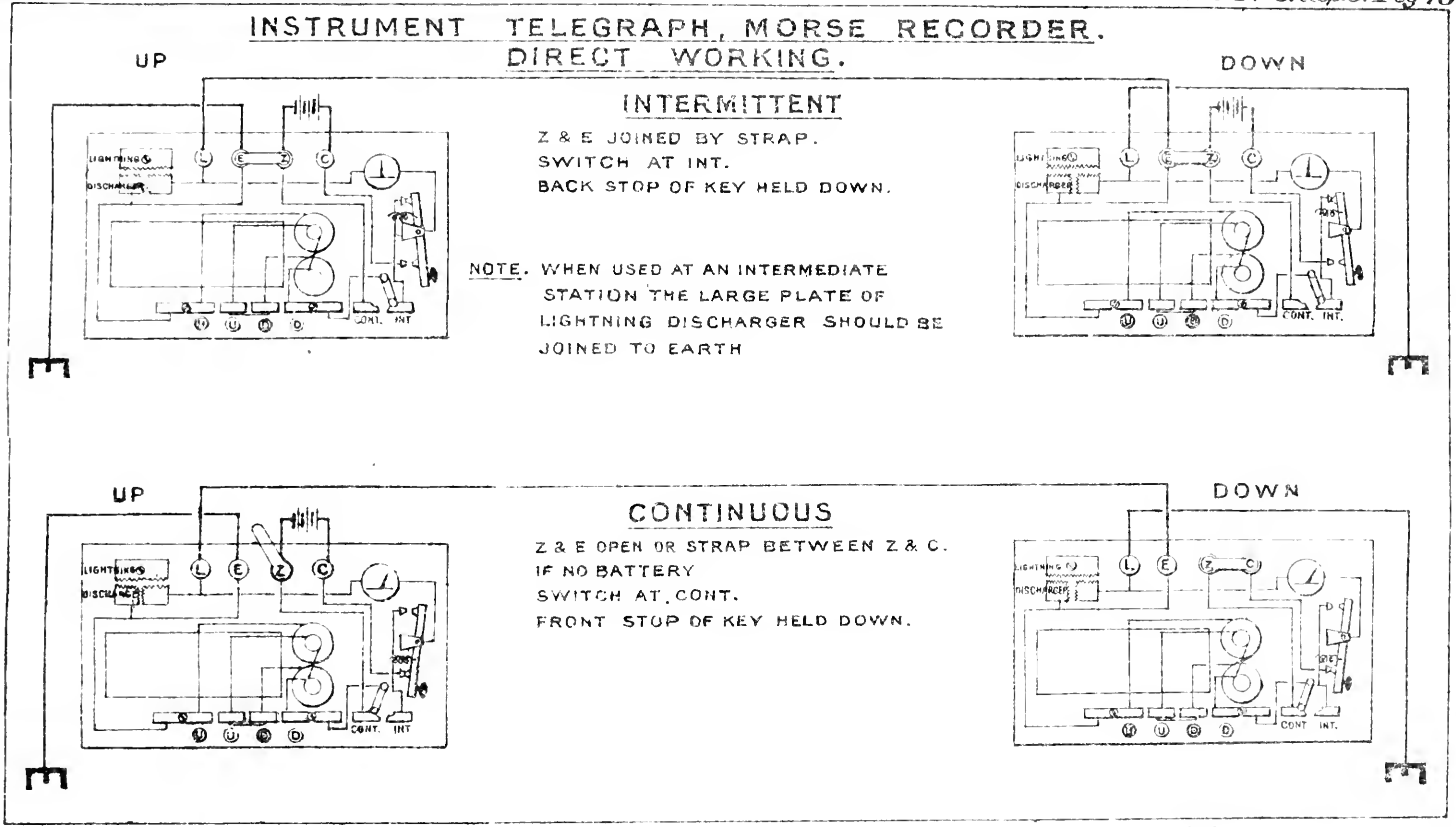
---

* The strength of the magnetic field depends on the ampere turns. The current when coils are in series is $\frac{E}{300 + R}$ flowing through all the turns; in divided current is $\frac{1}{2}\left(\frac{E}{75 + R}\right)$ also through all the turns, but through the two coils simultaneously. The turns being the same in both cases, the magnetic fields are in the proportion $\frac{E}{300 + R} : \frac{E}{150 + 2R}$. When R the remaining resistance in circuit is more than 150, the former (series) is greater, when R is less than 150, the latter (divided) is greater.

Vol. I. Chap 3. Fig 13.

INSTRUMENT TELEGRAPH, MORSE RECORDER.

DIRECT WORKING.



INTERMITTENT

Z & E JOINED BY STRAP.
SWITCH AT INT.
BACK STOP OF KEY HELD DOWN.

NOTE. WHEN USED AT AN INTERMEDIATE STATION THE LARGE PLATE OF LIGHTNING DISCHARGER SHOULD BE JOINED TO EARTH

CONTINUOUS

Z & E OPEN OR STRAP BETWEEN Z & C.
IF NO BATTERY
SWITCH AT CONT.
FRONT STOP OF KEY HELD DOWN.

H & C GRAHAM LTD LITHRS LONDON S.E

To face p 68.

the top contact (which would otherwise be electrically connected with the case through the lever) has an agate point. There is no electrical connection therefore between the screws till the armature is pulled down on to the lower stop. The object of this is to be able to join up a local battery and bell, so that the circuit is closed and the bell rings when signals are received. This local circuit should have a switch or plug to disconnect it when the clerk is at the instrument. The arrangement also allows of the recorder being used as a relay if required (see Chapter IV, para. 8).

Recording mechanism.

18. The recording apparatus is constructed as follows (see Fig. 12). The armature A is fixed to a lever L pivoted at P. Rigidly connected to L and working on the same pivot is a long bent arm L¹ inside the clockwork case. The clockwork consists of a mainspring and a train of wheels controlled by an expanding fan. The wheels I and R are both revolved by the clockwork. I is a flat disc with a fine edge and is called the inking disc. The spindle which carries it has one loose bearing, so that the arm L¹ can raise or depress the disc according as the armature is attracted or withdrawn. The disc dips into a trough or "well" of ink T. S is a spring roller which presses on the wheel R.

The paper slip is carried on a revolving drum in a drawer in the base, it is brought out through a slit, passed over the roller 3, over the steel rod 4, under the steel rod 5, and then between R and S. By this contrivance, as long as the clockwork is in motion, the strip of paper is made to pass over but not to touch the inking disc. When the armature is attracted the inking disc is raised till it touches the paper, and makes a mark representing the duration of the current used to attract the armature. The speed of the clockwork can be regulated by an expanding fan, which should be set so that the paper moves at the rate of 6 feet per minute.

Construction of coils.

19. There is another point worth noticing in the construction of this instrument, viz., the method of winding of the coils (Fig. 14). A partition is fixed in the centre of the core

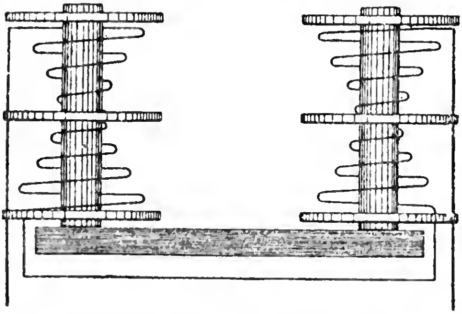


FIG. 14.—Method of Winding Coils.

of each bobbin, the wires to be wound on are brought through a hole in the partition to the middle of their length, and then each half-bobbin is wound starting from the central partition, the winding on each half being of course in the same direction round the core. By this means both ends of a winding are on the top of the bobbins, and can be easily unwound a turn and reconnected if the end is broken. If the coil is wound with no partition, the starting end is covered by all the layers of wire, and has to be brought out under them; if this gets broken the whole coil must be unwound to repair it. This is called "winding from the centre," and is adopted in most instruments.

Adjustments of recorder.

20. The adjustments of the recorder are differently performed from those of the sounder. The adjustment of the armature is not regulated according to electrical considerations at all. The first object is to adjust it to make clear marks on the paper.

The adjustments are as follows:—

(1) Unscrew the lower contact until, when the armature is attracted by the current or pressed down by hand, the inking disc makes clear marks on the paper. If the screw is withdrawn too far the marks will become blurred; if it is not unscrewed far enough the marks will be too light and the dashes may be split up into dots.

(2) The play of the armature should be limited by the upper screw, so that the inking disc just clears the paper when the armature is against the top stop. The play should be small, since the less the distance through which the armature has to move, the less the current required to move it.

(3) The position and play of the armature being thus fixed by mechanical considerations, the adjustment of the distance between the armature and magnet cores is effected by moving the magnet itself towards or away from the armature. This motion is performed by means of the milled screw M (Fig 12), which lifts or lowers the magnetic coils. The most sensitive adjustment is obtained when only a thin streak of light can be seen between the armature and the nearer core, the lever being pressed down on the lower contact.

(4) The tension spring is adjusted by the milled head S′ till the armature returns to the top contact with the same force that it is drawn down by the current. If no current is flowing, slack out the spring till the lever rests on the lower stop, then screw up again till it just rises against the top stop. This is the most sensitive position, but the adjustment may require modifying when the work begins.

The Instrument, telegraph, Morse recorder, Mark II, should work with a current of 2·5 milliamperes when in perfect order.

The clamping screws attached to the upper and lower contact screws should invariably be set quite tight after the latter are adjusted, to prevent the position of the contact screws being altered by the vibration of the armature. Fig. 13 gives diagrams of two field recorders connected up for intermittent or continuous working. The paper slip used is known as "Paper, Morse, $\frac{3}{8}$-inch" and the ink as "Ink, Morse instruments."

Post Office pattern.

21. There is a Post Office pattern of this instrument known as the "Combined inker." It differs from the military instrument in a few details of construction but its action and adjustments are the same. There are no commutator blocks for the coils which are connected in series (total resistance 300 ohms), and there are no arrangements for continuous working. Fig. 15 gives a diagram of connections. The resistance of the galvanometer is 30 ohms.

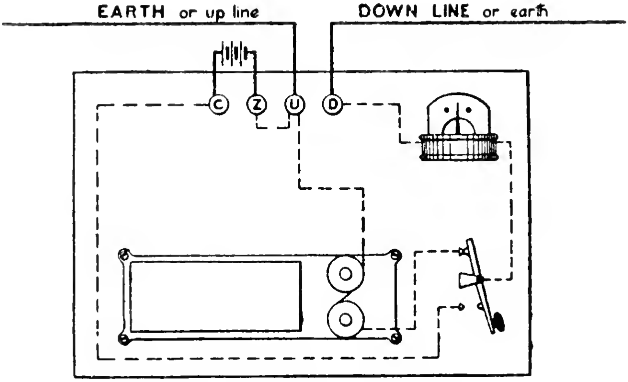


FIG. 15.—Post Office Combined Inker.

Use of recorders.

22. With good operators it is much quicker to read by ear from a sounder, than by eye from the tape of a recorder. These instruments are, therefore, seldom used unless only inferior operators are available, or where it is desired to keep a record of messages sent, *e.g.*, "line clear" messages, on a railway worked without block instruments. They are not part of the equipment of the field telegraph companies, but would be used for railway working.

CHAPTER IV.

RELAYS AND SINGLE CURRENT WORKING.

Relays.

1. The direct working systems (as mentioned in Chapter III, para. 16), cannot be used over any great distance, say more than 5 or 6 miles, without inconveniently large battery power. The sounder requires a good deal of current to work it, and when line resistance is large the battery voltage must be high to get enough current through. The longer also the line the greater is the leakage of current along it, and the greater the difficulty in getting enough of the current through to the receiving instrument. On long lines, therefore, the sounder is replaced by a relay. This instrument works with much less current than is required for a sounder. It does not itself give readable signals, but closes and opens a "local" circuit in which a battery and sounder are so arranged that when current flows through the relay the local circuit is closed and the sounder armature pulled down by the local battery current. The local circuit is of very low resistance, so that a few cells in the local battery supply enough current for the sounder. Besides working with less current the relay has the further advantage that whereas, for satisfactory working, the sounder requires the strength of the signals from all stations on the circuit to be equal, a result impossible to attain with badly insulated lines, the relay will efficiently perform its work with but little alteration in adjustment though the strength of the received current varies considerably. This quality of the relay is called its "range." Before describing how the relay is connected up in circuit it is necessary to explain its action, and as the instrument is used in nearly all telegraph circuits this should be thoroughly understood.

Relay, Telegraph, Mark II.

2. The service pattern relay (Relay, Telegraph, Mark II) is the same as the Post Office standard relay (Type A). Fig. 1 gives a view of the instrument with the cover removed, and its construction is shown diagrammatically in Fig. 2. It consists of two upright electro-magnets with soft iron cores. These cores are polarized by a horseshoe permanent magnet, which for convenience is bent round the electro-magnets. The S end of the permanent magnet is uppermost and the two ends of the cores near it are therefore polarized north, while the two bottom ends are south. Two short soft iron armatures are fixed on a vertical brass axis and oscillate, one between the upper or north ends of the cores and the other between the lower or south ends. The end of the upper armature nearer the permanent magnet

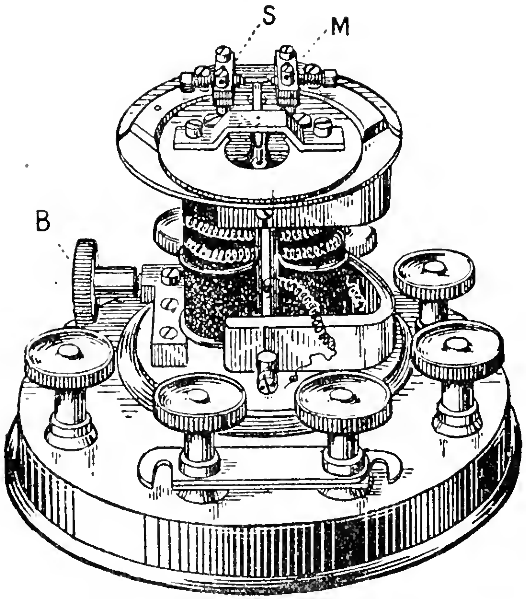


FIG. 1.—Relay Telegraph, Mark II (Post Office Standard Relay A).

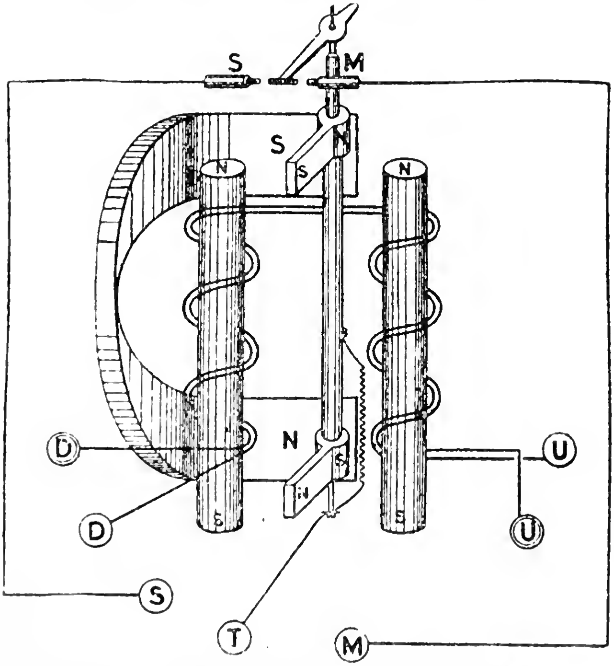


FIG. 2.—Relay Telegraph, Mark II, diagram of construotion.

is polarized north and its free end therefore south, and the free end of the lower armature is north. A light German silver tongue is attached to the brass axle and oscillates with the armatures. In doing so it makes contact with two platinum tipped studs M and S called respectively the "marking" and "spacing" stops, and prevents the armatures touching the cores.

When no current is flowing, the free end of the top armature being a south pole is attracted equally by the tops of both cores which are north (similarly with the bottom armature). If the tongue and the armatures were exactly central between the pole pieces they would be retained there, but if ever so slightly displaced to one side or other they will be further moved in that direction by the stronger pull of the nearer pole until the tongue rests against one of the stops. The stops can be set so as to limit the oscillations of the tongue to any desired extent. They are held in a frame C, see Fig. 3, called the carriage, which can be moved to one side or other by a milled headed screw, so that while the amount of freedom given to the end of the tongue by the stops remains the same, the position of the tongue (and armatures) with respect to the cores can be altered at will by turning the screw B (Fig. 1) to one side or other. By screwing B so that the tongue is made to approach S and recede from M it is given a "bias" to rest in contact with the spacing stop, while the reverse movement will give the tongue a bias to rest in contact with the marking stop.

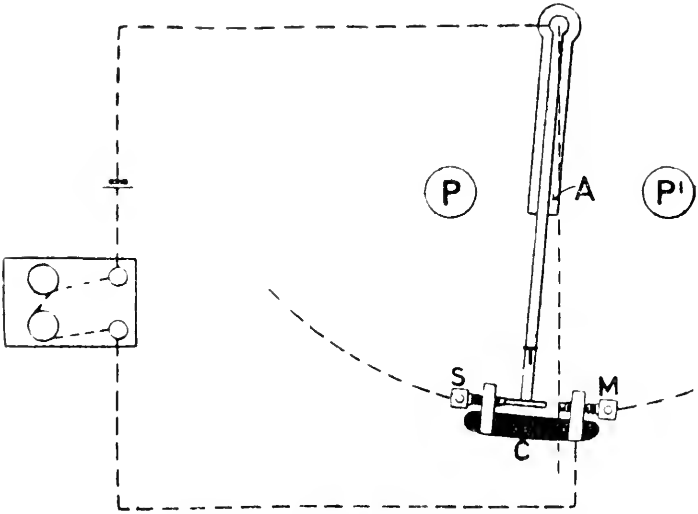


FIG. 3.—Relay Telegraph, Mark II, diagram of action.

4. Two coils of equal resistance (each 200 ohms) and

number of turns are wound on the cores and their ends brought out to terminals U D, and Ⓤ Ⓓ respectively on the base of the relay. The terminals can be connected by brass straps so that the coils are joined in series or divided, as in the case of the S. and D. galvanometer. The marking stop is connected to terminal M (Fig. 2) on the base, the spacing stop to S. and the tongue to T. Fig. 3 shows the top ends of the electro-magnets P P^1, the top armature A, tongue T, and carriage C with stops M and S (the lower armature is not shown but is attracted and moves always in same direction as the top one). The action of the relay when in use for single current working is as follows:—The local circuit is joined to T and M so that current only flows in it when the tongue is against the marking stop. When no current from line is flowing through the coils of the relay the tongue is held against the spacing stop; because though P P^1 are polarized equally strongly by the permanent magnet, the armatures have been pushed nearer P than P^1 and are therefore attracted more strongly to that side. The local circuit then is broken and no current flows in it. When the line current flows through the coils from U to D, or Ⓤ to Ⓓ, it also magnetizes the cores, making P^1 north at the top and south at the bottom, and P south at the top and north at the bottom, so that the original polarity of P^1 is made much stronger than before, and that of P much weaker or may be reversed. P^1 therefore pulls the armatures towards it and away from P until the tongue is brought up against the marking stop. The local circuit is then closed and a current flows in it pulling down the sounder armature as long as the line current continues. When line current is cut off P and P^1 are again left equal, and the armatures being still nearer P than P^1 are drawn away from P^1 (breaking the local circuit) till the tongue strikes the spacing stop.

It will be noticed that enough bias must be given to keep the armatures nearer P than P^1 even when the tongue is against the marking stop. If they cross the central line when going over to marking the tongue will remain against the marking stop when the line current ceases, for the armatures would then be nearer P^1 than P.

The coils are wound half on each bobbin (being wound from the centre, see Chapter III, para. 19), of single silk-covered copper wire, No. 40 S.W.G. Each end of each coil has a sufficient length of No. 30 S.W.G., double silk-covered wire connected to it to form one complete layer. Each coil has ends of different colours (green and white). The coils are jacketed with paper and book-binders' cloth. The coils are differential, and are of 200 ohms resistance, each within 1 per cent at 60° F.

When properly adjusted the relay should give reliable signals with reverse currents of 0·55 milliampere, and with a single current key when the current is 1 milliampere, the coils being in series in each case, if the coils are in parallel double the current is required in each case.

Relays depend for their action on the polarization of the cores and armatures by permanent magnets, and are called therefore "polarized" instruments. The direction in which the current flows through their coils makes a difference in their working. They differ in this respect from "non-polarized" instruments, such as the sounder, which do not depend on a permanent magnet and work in the same manner in whichever direction the current flows.

Relay Telegraph, Mark I. (Siemens relay).

3. The Relay, Telegraph, Mark I, often known as the Siemens relay, may still sometimes be met with, though it is now becoming obsolete. It is shown diagramatically in Fig. 4. Its action is similar to that of the Mark II. It has a L-shaped permanent magnet which polarizes the cores of the electro-magnets and the single armature. The latter is pivoted in a notch at the upper end of the permanent magnet. The two cores are joined by a yoke and have adjustable pole pieces. The relay is not so sensitive as the Mark II, *i.e.*, it requires more current (about twice as much) to work it owing to there being only one rather heavy armature instead of two light ones. The carriage also moves in a straight line, not in the arc of a circle, as does that of the Mark II. The drawback of this is that the amount of play of the tongue is reduced slightly as bias is given and with fine adjustments is liable to jam between the stops. With the Mark II the amount of play remains the same whatever the position of the carriage.

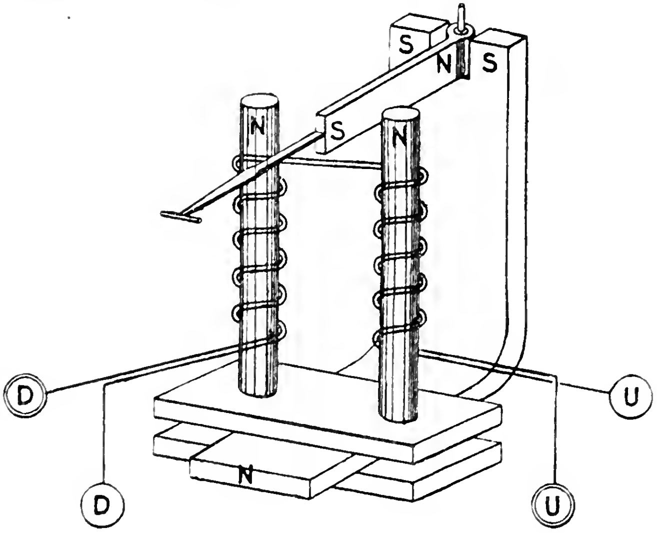


FIG. 4.—Relay, Telegraph, Mark I.

Single Current System, with Relay.

Single current system.

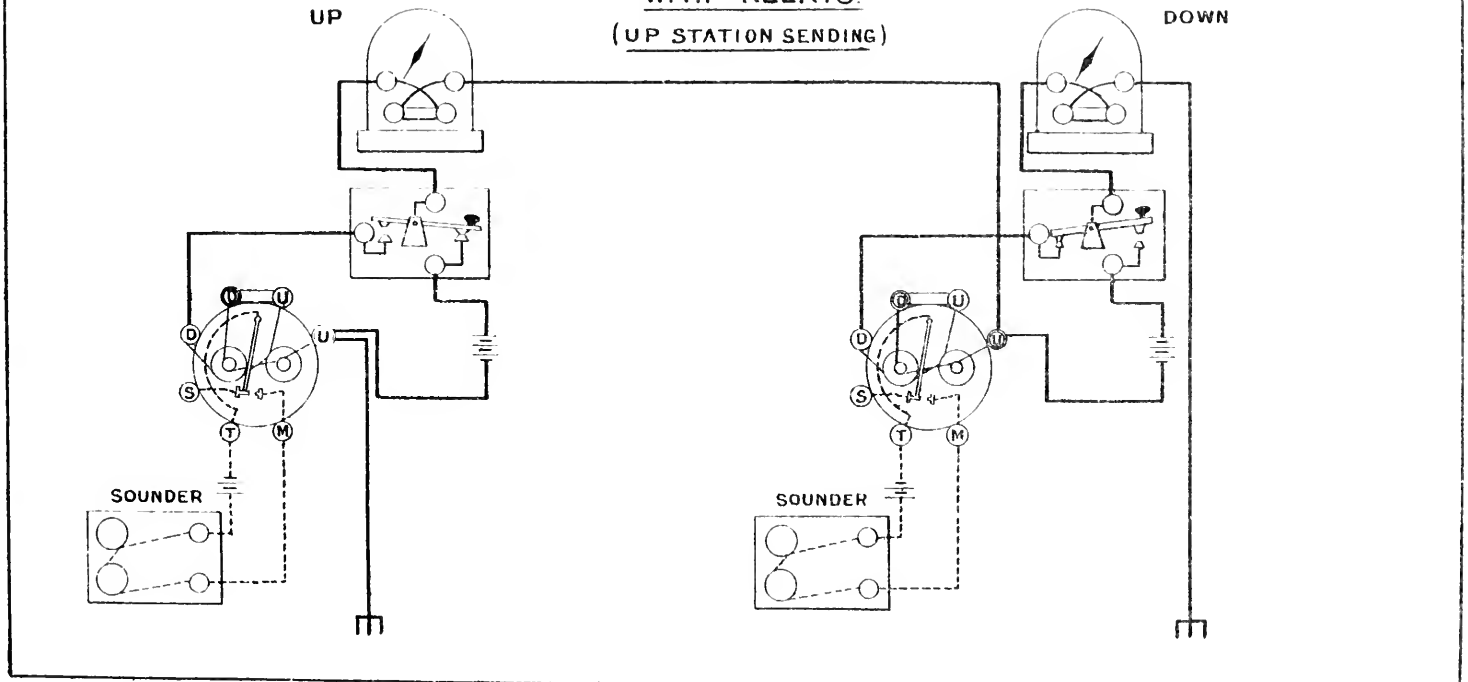
4. The connections for single current working are shown in Fig. 5. The relay takes the place of the sounder in direct

Chap. 4. Fig. 5.

SINGLE CURRENT WORKING

WITH RELAYS.

(UP STATION SENDING)



To face p. 77

H & C GRAHAM L^TD, LITH^RS, LONDON, S.E.

working and a local circuit is added. Care must be taken to connect the up line to Ⓤ of the relay so that the incoming current flows flow Ⓤ to D through the coils (coils being in series), otherwise the tongue will remain over to the spacing stop, and no signals will be received. The terminals are marked "U" for "Up" and "D" for "Down" to prevent this mistake being made. Terminal S of the relay is not used.

Tracing the circuit when up station is sending, the current flows from copper of the battery to front stop, to bridge, to galvo, to line; enters down station at Ⓤ of relay, through the coils to D, to back stop of key, to galvo, to earth; returns to up station at earth to Ⓤ of relay to zinc of the battery.* At the down station the current from Ⓤ to D of relay has closed the local circuit and current flows from copper of local battery, through coils of sounder to M to T, back to zinc of the battery.

5. The adjustments of the relay for working "Single current" are as follows:—

Adjustments of relay for S.C. working.

(1) Screw up the marking and spacing stops so that the tongue has only a very small amount of play. The movement should be as small as possible, provided only that contact at the marking stop is completely broken when the line current ceases.

(2) Adjust the milled headed screw to give the tongue the bias required to ensure it returning to the spacing stop when the line current ceases. If too much bias is given the effect of the incoming current is weakened and the signals may be split. If too little bias is given the tongue will remain in contact with the marking stop when the current ceases. The best position of the carriage should be determined by trial when the working current is flowing.

Sounder shunt.

6. The fact that a resistance of 420 ohms is placed across the terminals of the later pattern Post Office sounders was referred to in Chapter III, para. 10. The E.M.F. induced in the sounder coils when the tongue of the relay breaks the local circuit is very considerable, and, if no other path is available, produces a spark between the tongue and the marking stop. This sparking oxidizes the contact points, and may thus put a high resistance into the local circuit. When a shunt is provided, this E.M.F. from the coils causes a current to flow through the shunt, instead of forcing a path by sparking.

Sounder, Field, Mark II, and instrument telegraph, Morse recording

7. The field sounder and military recorder are not designed to work in a low resistance local circuit, but can be used in place of a local sounder if necessary. E terminal should be joined to

---

* No path is open through coils of up relay since the back stop of key is dis.

used in local circuit.

M of the relay, Z terminal to one pole of the local battery and the switch should be at "continuous." This is a better arrangement than using L and E terminals with the switch at "intermittent," since in the latter case the local current has not only to traverse the galvanometer, which is unnecessary, but has also to pass across the back stop of the key, which may be a source of trouble. The coils of the recorder should be joined up in parallel. Fig 6 shows a single current set (up station) with a recorder in local circuit.

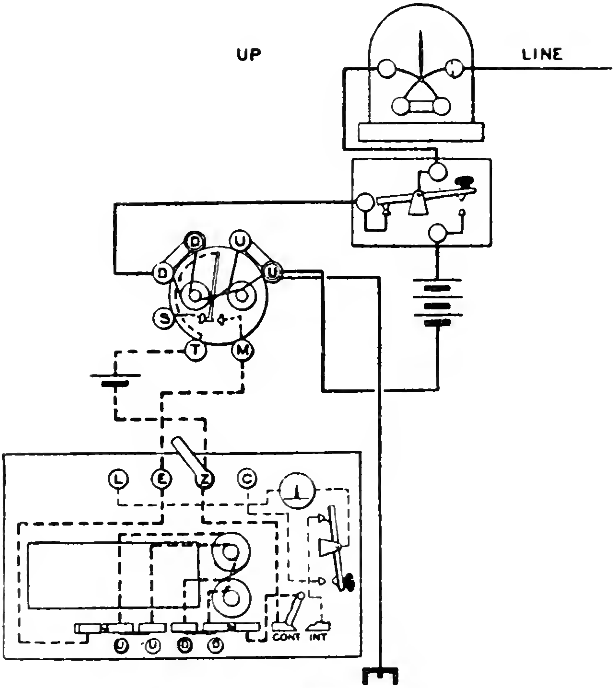
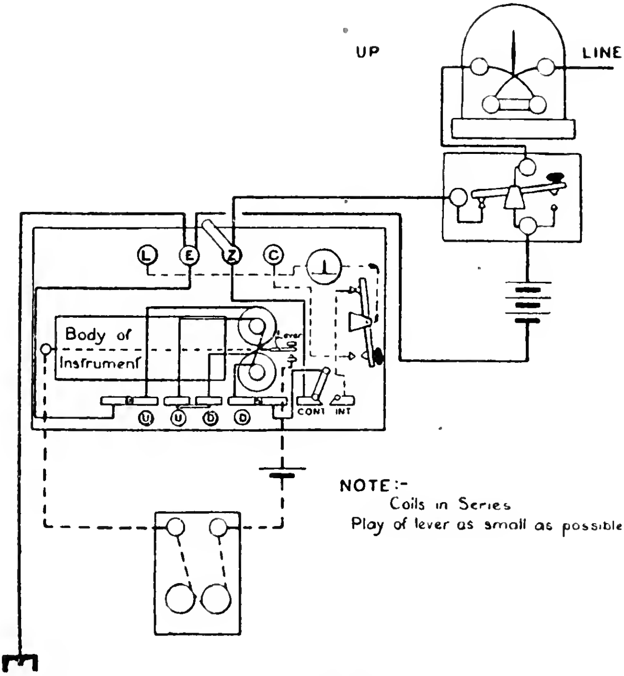


FIG. 6.—Single Current Set (using Military Recorder in Local Circuit).

Military recorder used as a relay.

8. The military recorder being a fairly sensitive instrument working with less current than a sounder, may, if occasion arises, be used as a relay. It is not, of course, as sensitive as a relay, but can be improved in this respect by bringing the armature very close to the cores of the electromagnet and limiting its play to a very small fraction of an inch. The screws B, B^1 Fig. 13, Chapter III, are used as "T" and "M" of the relay and terminals E and Z as Ⓤ and "D" of relay, and switch should be at "cont."

The adjustments should of course be made without reference to the marking of the tape ; in fact, the disc must *not* touch the paper when the armature is attracted, as this would interfere with the firmness of the contact on the lower stop. Fig. 7 gives a diagram of connections.



NOTE:-
Coils in Series
Play of lever as small as possible

FIG 7.—Single Current Set, using Military Recorder as a Relay.

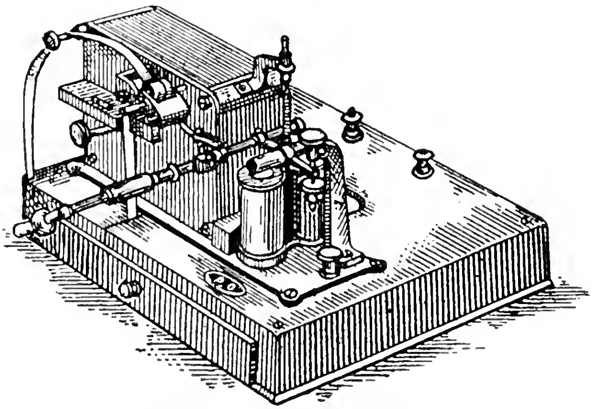


FIG. 8.—Post Office Local Inker.

Local inker.

9. Fig. 8 is a view of a Post Office pattern inker, designed for working in a local circuit. The resistance of the coils is 40 ohms only, and they have a shunt of 500 ohms across their terminals, reducing the total resistance to 37 ohms. The mechanical details are the same as those of the "Combined inker" (para. 21, Chapter III). The two terminals shown in Fig. 8 are connected direct to the end of the coils, and the instrument simply replaces the sounder in the local circuit. It should work when in perfect order with 69 milliamperes.

CHAPTER V.

DOUBLE CURRENT WORKING.

Principle of double current working.

1. When explaining the action of the relay in single current working (Chapter IV, para. 2), it was explained that it was necessary for the tongue to work between limits which were wholly to one side of the central line between the poles. The "marking pole" (P^1, Fig. 3, Chapter IV) therefore has to exercise its pull on the armature from a distance always more than half that between the poles. In double current working the tongue is allowed to work equally to either side of the centre line, and is therefore nearer to the marking pole than when adjusted for single current working. With the same strength of pole as in single current the pull on the armature will be greater, or the same pull on the armature can be given by a weaker pole, that is with a weaker current flowing through the coils. Improved signals, or signals at a greater distance than with single current working, are thus obtained.

Advantages.

2. To take the tongue back to the spacing stop after the marking current has ceased, a reverse or spacing current is used. This current flows in the opposite direction round the circuit as soon as the marking current ceases. It passes through the coils of the relay from D to Ⓤ, making the original induced polarity of P (Fig. 3, Chapter IV) much stronger than before and reversing or neutralizing the polarity of P^1, thus producing the opposite effect to the marking current. P is now much stronger than P^1, and the armatures carry the tongue back to the spacing stop. No bias is necessary, and the tongue can work centrally between the poles. Double current working has the further advantage that the range of the relay is increased, or rather the full range of the instrument can be utilized. Changes of adjustment required in single current working when varying currents are received from stations at different distances or in consequence of changing amount of leakage on the line, are unnecessary in double current working, since if the marking current varies for any reason the reversing current will be altered to the same extent.

Effects of capacity of long lines.

3. Double current working counteracts also the effects of capacity on long lines or cables. In single current working the capacity of the line delays the rise of current at the receiving station at the beginning of a signal and prolongs it at the end, making the relative length of dots and dashes different at the receiving station to what they were at the sending station. The "marks" may be lengthened and the "spaces" shortened, or

vice versa; and when the capacity is very large signals may either run into one another or fail to get through. This involves slow sending in order to get distinct signals. In double current working the battery is kept connected to line but reversed for "spacing"; by this means the rates of charge and of discharge are hastened, and the reversals of charge take the same time, so that the relative lengths of marking and spacing currents are kept the same at sending and receiving stations. Signals are therefore clearer than when working single current, and can follow one another more quickly. Fig. 1 will give some idea of the action.

Key, double current, Mark I.

4. A special form of key, known as "Key, double current, Mark II," is used with the double current system, which contains a switch connecting the line to the receiving or sending portion of the circuit at will. With the switch in the sending position, the operator can put the current on the line in either direction, as required, from the same battery. It consists practically of two single current keys joined in one, and moved together by one handle. For convenience of construction, the front contact of each key is removed, and the back part has two contacts, an upper and a lower, working between two springs or stops. A spiral spring keeps the key normally in contact with the lower stops. Fig. 2 gives a view of the key, and Figs. 3 and 4 plans of the instrument with switch at "send" and "receive" respectively.

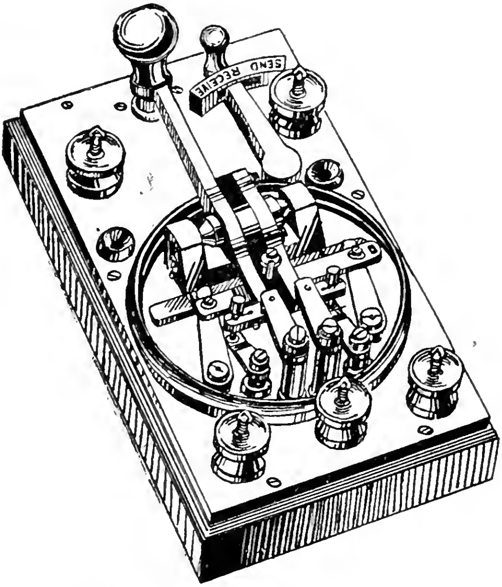
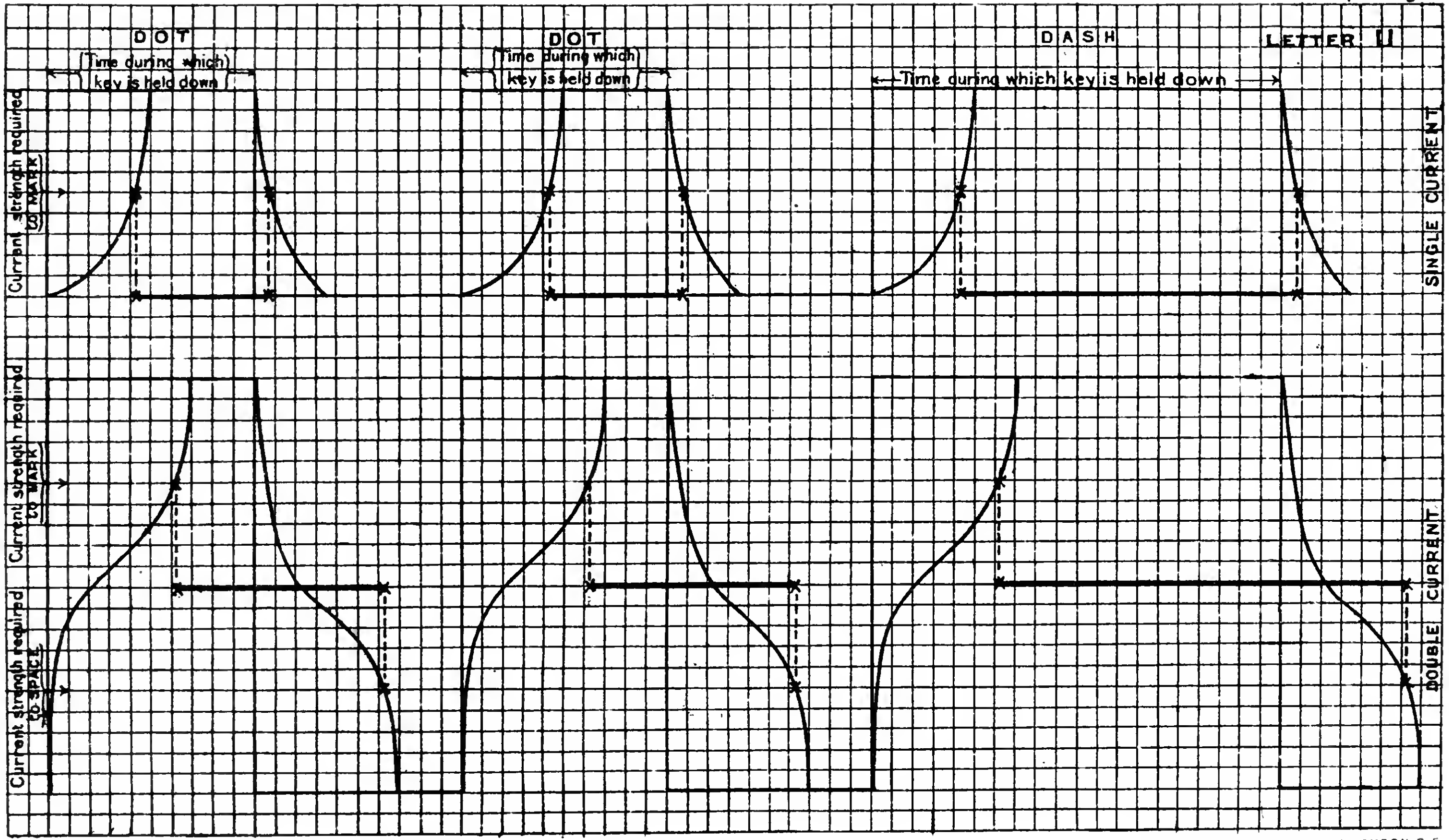


FIG. 2.—Key, Double Current, Mark II

Chap 5. Fig. 1.



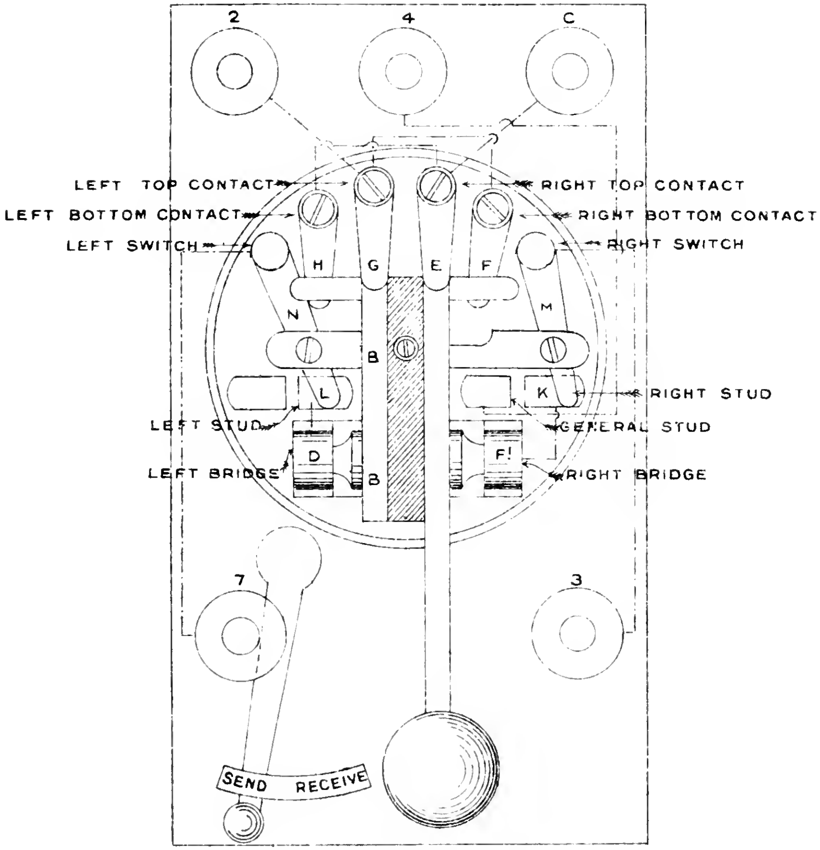
H & C GRAHAM LTD, LITHRS, LONDON, S.E.

To face p 82.

(Chap. V)

Fig. 3.

KEY, DOUBLE CURRENT.



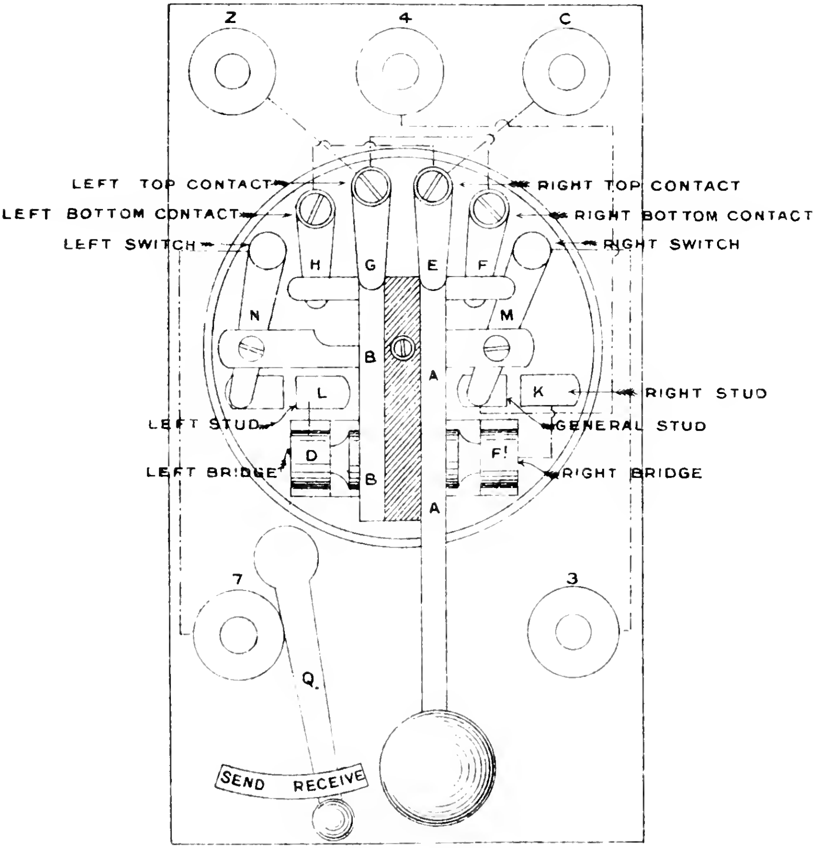
To Face p. 82

H & C GRAHAM LTD, LITHRS LONDON S E

(Chap. V)

Fig. 4.

KEY, DOUBLE CURRENT.



To face p. 82

H & C GRAHAM LTD. LITHRS LONDON S.E.

AA is the right key and BB the left. The two keys are insulated from one another by a piece of ebonite, shown shaded, and each has a separate bridge, F^1 being the bridge of A, and D that of B. E and F are the upper and lower contacts of key A, and G and H those of key B. When the key is at rest, contact is made with the stops F and H, and when it is pressed with E and G.

The bridges of the key are connected to two studs, K L respectively. M N are the right and left switches, joined by an ebonite (or insulated brass) link, and moved together by the switch handle Q. When the handle is at "send," the switches rest on the right and left studs. When it is at "receive," the right switch rests on a third stud called the "general stud," and the left switch on a fourth stud, which is dis.

The instrument has five terminals, Z and C are for the battery connections, Z is joined to the left top contact and right bottom contact, C to right top contact and left bottom contact. Terminal 3 is connected to the right switch, terminal 7 to the left switch, and terminal 4 to the general stud. The up line is brought (*viâ* Ⓤ of relay) to 7 and down line through the galvanometer to 3. When the switch is at "send" and the key depressed, the current flows from C through the right key to 3 to down line and back along up line to 7 to the left key to Z; this is the marking current. When the key is released the current flows from C along the left key out to the up line at 7 and returns by the down line to 3 along the right key to the zinc. This is the spacing current traversing the line in the reverse direction. One end of the relay coils, Ⓤ, is joined to 7, and the other end of the coils to 4, but the circuit through the coils is disconnected at the general stud when the switch is at "send." When the switch is at "receive" the general stud is joined to 3 by the right switch, putting the relay in circuit, and the left switch and 7 are dis., cutting out the battery.

Key, double current, Mark II.

5. The key double current, Mark II, is electrically the same as Mark I. The differences are as follows :—

(*a*) Mark II has standard terminals.
(*b*) Mark I has a glass top to the cover, and Mark II has the cover entirely of brass.
(*c*) The contact between the moving portion of the key and the "bridge" is differently arranged.

Key, double current, Mark III.

6. The difference between the Mark II and Mark III keys are as follows :—

(*a*) Mark III has adjustable upper and lower contacts, and clamping screws are provided instead of fixed contact blocks.
(*b*) Instead of curved brass springs let into the underside of the "bridge," steel springs with platinum contacts are fitted at the ends of the brass blocks to make contact on the ends of the spindle.

Double current set.

7. The fact that a switch has to be used for sending or receiving is a slight drawback to the double current system, but it is not found that it gives any trouble in practice.

Fig. 5 gives a diagram of a double current set with double current keys. Tracing currents when up station is sending, we have, when key is pressed:—Copper to C, to right top contact, to right key, right bridge, right stud, right switch to 3, thence through galvanometer to down line, enters down station at Ⓤ of the relay through the coils to D, to 4, to general stud, to right switch, to 3, through galvanometer to earth; returns to up station at earth, to Ⓤ of relay, to 7, to left switch, to left stud, left bridge, left top contact to Z. This is the marking current which has passed through the down relay from Ⓤ to D, drawn over the tongue to marking stop and closed the local circuit.

When the key at the up station is released, the current flows from copper to left bottom contact, to left key, left bridge, left stud to 7, to Ⓤ of relay to earth. Enters down station at earth, through galvanometer to 3, to general stud, to 4, to D of relay, through coils to Ⓤ to up line; returns to up station through galvanometer to 3, to right switch, right stud, right bridge, right key, to right lower contact, to zinc. This is the spacing current which has passed through the down relay from D to Ⓤ, drawn back the tongue to the spacing stop, and opened the local circuit. It is convenient to remember, as far as the key is concerned, that the marking current flows from C to 3 and returns from 7 to Z, while the spacing current flows from C to 7 and returns from 3 to Z, as shown in Figs. 6 and 7.

When a station is not sending, the switch must always be left at "receive," otherwise it cannot be called up, and its battery is exhausting itself by sending a continuous (spacing) current to line. Care must be taken not to put the switch over from "send" to "receive" while the key is pressed. If this is done the last current sent out will be a marking current, and the tongue of the relay at the receiving station will remain against the marking stop, exhausting the local battery. To avoid this the relay, even in double current working, is as a rule given a slight bias so that the tongue will return to the spacing stop even if no spacing current is sent. Some of the advantage of double current working is lost by so doing, and it should not be necessary with good clerks.

Common faults in key.

8. It also happens occasionally that, due to a not uncommon fault in the key, a double current set is worked single current only.

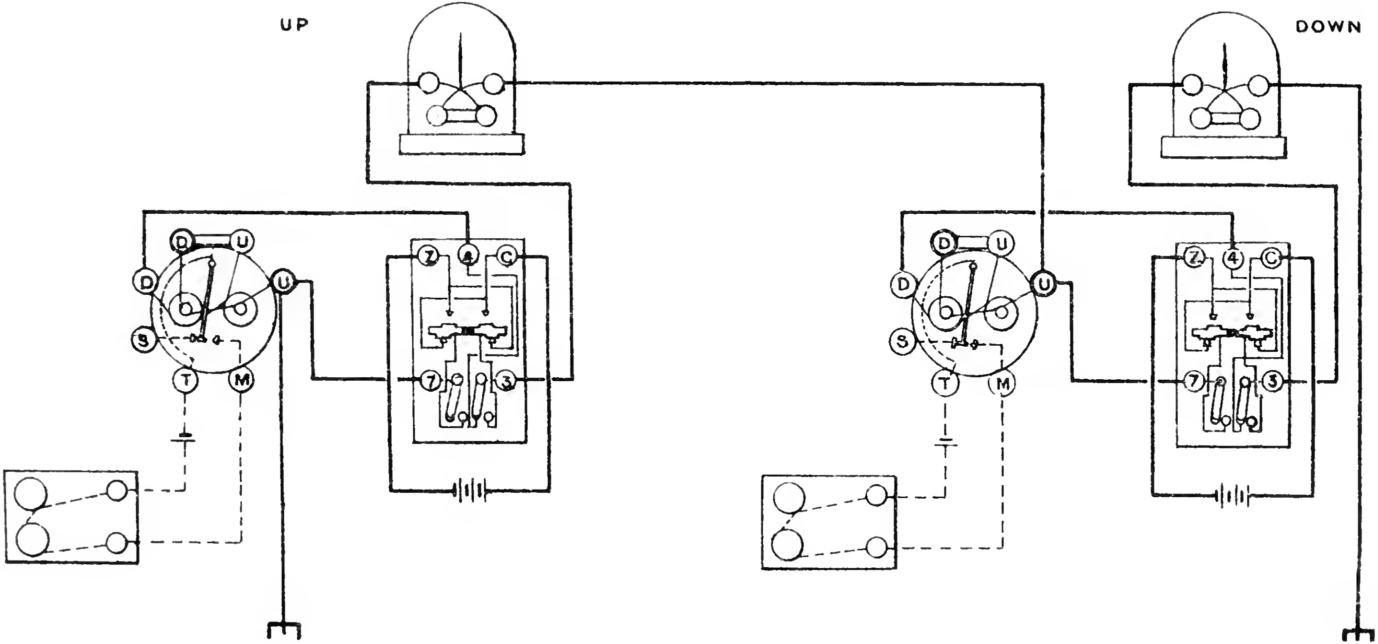
If one of the top springs fails to make contact and no marking current is flowing, the receiving station, by giving bias to the marking side, may still get signals; but when the

Chap 5 Fig 5

DOUBLE CURRENT SYSTEM

USING DOUBLE CURRENT KEYS

Keys shown in "Receive" position

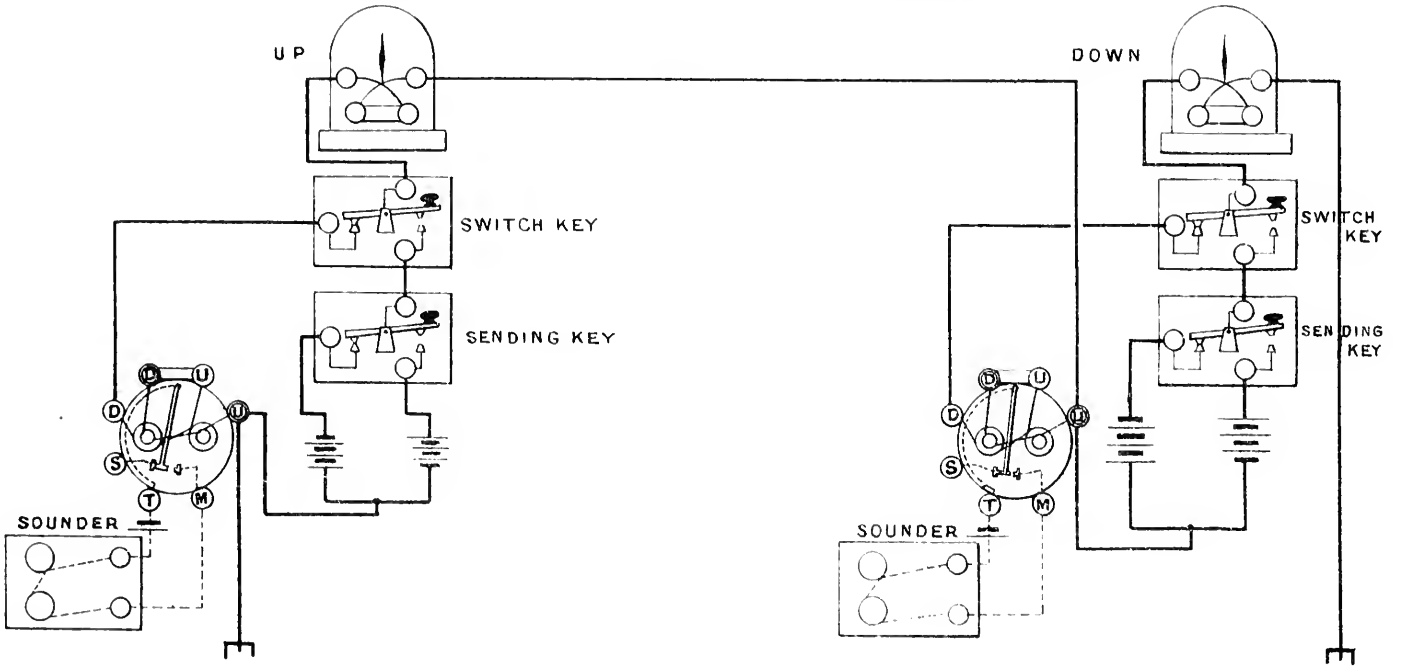


To Face p 84.

H & C GRAHAM LTD LITHRS. LONDON, S E

Chap 5 Fig 8.

DOUBLE CURRENT SYSTEM WITH SINGLE CURRENT KEYS.



H & C GRAHAM LTD LITHRS LONDON S.E

sending ceases the tongue remains against the marking stop. The set is then working single current with current and bias reversed. Similarly, if the lower contact springs of the key do not make contact the receiving stations may get signals by giving bias to the spacing side, thus working ordinary single current. These faulty methods of working are occasionally used when clerks are careless or do not understand their instruments, the sending clerk not noticing that the galvanometer needle swings to one side only, the receiving clerk that a large amount of bias is required to get signals and (in first case) that armature of sounder is down when signal stops. The adjustable contacts introduced in the Mark III key are to enable these faults to be removed with greater ease.

Careless working.

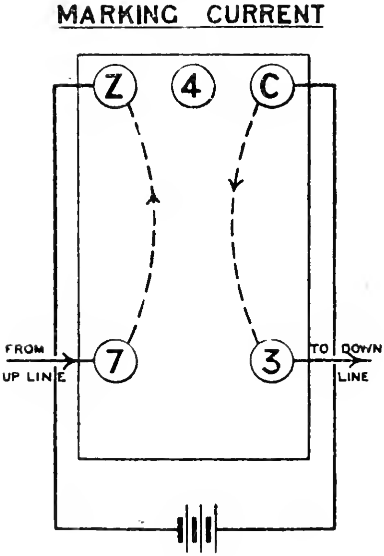


FIG. 6.

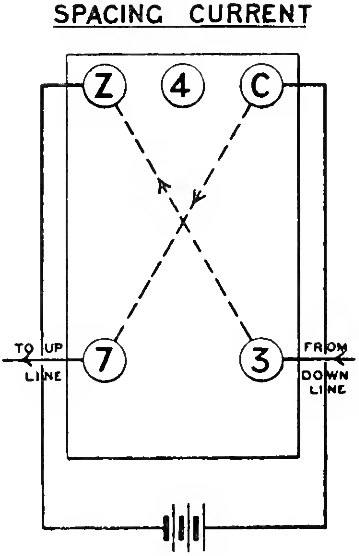


FIG. 7.

D.C. working with S.C. keys.

9. If double current keys are not available double current working can be arranged with two single current keys. One key is used as a "send-receive" switch, and held down while signals are being sent with the other. Two batteries to provide marking and spacing current respectively must then be used. Fig. 8 gives the connections—any form of two-way switch can be used in place of the "switch" key in this arrangement.

Baseboard Simplex.

10. The "Baseboard Simplex" consists of all the instruments forming a double current set mounted ready connected

up on a baseboard. Fig. 9 shows three boards connected up for double current working—connections shown in fine lines are for translation (see Chapter VI)—a switch with six terminals, generally called a "single and duplex" switch, is also fitted. This switch and its object are described in Chapter VI.

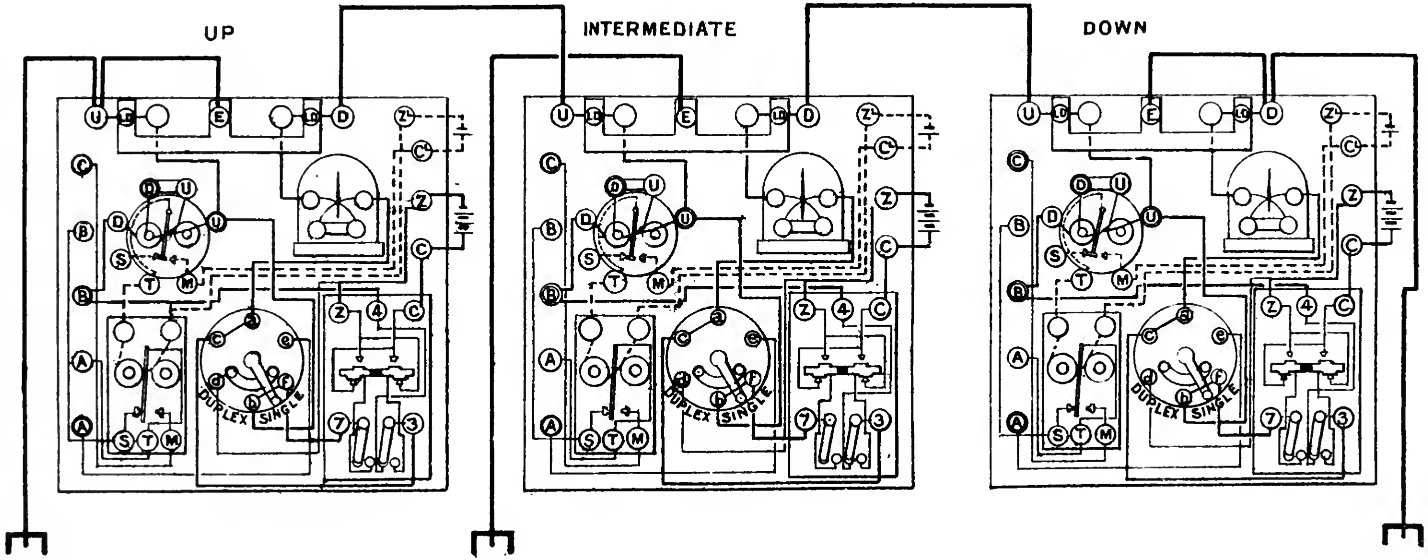
For double current working the handle must be to the right, the terminals marked *a—c* and *f—b* being then respectively connected together. The ш-shaped plate, with terminal marked E, carries the lightning dischargers (L D in diagram), consisting of small metal bobbins, on which thin single silk covered wire is wound, the wire being in the circuit. Spare wire for re-winding the lightning dischargers is carried on two reels in the base of the instrument, and two spare bobbins also. The board with its instruments has a wooden cover fitting over for transport. Further details of the lightning dischargers are given in Chapter XVII, para. 5.

BASEBOARDS SIMPLEX

CONNECTED UP FOR DOUBLE CURRENT WORKING

WITH LIGHTNING DISCHARGERS IN CIRCUIT

NOTE Connections shown in Fine lines are for Translation, see Fig: 10 chap: 6.



H & C GRAHAM Lᵀᴰ, LITHᴿˢ, LONDON, S.E

CHAPTER VI.

TRANSLATION.

Object of translation.

1. On very long or imperfectly insulated lines, to get a current at a distant station capable of working a relay with certainty in the ordinary way, would necessitate the use of a very large battery. The greater the length of the line the greater are the resistance and the capacity, and also, and this is as a rule more important, the leakage is greatly increased. Owing to slight loss of current at the supports on an ordinary aerial line, the current received at the distant station is never so large as that sent out, and the greater the number of supports the greater the total loss of current. The amount of leakage varies also with the weather. To give an example of how greatly this leakage affects the battery power required, take a line 500 miles long with a conductivity resistance of 20 ohms per mile. If the insulation resistance is perfect, *i.e.*, there is no leakage, the number of Daniell cells required to work a relay through it will be 150; if, however, the insulation resistance is only 500,000 ohms or ½ a megohm per mile, the circuit is equivalent to a perfectly insulated line 1,750 miles long, and it would require 525 cells to work the relay. The extreme distance in England over which ordinary double current working can be used is about 400 miles, though in dry climates it might be greater. For distances above this limit it becomes necessary to divide up the line into two or more sections, and re-transmit the message from one section to the next. To take it down and re-transmit it by hand involves time, labour, and inaccuracy, and the usual arrangements is to make the receiving instrument (the relay) on one section automatically work the sending apparatus on the next section. This operation is called "translation," and the complete set of instruments at the translating station, a "translating" or "repeating" set, or shortly, a repeater.

Principles of translation.

2. The principle is really the same as in ordinary relay working, where the relay is actuated by a weak current and turns on a strong current in a local circuit; in translation this local circuit is replaced by the next section of the line. The simplest method of repeating is shown in Fig. 1, using two relays only. The current from the up station enters the up relay at Ⓤ, passes through the coils to D, to S of the down relay. S is connected to the spacing stop against which the tongue rests, the tongue is joined to T, whence the current goes to earth and returns by earth to the up station from

which it started. This current, by flowing through the up relay, has caused its tongue to go over to the marking stop. The down battery can now work, and sends a current from copper to M of up relay, to T, to down line. This current flows through the relay at the down station to earth, returns at earth to the translating station to zinc of down battery. A current from down station repeated to up station can be similarly traced. This system is simple but not complete, as the clerk at the translating station cannot hear the signals nor tell if they are going through satisfactorily, nor if the relays require adjusting. To get over this a translating sounder is used.

Translating sounder.

3. The service translating sounder, "Instrument, telegraph, sounder, translating," was described in Chapter III, para. 11. The three terminals marked "S," "T," and "M" are connected to the top contact, lever, and lower contact respectively. The lever therefore corresponds to the tongue of a relay, the top contact to the spacing, and the lower contact to the marking stop. When no current is flowing S and T are connected; when current flows through the coils the lever is pulled down, and M and T are connected. The resistance of the military translating sounder is 40 ohms. That of the post office pattern is 40 ohms, with a shunt of 500 ohms across its terminals. The latter instrument is known as a "relaying sounder," and differs from the military pattern only in details of manufacture.

Use of translating sounder.

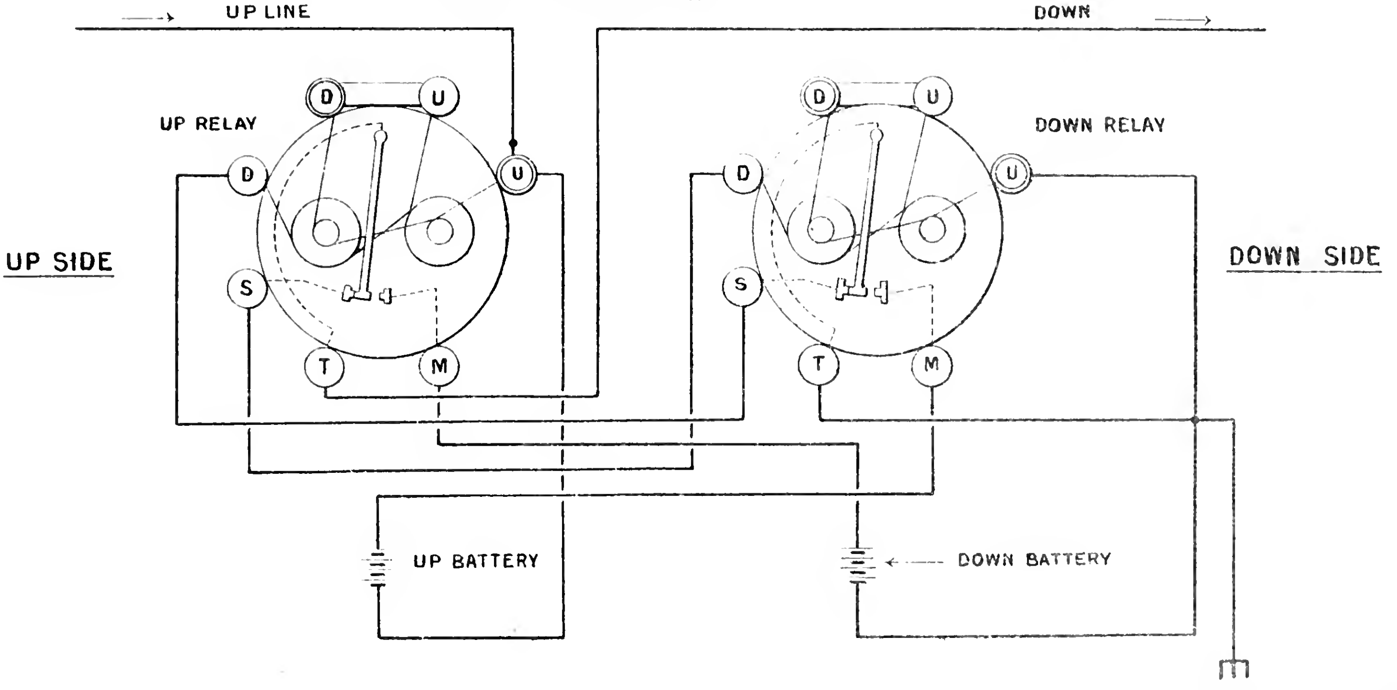
4. Fig. 2 shows a translating set using translating sounders. The current (1) flows from up station to Ⓤ of up relay, to D, to S of down sounder, to T, to earth back to up station. This current actuates the up relay, and causes a current (2) to flow from copper of up local battery through coils of up sounder to M of up relay, to T, to zinc of battery. The lever of up sounder being pulled down current (3) flows from copper of down battery to M of up sounder, to T, to down line, returning from down station at earth to zinc of down battery.

By this arrangement the message can be read from the sounder at the same time that it acts as an automatic key to transmit current from the down battery. The circuits when signals from the down station are being transmitted to up station can be similarly traced. Fig. 2 and subsequent diagrams of translating circuits appear somewhat complicated, but noticing that there are three distinct currents (as numbered when tracing circuits above), and knowing what each has to do and the order of the operations, there should be no difficulty in tracing the connections.

A complete translating set includes arrangements for dividing the set, if desired, into two terminal stations working to the distant up and down stations respectively, so that a message can be sent to the translating station without being

Chap 6. Fig. 7.

S. C. TRANSLATION
USING RELAYS ONLY.

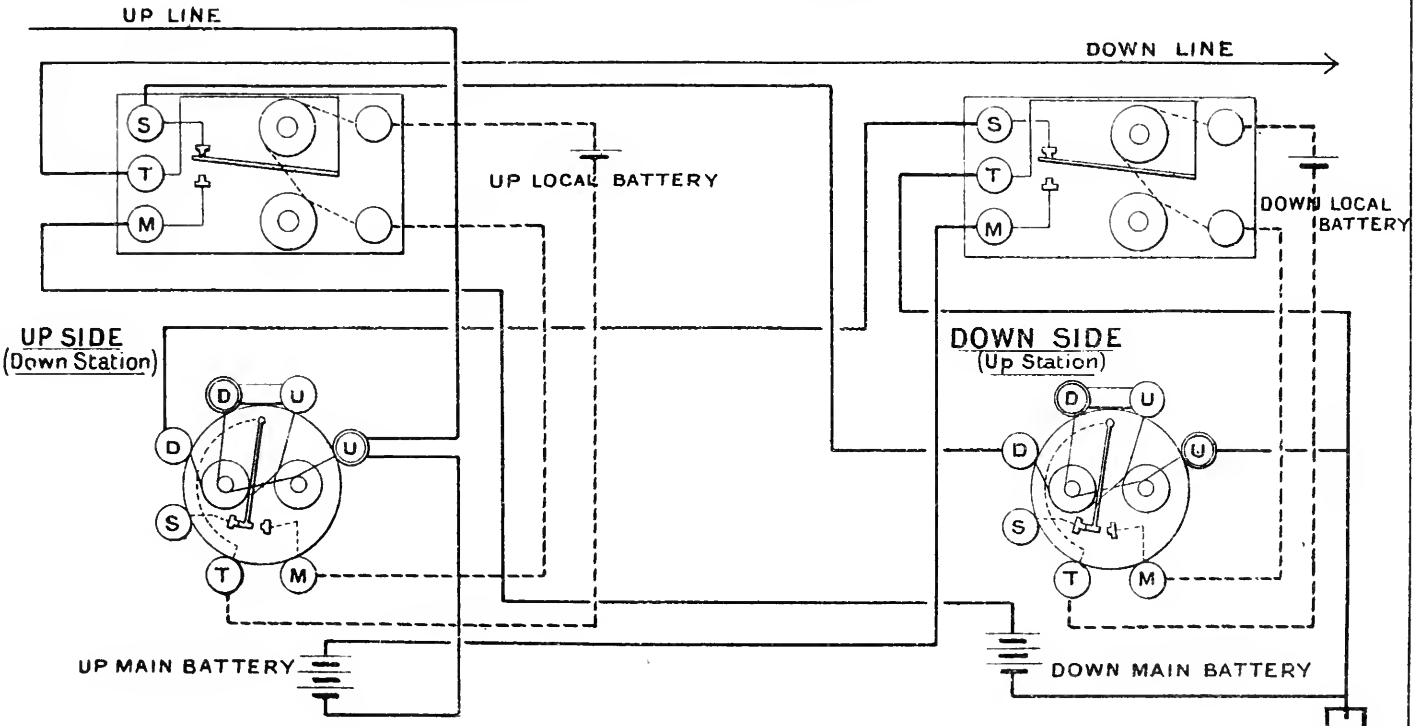


H & C GRAHAM Ltd LITHrs LONDON S.E

To face p 88

SINGLE CURRENT TRANSLATION

USING TRANSLATING SOUNDERS AND RELAYS ONLY



To face p 88.

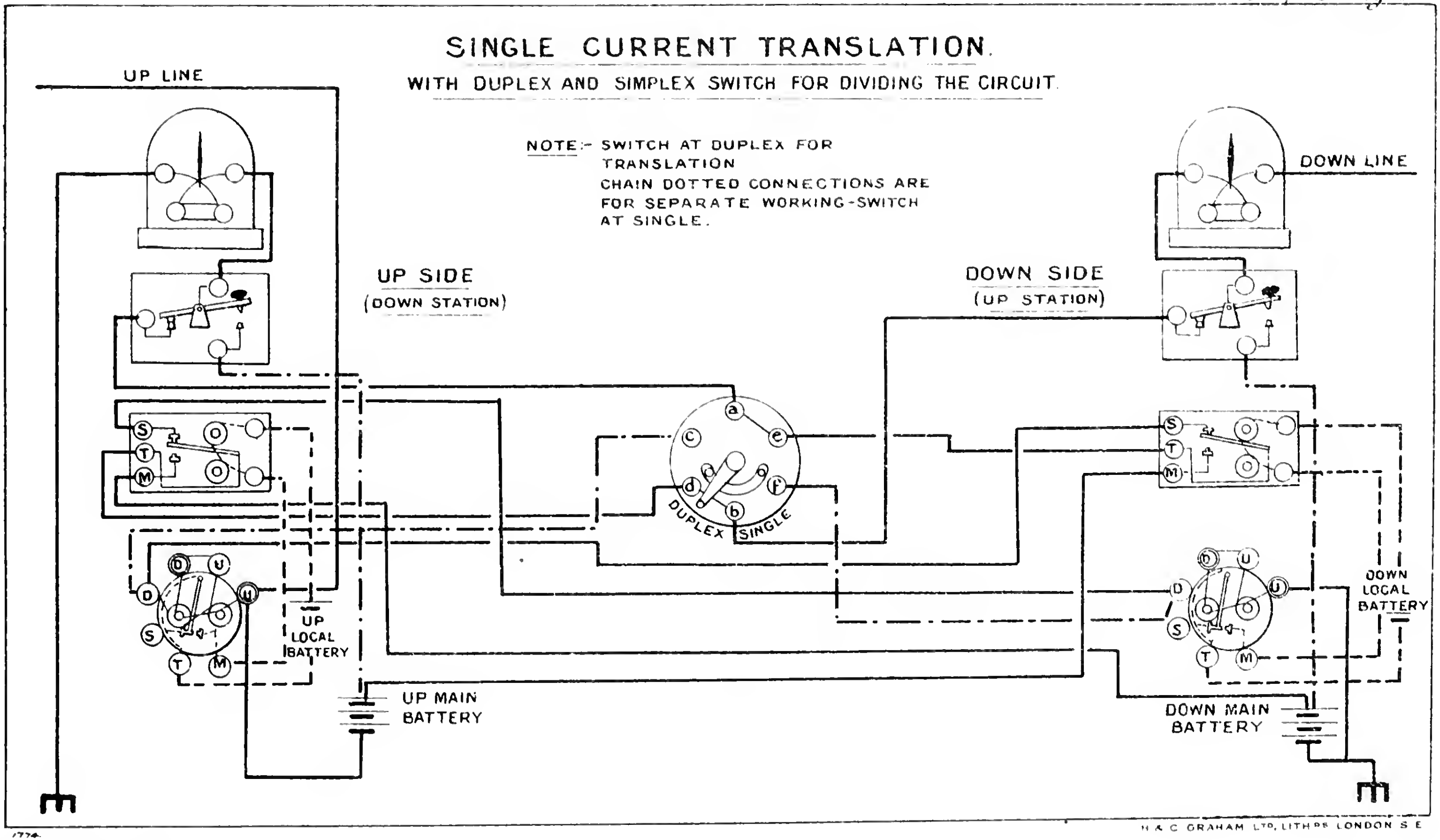
H & C. GRAHAM LTD. LITHRS. LONDON S.E.

Chap. 6. Fig. 5.

SINGLE CURRENT TRANSLATION.

WITH DUPLEX AND SIMPLEX SWITCH FOR DIVIDING THE CIRCUIT.

NOTE:- SWITCH AT DUPLEX FOR TRANSLATION
CHAIN DOTTED CONNECTIONS ARE FOR SEPARATE WORKING-SWITCH AT SINGLE.



1774
H & C GRAHAM LTD, LITHRS LONDON S E

transmitted further, and messages orginating at the translating station can also be sent in either direction. The translating station can also by this means interrupt a message which is being repeated, and ask for repetitions or corrections if necessary. This is effected by adding a single current key to each side of the set, and using a "switch, single and duplex."

Switch, single and duplex.

5. This is a very useful pattern of switch, and is used for a good many purposes. It has six screw terminals, and the connections are so arranged that the two pairs of adjacent terminals between which the handle points in either direction are connected, and the two remaining terminals are dis. It is, in fact, a double two-way switch. Figs. 3 and 4 show the conditions when the handle is at "Duplex" and at "Single" respectively. As this switch is now used for many purposes where the words "Single" and "Duplex" are meaningless, the switches will in future be issued with blank labels, instead of the words "Single" and "Duplex" being engraved on them.

SINGLE AND DUPLEX SWITCH.

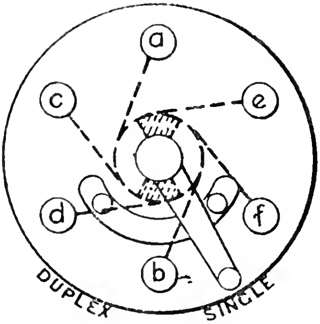


FIG. 3.—Switch at Single.

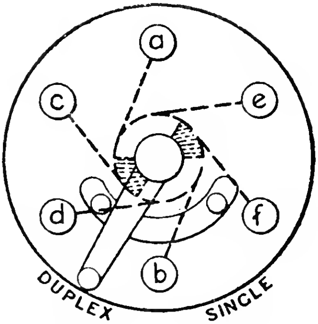


FIG. 4.—Switch at Duplex.

Complete translating sets.

6. The complete connections for a translation station are given in Fig. 5. For repeating, the handle of switch is placed at "Duplex"; for separating work, to "Single." When a message is being sent from the up station the current (1) enters the translating station by up line, flows from Ⓤ to D of up relay to S of down sounder, to T, to switch, through $e-a$, to back stop of up key, to bridge, to galvanometer, to earth and back to up station. This current closes the up local circuit, and current (2) flows from copper of up local battery through coils of up sounder to M of up relay, to T, to zinc of battery. M and T of up sounder are now joined; current (3) then flows from down battery to M of up sounder, to T, through $d-b$ of switch, to back stop of down key, to bridge, to galvanometer, to down line, returning from down station at earth to zinc of down battery.

If the translating set is to be divided so that the up side communicates with up station only, and down side with down station, the handle of switch is moved to "single." Tracing currents on the up side—a current from up station will enter as before at Ⓤ and flows through coils of up relay to D, but from D to *c* of switch (instead of through down sounder to E) to *a* of switch, to back stop of up key, to bridge, to galvanometer, to earth. When the "up" side of the translating station sends, the currents flow from up battery to front stop of up key, to bridge, to galvanometer, to earth, to up station and return via Ⓤ of relay to zinc of up battery.

Translation between two up or two down stations.

7. Translation can be carried on equally well between two distant stations when both are up or both down stations. The connections for the latter case are shown in Fig. 6. One main battery only is required, sufficient cells being provided to work the section of line with the greater resistance.

Translation with four relays.

8. Figs. 7 and 8 show how translation can be effected by means of four relays if translating sounders are not available.

Speed of working.

9. As many translating or repeating stations may be inserted in a line as its length and insulation require, but the more there are the slower must be the sending. Suppose the length of time the key at the up station is depressed when making a dash is represented by A, Fig 9, then B will represent the length of the current in the local circuit at the translating station, for it takes a short time for the tongue of the translating relay to move to the marking stop before the current B begins. The lever of the translating sounder does not begin to move till current B begins to flow, and takes a little time to move to its marking stop, and the current C from main battery therefore starts later than B. Lastly, the current D in down station local sounder cannot start till the line current has moved the tongue of its relay. On the other hand, when the key at the up station is raised, all these

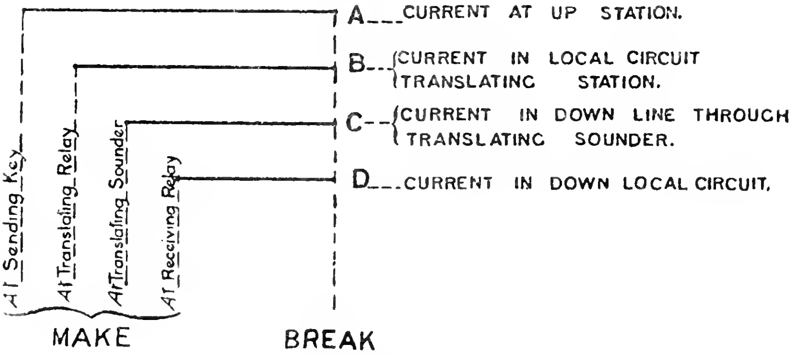
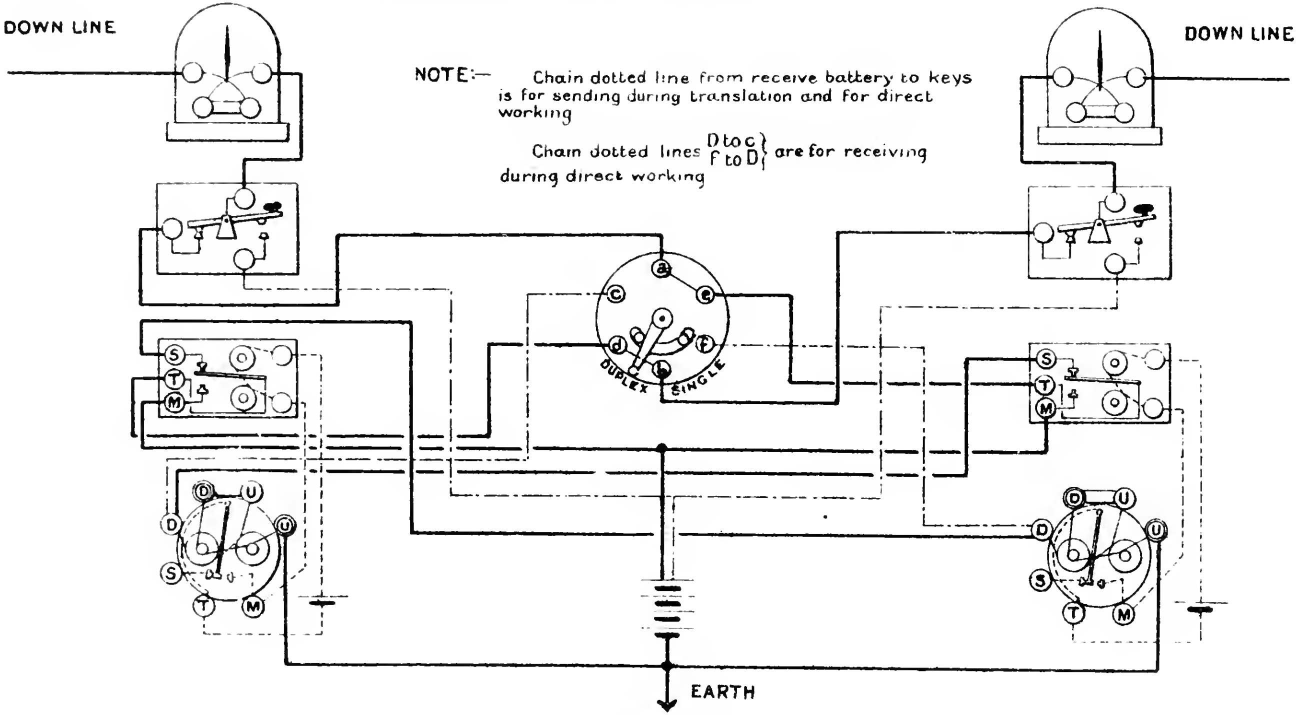


FIG. 9.—Duration of Currents S.C. Translation.

Chap 6. Fig 6.

SINGLE CURRENT TRANSLATION

BETWEEN TWO DOWN STATIONS.



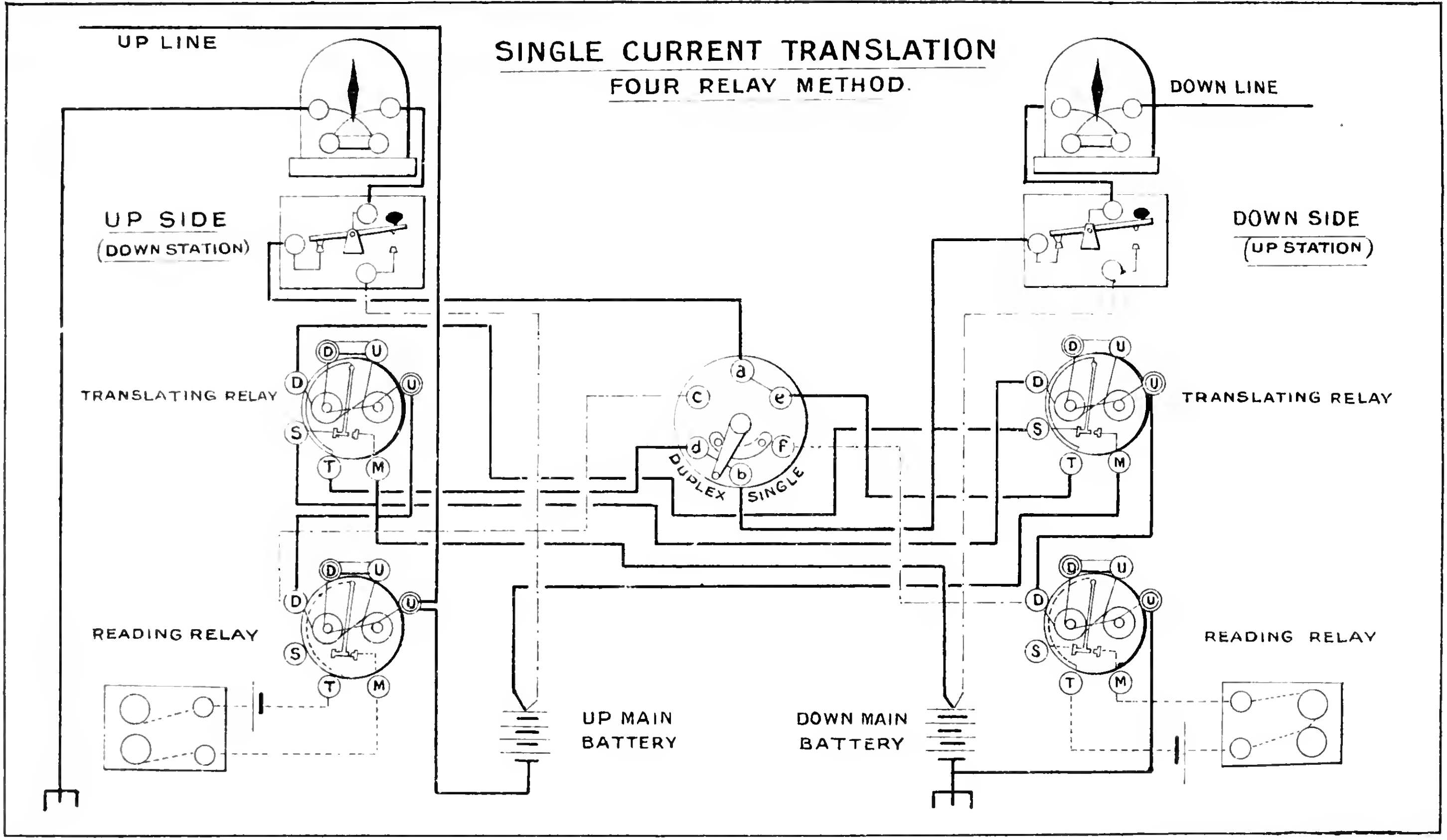
NOTE:— Chain dotted line from receive battery to keys is for sending during translation and for direct working

Chain dotted lines $\left.\begin{matrix}\text{D to c}\\ \text{f to D}\end{matrix}\right\}$ are for receiving during direct working

To face p 90.

H & C. GRAHAM LTD, LITHRS, LONDON, S.E.

Chap. 6. Fig. 7.



SINGLE CURRENT TRANSLATION

FOUR RELAY METHOD.

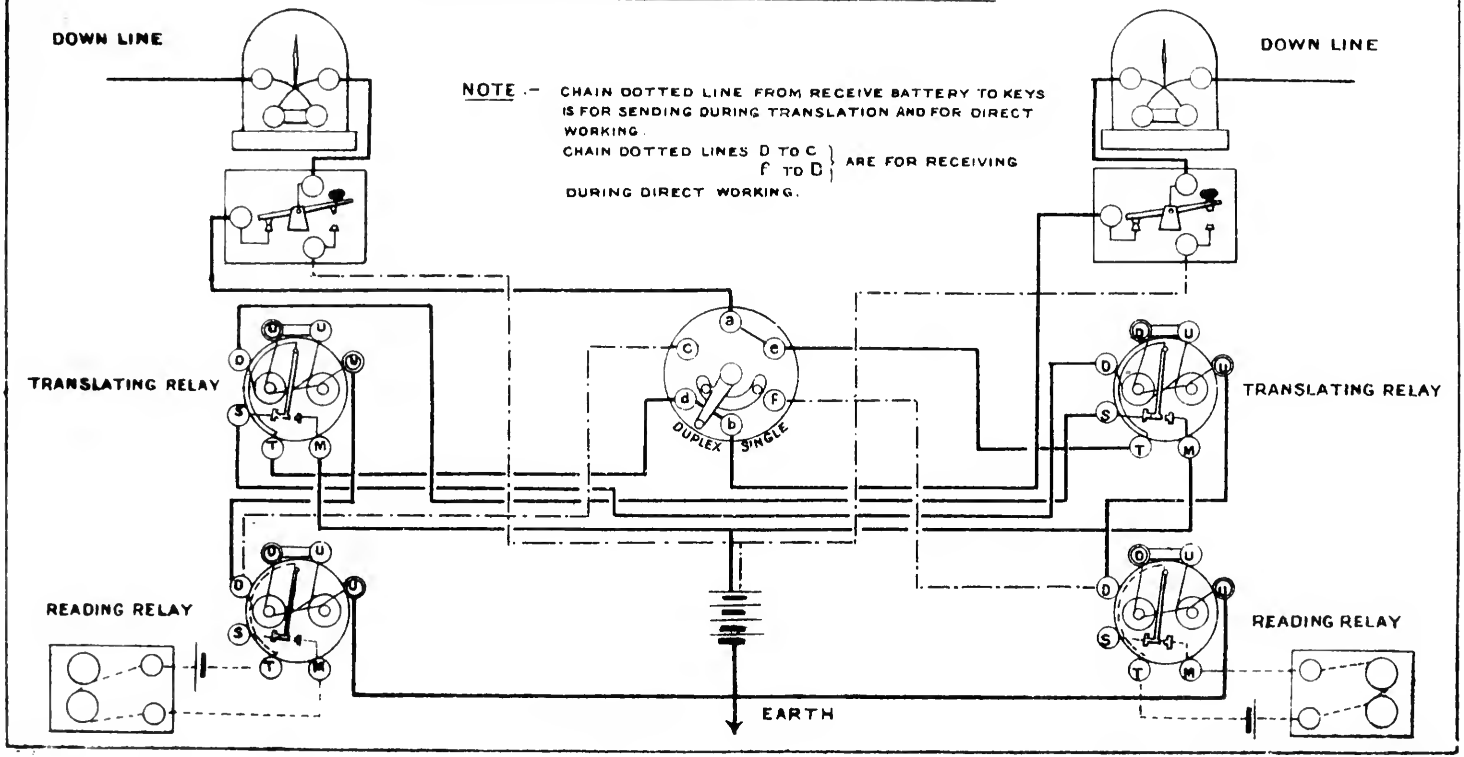
H & C. GRAHAM LTD. LITHRS. LONDON, S.E.

To face p. 90.

Chap. 6. Fig. 8.

SINGLE CURRENT TRANSLATION

FOUR RELAY METHOD BETWEEN TWO DOWN STATIONS.



NOTE.— CHAIN DOTTED LINE FROM RECEIVE BATTERY TO KEYS IS FOR SENDING DURING TRANSLATION AND FOR DIRECT WORKING.

CHAIN DOTTED LINES D TO C }
f TO D } ARE FOR RECEIVING DURING DIRECT WORKING.

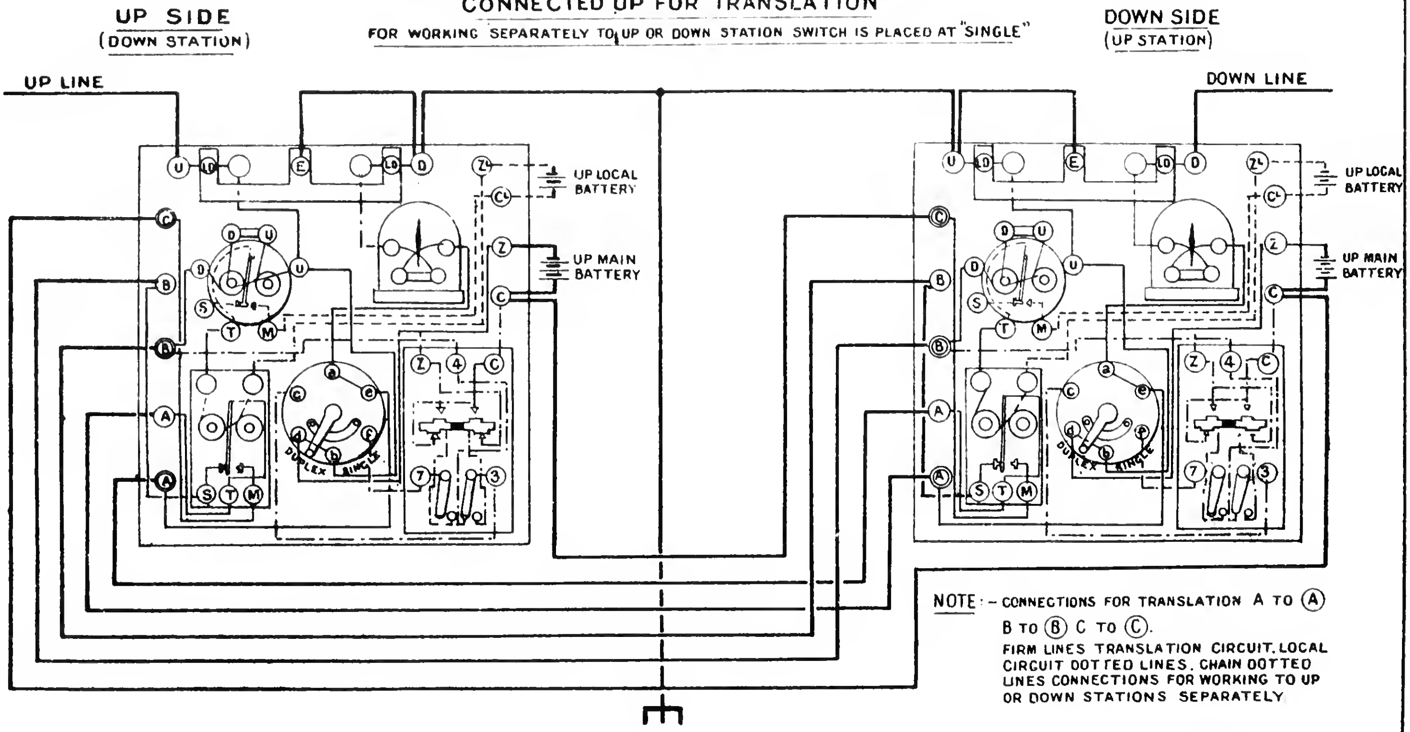
H & C. GRAHAM LTD., LITHRS., LONDON, S.E.

To face p. 90.

TWO BASEBOARDS SIMPLEX.

CONNECTED UP FOR TRANSLATION

FOR WORKING SEPARATELY TO UP OR DOWN STATION SWITCH IS PLACED AT "SINGLE"



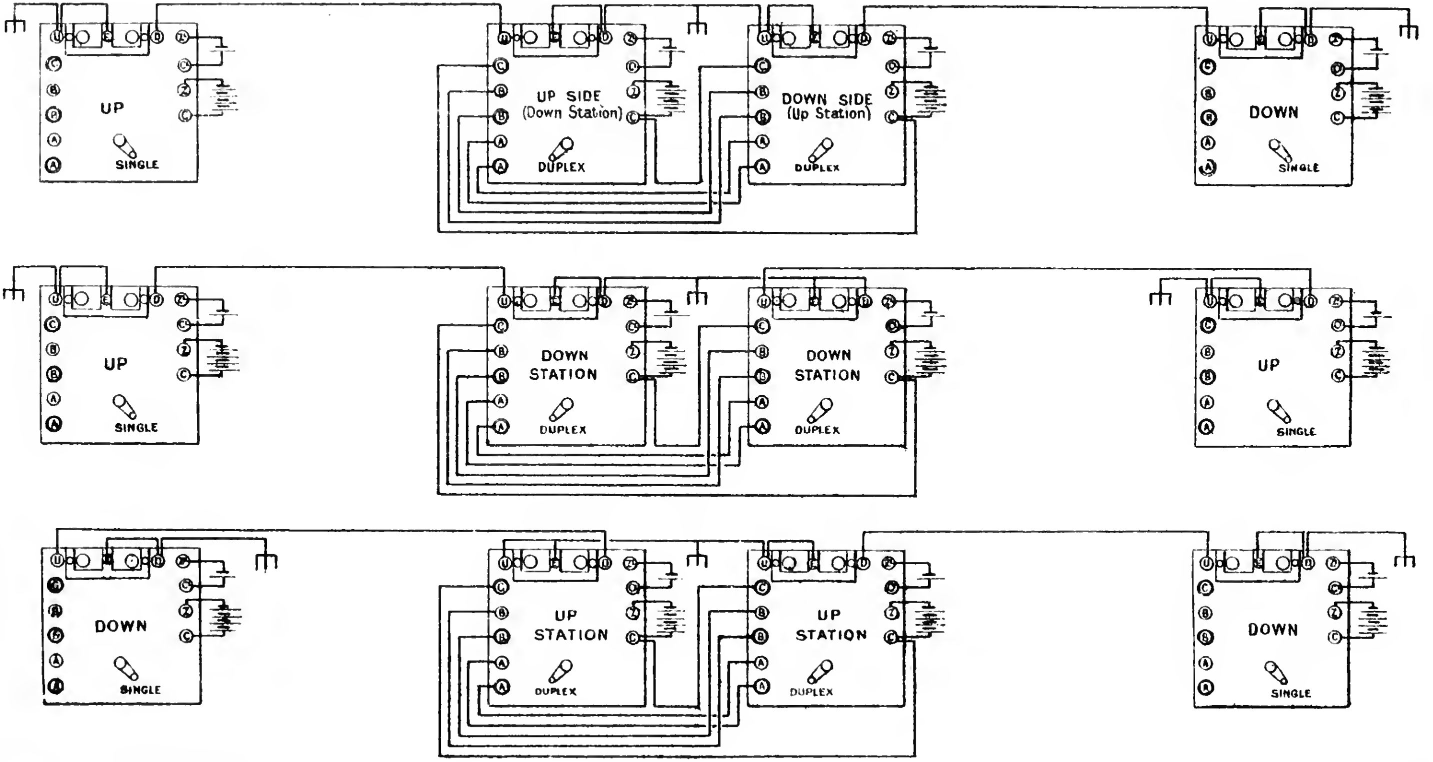
NOTE:— CONNECTIONS FOR TRANSLATION A TO Ⓐ
B TO Ⓑ C TO Ⓒ.
FIRM LINES TRANSLATION CIRCUIT, LOCAL CIRCUIT DOTTED LINES, CHAIN DOTTED LINES CONNECTIONS FOR WORKING TO UP OR DOWN STATIONS SEPARATELY

H & C. GRAHAM LTD, LITHRS, LONDON, S.E.

To face p. 91.

Chap. 6. Fig. 11.

TRANSLATION — BASEBOARDS SIMPLEX.



1278.

To face p. 91.

H & C. GRAHAM LTD, LITHRS, LONDON, S.E.

circuits are broken practically at the same moment, for the current ceases the moment the tongue leaves the marking stop (before it has got back to the spacing stop), so that there is no delay in the successive movements. Though the time required for any one tongue to move from "marking" to "spacing" is very small, a number of these intervals one after another make a considerable difference to the possible rate of sending.

Adjustment

10. Careful adjustment of the translating sounder at the repeating station is of greater importance. The signals from the translating sounder may be quite readable, but, owing to the marking current being cut short as described, those at the receiving station may be bad. An experienced clerk, by adjusting the tension spring of the translating sounder so that the marking contact is kept closed as long as possible, can improve the translated signals considerably.

Translation with "baseboard simplex."

11. The baseboard simplex is as previously mentioned, fitted for translation. The handle of the S & D switch must be at "Duplex" on both translating boards while translating is going on. Fig. 10 shows the complete circuits of a translating station, and should be compared with Fig. 5. Fig. 11 gives external circuits of a translating and two terminal stations.

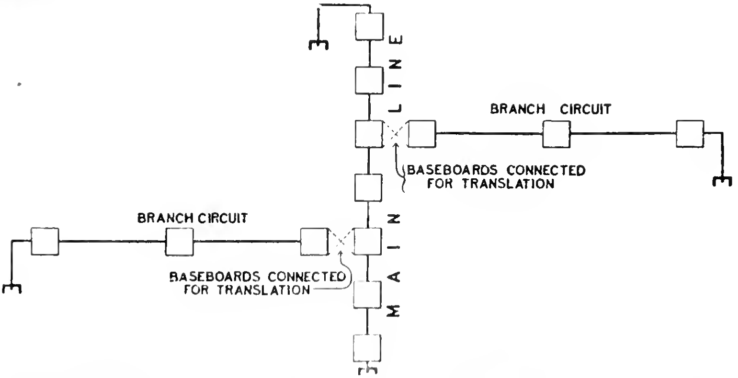


FIG. 12.—Method of Linking Branch Circuits to a Main Line by means of Translating Sets.

When using the baseboard simplex for translation, it must be noticed that though the working on the first section of the circuit is double current, single current only is translated on succeeding sections. All relays in circuit must, therefore, be adjusted for SC working when the boards are being employed for translation. This applies also to a circuit such as that shown in Fig. 12, where translation from a main line to branch lines is carried on. Stations on the branch circuits could not send to stations on the main circuit if the latter have their relays adjusted for double current. This circuit on Fig. 12 gives a simple method of linking branch lines to a main route, and might be found useful.

Double current translation.

12. DC translation involves the introduction of automatic switches. It is a complicated process, and not likely to be required for military work. It is not further described here.

Duplex translation.

13. Duplex translation (S.C. working) is described in Chapter VII after ordinary duplex working has been explained.

CHAPTER VII.

DUPLEX WORKING.

Object of duplex.

1. The systems hitherto described only admit of single working, that is of sending in one direction at a time. Duplex telegraphy admits of sending in opposite directions at the same time on the same wire. This doubles the carrying capacity of a wire, and is useful when pressure of traffic makes single working insufficient. On military lines pressure generally arises in consequence of an unusually large number of messages having to be sent in one direction. Duplex telegraphy provides little relief against this. It is chiefly of service if the pressure arises from a nearly equal number of messages having to be transmitted from either end. However, it is frequently required and found useful in military telegraph work.

Principle of differential system of duplex working.

2. There are two systems of duplex telegraphy, the "Differential" and the "Bridge," but the former is almost universally employed, chiefly because it is more economical in battery power. Differential duplex depends for its action on two facts: 1st, that if two circuits of equal resistance be open to a current, it will divide equally between them: and 2nd, that if an electro magnet has two exactly similar coils of an equal number of turns wound together round its core, and equal currents flow in the two coils *but in opposite directions* the resulting magnetic effect will be nil. The magnetic field produced by one current neutralizes that produced by the other. Instruments that are so wound are called "differentially wound," see also Chapter I, para. 58. Differential duplex requires about twice the battery power necessary for single working. The reason for this is that the line current passes through only one coil of the relay at the receiving station (except at the instant when the key at the latter is in an intermediate position), and consequently, in order to ensure equally good working of the relay, the line current must be doubled.

Now, the single and duplex galvanometer is wound with two similar coils (see Chapter III, para. 3). If the brass straps be joined as in Figs. 1 and 2, the current flows in at A and divides, part through each coil. If the resistance X and Y be equal, the current in each branch will be equal and the needle will remain steady, as there is no magnetic field to move it. Suppose resistance X be greater than Y, the current will divide unequally, more going through the smaller resistance than through the greater. The stronger magnetic field is only partly neutralized by the weaker and the needle moves in the case illustrated to the right.

In the same way, if a relay is joined up as shown in Fig. 3, so that equal currents pass through the coils in opposite directions, as shown by the arrows, the armature and tongue will not move. If the current from Ⓤ to Ⓓ is greater than

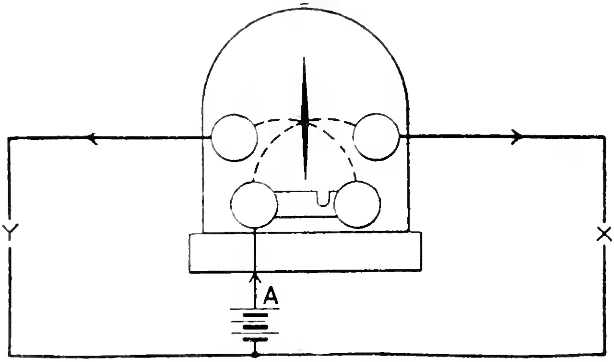


FIG. 1.—Galvanometer, Single and Duplex, Coils connected for Duplex Working.

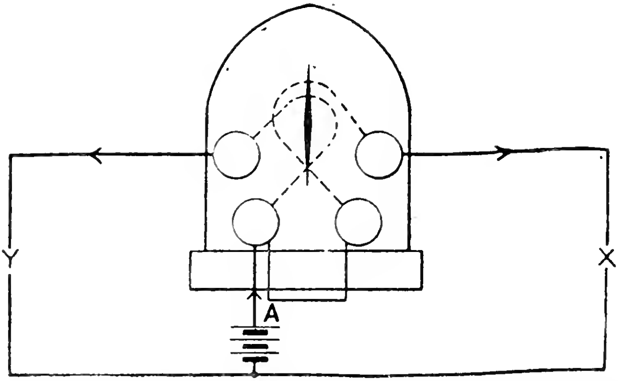


FIG. 2.—P.O. Differential Galvanometer, Coils connected for Duplex Working.

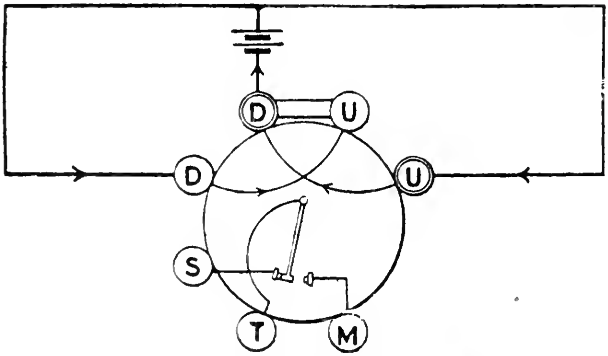
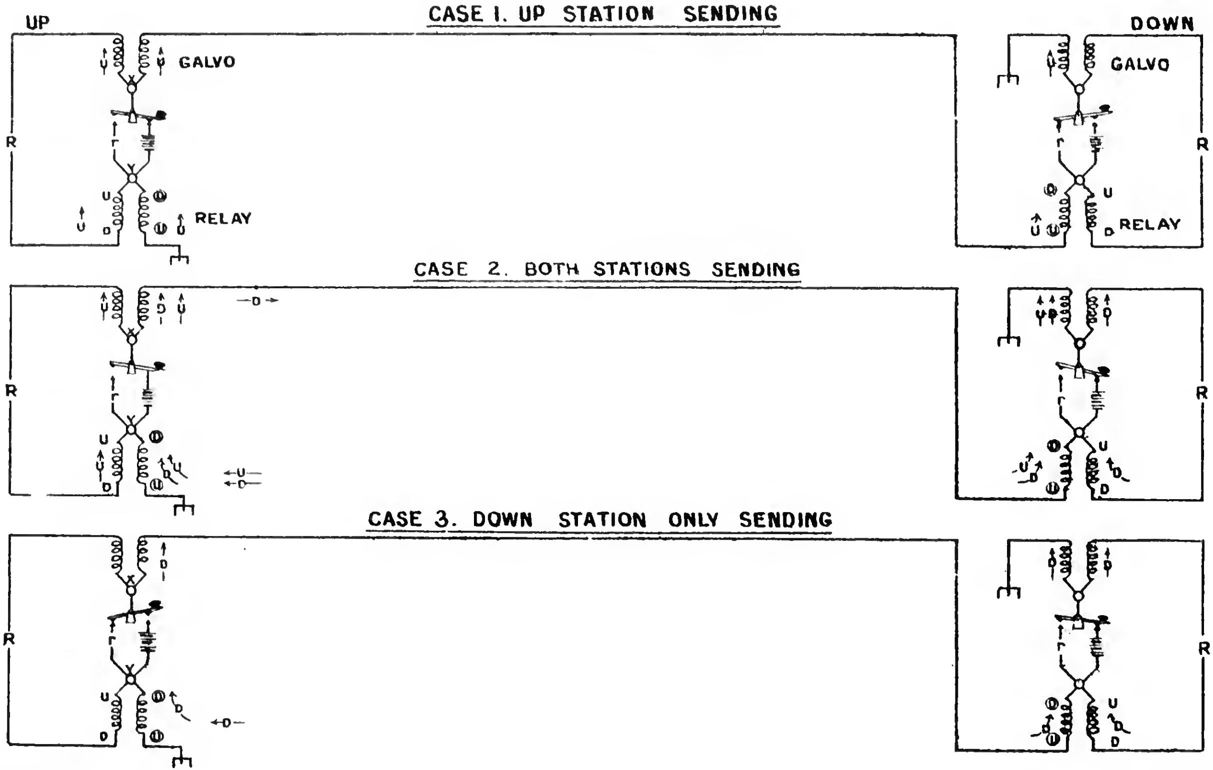


FIG. 3.—Relay connected for Duplex Working.

Chap. 7. Fig. 4.

DUPLEX WORKING



1270.

To face p. 95

H & C GRAHAM L^TD, LITH^RS LONDON, S.E.

from D to U, the tongue will be attracted towards the marking stop; if that from D to U is greater, it will be drawn (or held) to the spacing stop. Similar effects are of course produced in galvanometer or relay if the battery and, therefore, the direction of the current is reversed.

Fig. 4 gives a theoretical diagram showing how these principles are used to effect Duplex working. The two coils of the galvanometer and of the relay are shown separately. The arrows show the direction of the currents and are marked "U" and "D" to distinguish from which battery they are derived. R and *r* are resistances.

We will consider the action at the up station only, for sake of clearness.

Up station only sending.

Case 1.—Suppose the up station only is sending. When the key is depressed, current flows to point X and divides, part goes through right coil of galvanometer to line, through down station, back to up station at E, through Ⓤ Ⓓ to Y. The other part of the current goes from X, through left galvanometer coil, through R, through D U of relay to Y, where the two portions unite again and return to zinc of the battery. The branch circuit through R is called the compensation circuit. If R be made equal to the resistance of line, down station, and earth, the two branches of the circuit from X through down station to Y and from X through R to Y will be equal. Equal currents will flow through the two coils of the up galvanometer in opposite directions, so there will be no deflection, and equal currents will flow through the up relay coils from Ⓤ to Ⓓ and from D to U, so that there is no movement of the tongue. Sending at the up station does not, therefore, affect its own instruments.

Both stations sending.

Case 2.—Now suppose that while the up station key is pressed, the down station also sends. Half the current from down station battery will flow through its own compensation circuit, the other half will enter the up station at earth, flow through relay from Ⓤ to Ⓓ, to Y, through battery to X, through right galvanometer coil to line, back to down station. (Practically none of this current will flow from Y to X through the up compensation circuit instead of through the battery, because the resistance of the battery is very small, and that of the compensation circuit is comparatively very great.) The currents from up battery remain as in Case 1. The total current, therefore, from Ⓤ to Ⓓ of relay is now approximately double, that from D to U and the relay marks; also the current through right coil of galvanometer is double that through left coil, and the needle is deflected. The down station signals are therefore received when the up key is pressed. (Note that the portion of the current from the down station flowing through the compensation circuit, flows in the opposite direction to the current from the up battery, and thus its effect, though small, is to assist in pulling the relay over to the marking stop.)

Down station only sending.

Case 3.—Suppose that the up station key is released while the down station is still sending. The currents from the up battery cease. The only current through the relay is the down station current from Ⓤ to Ⓓ, and the small current through the compensating circuit which flows from U to D, therefore the relay still marks, the same current flows through the galvanometer, both deflecting the needle to the right, as before. The down station current has now to flow from Y to X, through *r* instead of the battery, but *r* is made equal to the battery resistance, so that the total resistance in circuit is unaltered. Signals, therefore, are received at the up station whether it is itself sending or not. If the resistance *r* is not made equal to that of the battery, the resistance of the line as measured from the down station would vary when the up key was depressed, and consequently the down current would not always divide equally between the line and the down compensating circuit. If, however, the resistance of the battery (as is usually the case) is small compared to that of the line, this variation would be so small that it does not practically matter, and if the point Y be connected to the back stop of the key without inserting a resistance, this would not, as a rule, affect the working.

There is a 4th Case possible, viz., when down station is sending and the key of up station is passing from one contact to the other, leaving, for the moment, both front and back stops dis. The received current from the down station is not, however, even in this case, entirely cut off. It has the path through the compensation circuit, and though by passing through this path the current is halved, it now passes through both coils the same way and the resultant effect on the relay and galvanometer is the same as before. At the down station, however, the line current is halved but the compensating current remains the same, hence the current from the down station keeps (or helps to keep) the tongue of its own relay against the spacing stop. As the up station is not at that moment sending, this is its correct position.

This explanation has been confined to the consideration of the up station, but the corresponding effects at the down station can be seen from the diagrams. The local circuits are not shown in these diagrams.

Complete circuit for duplex working.

3. In actual practice a duplex circuit includes a switch, single and duplex (see Chapter VI, para. 5), at each station, so that when there is no press of work, single working can be used and the batteries saved.

Rheostat, Mark I.

4. The resistance R (Fig. 4) is usually in the form of an adjustable resistance box called a rheostat. The "Rheostat, Mark I" is illustrated in Fig. 5. Two movable arms pivoted at the centre are in electrical contact with each other, and also at their outer ends with one or other of a series of studs. The studs are arranged in two sets of 10, over each set one arm moves. Between each pair of adjacent studs of the first set is

a resistance coil of 40 ohms, and between each adjacent pair of the second set a coil of 400 ohms. The first stud of the first set is connected to one terminal, and the first stud of the second set to a brass block on the rim of the base. There are four of these blocks, capable of being connected by pegs, and having resistances of 10, 20, and 4,000 ohms between them, the fourth block being connected to the second terminal. Thus, by inserting the pegs and moving the arms, any resistance from 0 to 4,400 (in steps of 40 ohms) can be inserted between the terminals, and by means of the pegs an additional 4,000 ohms can be inserted, and also 10, 20, or 30 ohms additional, making the total range from 0 to 8,430 ohms in steps of 10 ohms.

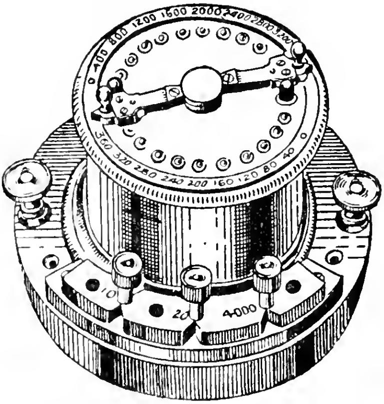


FIG. 5.—Rheostat, Mark I.*

Rheostat, Mark II.

5. The Rheostat, Mark II, which has superseded Mark I, is electrically similar, but the studs are arranged in two circles instead of one—Fig. 12 shows the connections and Fig. 6 gives an illustration.

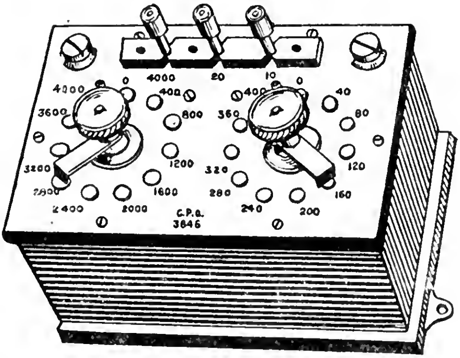


FIG. 6.—Rheostat, Mark II.

---

* Obsolescent.

The coils are wound on four bobbins, they are all non-inductively wound of silk-covered platinoid wire, and the resistances must be correct to within ± 1 per cent. at 60° F. The first bobbin carries the 4,000 ohm coil and is wound with wire of ·005-inch diameter, single silk covered. The second bobbin carries the 10 and 20 ohm coils and is wound with ·024-inch wire, double silk covered. The third bobbin carries the 40 ohm coils, and is wound with ·014-inch double silk covered wire. The fourth bobbin carries the 400 ohm coils, the first three sections are wound with single silk covered wire of ·010-inch diameter (connected to the studs marked 400, 800, and 1,200 ohms), and the remaining seven with single silk covered wire of ·008-inch diameter. The third and fourth bobbins are dipped in melted paraffin wax after they are wound.

Battery, compensating, resistance.

6. The resistance *r*, which should be equal to the resistance of the battery, is usually a fixed resistance of from 20 to 30 ohms, mounted on a block, but, as explained in para. 2, it can usually be omitted and the two terminals, *c d* of the switch, joined by a piece of wire.

Connections for S.C. duplex.

7. Fig. 7 gives the complete diagram for a single current duplex circuit. Tracing the current we have copper to front stop, to bridge, to galvanometer, where it divides (this corresponds to point X, Fig. 4), half flows through one coil of galvanometer, to line, to Ⓤ of down relay, to Ⓓ, to *d* of switch. From *d* it flows either to *b*, through down battery to front stop, to bridge of key, if down station is also sending, or through *r* to *c*, to back stop of key, to bridge, if down station is not sending; from bridge of key it flows through galvanometer to earth, and returns to up station at earth, to Ⓤ to Ⓓ. The other half of the current flows through the other coil of galvanometer, through the rheostat to *e* of switch, to *a*, to D of relay, to U. The two parts of the current join at the brass strap connecting Ⓓ and U, which corresponds to point Y in Fig. 4, and the whole current flows to *d* of switch, to *b*, to zinc of the battery. If the switch is moved from "duplex" to "single" the circuits are those of an ordinary S.C. set. When up station sends the current flows from copper to front stop through one coil of galvanometer to line (the compensation circuit is dis at *e* of switch) enters down station at Ⓤ, through coils to Ⓓ to *d* of switch, through *r* to *c*, to back stop of key, to bridge, to galvo, to earth, return to up station at earth to Ⓤ, to *f* of switch, to *b*, to zinc of battery.

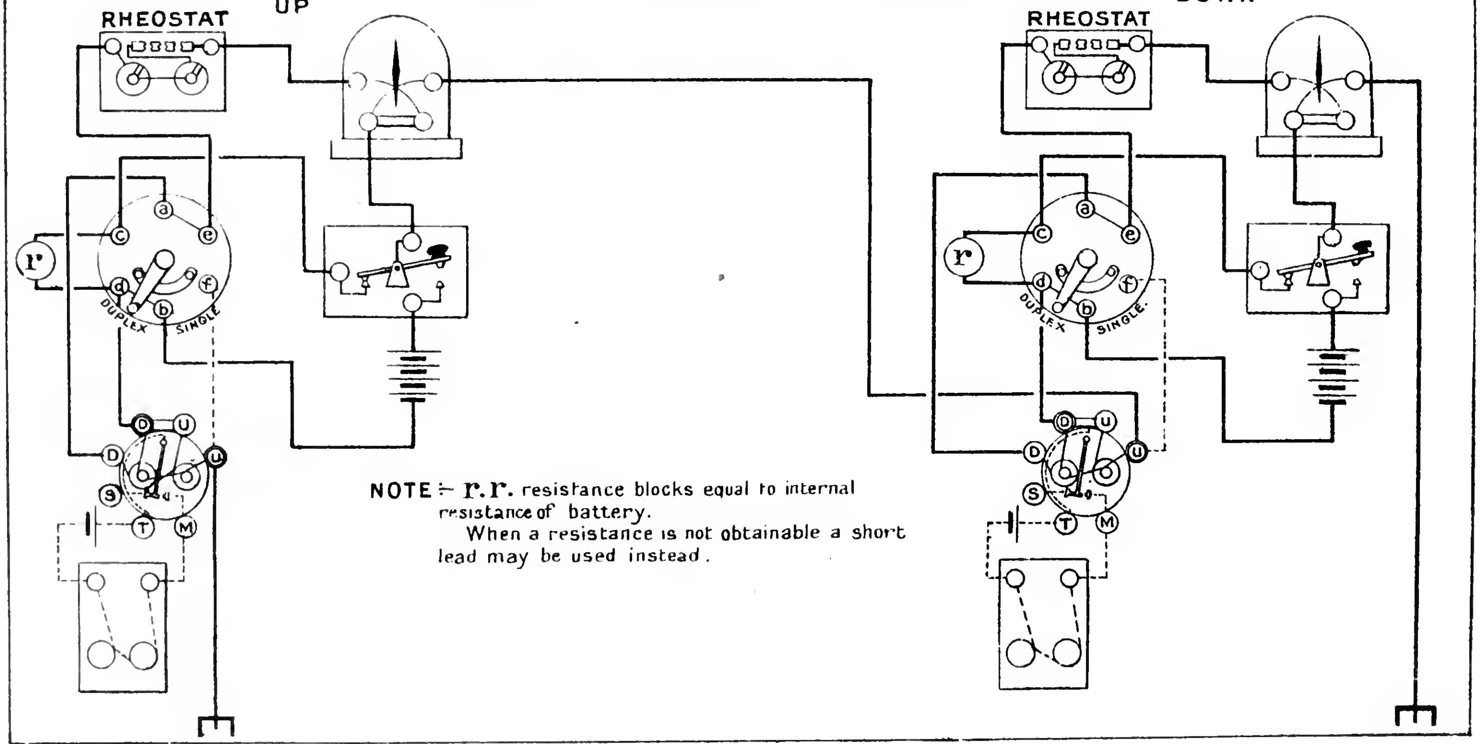
Note.—Another path also exists:—Ⓓ to U, to D, to *a* of switch, to *c* of switch, to back-stop. This path has, however, a comparatively high resistance, and only a small portion of the current will flow through it; this small current, such as it is, assists the relay.

Adjustments of S.C. duplex.

8. The relay and sounder are adjusted as in ordinary simple current working. To adjust the resistance of the compensation circuit one station only sends and at same time moves the contact arms of the rheostat till working the key produces no deflection on

Chap 7, Fig 7.

SINGLE CURRENT DUPLEX.



NOTE:– r.r. resistance blocks equal to internal resistance of battery.

When a resistance is not obtainable a short lead may be used instead.

H & C GRAHAM L^{TD} LITH^{RS} LONDON S.E.

To Face p 98

the galvanometer. If there is a deflection on galvanometer to the left on pressing the key the resistance in the rheostat must be increased, if to the right it must be decreased. When the resistance of line and compensation circuit are very much out of balance, and the resistance of latter too great, the relay tongue will go over to the marking stop on completing the circuit, for the current from Ⓤ to Ⓓ is sufficiently greater than that from D to U to move the armature.

Intermediate offices.

9. It will be noticed that intermediate offices cannot be inserted in a line working duplex. If duplex working is necessary between terminal offices on which there are intermediate offices, communication must be kept up to the latter by "vibrators" (*see* Chapter XV), or by reverting to "single" working at fixed and stated intervals. In the latter case the intermediate offices must put the line through and cut out their instruments when duplex working is required.

Effect of capacity in duplex working.

10. As explained in Chapter I, every line has a certain capacity, short aerial lines having very little and long cable lines having a considerable amount. The effect of this capacity is that when a circuit is first completed by depressing a key, more current flows from the battery to line than would flow if the line had no capacity. This effect is only momentary, and the current soon attains its proper value. When the circuit is broken, however, and line and earth joined by some other path, a momentary current flows back in the opposite direction. If in duplex working the compensation circuit has no capacity, and the line circuit considerable capacity, both circuits having the same resistance, then at the first moment of making contact more current flows to line than round the compensation circuit (compare Fig. 17, Chapter I). For the moment the current in the line branch is too strong and causes the tongue of the relay to move towards the marking stop and the galvanometer to kick to the right. On breaking the current part of the accumulated charge flows back to earth through *r* and ⒹⓊ and the galvanometer kicks to the left. If at the same time the distant station is sending, its incoming current will be neutralized for a moment and the received signal split. If the compensation circuit has too much capacity the opposite results are produced. The galvanometer kicks to the left on "make," and a received signal is split, while on "break" the galvanometer kicks to the right and the tongue of the relay moves towards the marking stop. In adjusting the circuit these effects of capacity must be distinguished from those caused by want of balance in resistance. Any deflection of galvanometer or movement of the relay caused by the latter lasts as long as the key is pressed, but if caused by capacity it is only momentary. As a matter of fact the effects of capacity are only noticeable on long lines, or cables, with delicate adjustment of the relays; on short aerial lines they are usually negligible.

Adjustable condenser (condenser 7·25 microfarads).

11. The adjustable condenser used for duplex working (Condenser, 7·25 microfarads) is illustrated in Fig. 8 and a diagram of its internal connections given in Fig. 9. The

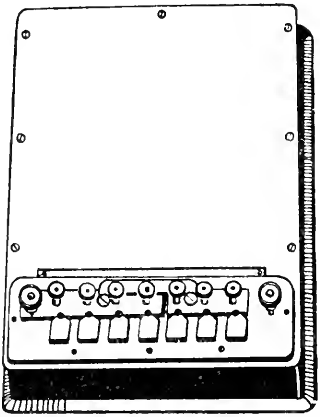


FIG. 8.—Condenser, 7·25 Microfarads.

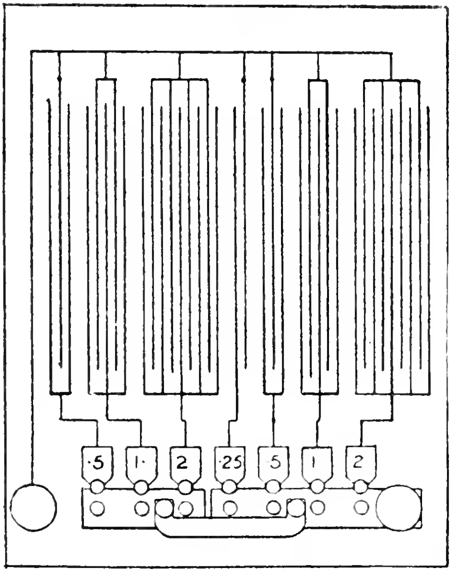


FIG. 9.—Condenser, 7.25 Microfarads.

condenser is composed of sheets of tinfoil insulated by paper dipped in paraffin wax. Alternate sheets of tinfoil are connected together and to one terminal. The remainder are connected in sections of varying number of sheets and each section joined to a brass block. The capacity between the terminals of the instrument may be varied by inserting plugs between the brass bar which carries the second terminal and the brass block. The range is from ·25 microfarad by graduations of ·25 microfarad to a total of 7·25 microfarads.

Retardation and condenser coils.

12. The act of charging or discharging a long line is not effected instantaneously, and for very accurate balance the charging and discharging of the compensating condenser must be delayed to the same extent as that of the line. The brass bar referred to above is divided into two parts, normally joined by a strap. If necessary the strap may be disconnected and an adjustable resistance inserted in place of it. This resistance, known as the condenser coils, is thus included in the path of the charge or discharge and produces the retarding effect required. In a condenser thus divided one portion represents the capacity of the near end, and the other the far end of the line. The process of charging and discharging can be further regulated by another set of resistance coils placed in series with the condenser, and known as "retardation" coils. The condenser coils may be required on circuits over 120 miles; retardation coils also when the lines are over 200 miles. Figs. 10 and 11 show the ordinary form of coils; Fig. 12 gives a diagram of the complete compensation circuit. Note that capacity is inserted by inserting pegs in the condenser, and resistance is inserted by withdrawing pegs in

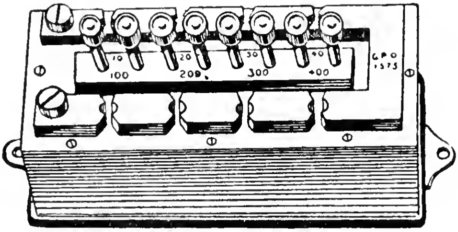


FIG. 10.—Retardation Coils.

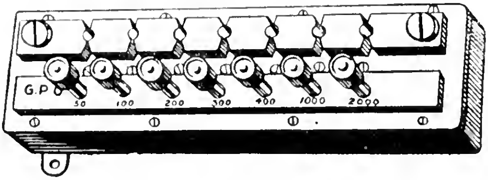


FIG. 11.—Condenser Coils.

resistance coils. The retardation and condenser coils are not service instruments.

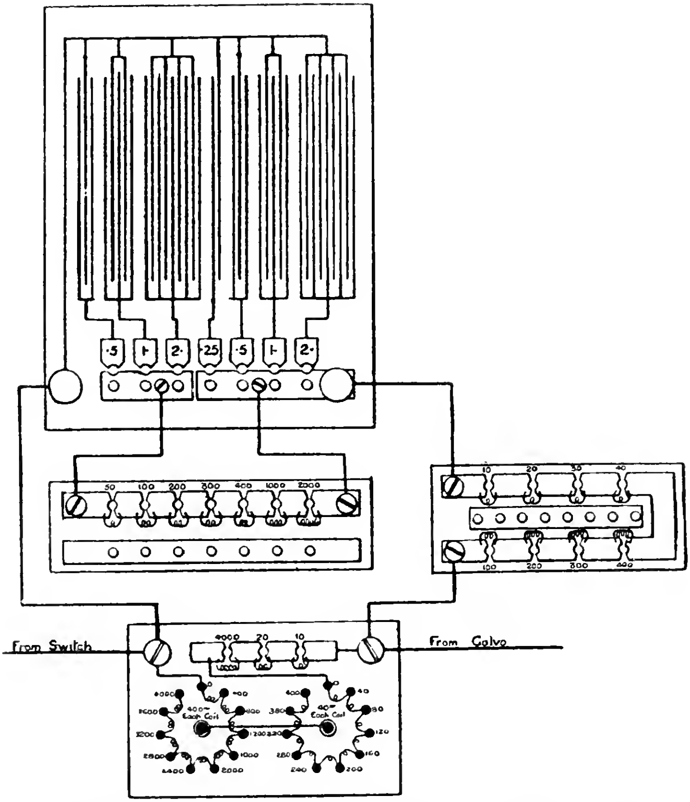


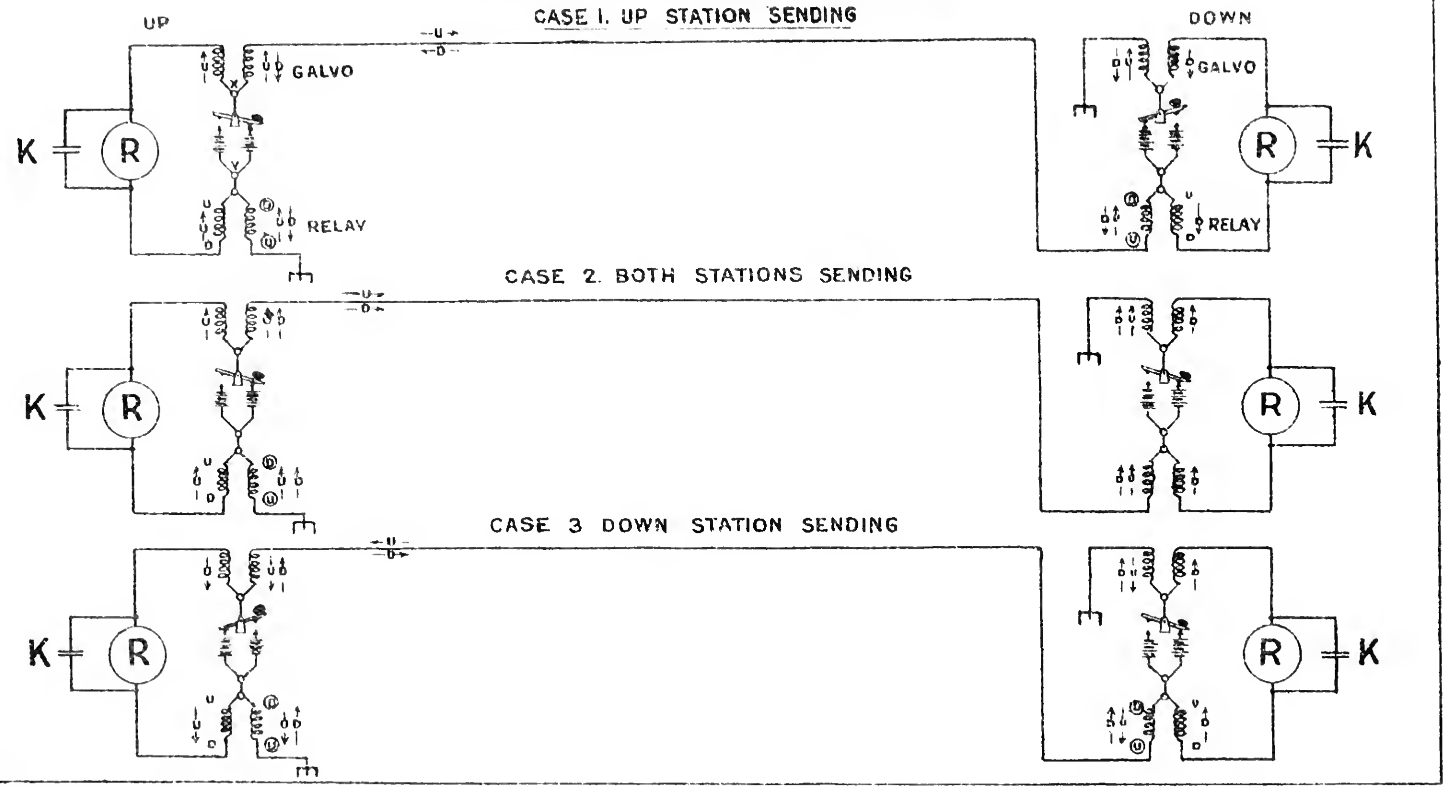
FIG. 12.—Connections of Rheostat, Condenser, Condenser Coils, and Retardation Coils, for D. C. Duplex Circuit over 200 miles.

Effect of self-induction on duplex working.

13. Every line has also self-induction, the effect of which is to retard the growth of the current (*see* Chapter I, para. 54); this effect is especially noticeable on low-resistance lines. The compensation circuit has practically no self-induction, and if the resistance of the line is very low this may interfere with the working, the effect on the galvanometer being similar to that of capacity in the line, but the kick of the needle is in the opposite direction. This effect can be neutralized by adding self-induction to the compensation circuit (inserting a spare relay, or sounder, will usually have the desired effect), or the line resistance may be raised by adding a resistance coil, but this entails an increase of battery power. The difficulty disappears on lines of over a few miles in length.

Chap 7. Fig 13

DOUBLE CURRENT DUPLEX



H & C GRAHAM LTD, LITHRS LONDON, S.E.

Double current duplex.

14. D. C. Duplex has the same advantage over S. C. duplex as D. C. simplex over S. C. simplex. The adjustment of the relay can be made more sensitive and a greater rate of sending is possible. Fig. 13 gives theoretical diagrams of D. C. duplex similar to that given for S. C. duplex in Fig. 4. A divided battery with S. C. key is shown for clearness in place of the single battery and D. C. key generally used. No "send and receive" switch is required, while duplex working is going on. Following out the circuits as in case of S. C. working we have :—

Case 1.—Up station only sending—When key is pressed the marking current divides at X through galvanometer coils to compensation circuit and to line—The two portions return through the relay coils and unite at Y. These currents, as in S. C. working, produce equal and opposite effects in the up galvanometer and relay. At the same time the down station is sending a *spacing* current which enters the up station from line through right coil of the galvanometer (in the opposite direction to the "up marking" current) through battery and out to earth, passing through relay from Ⓓ to Ⓤ. The effect of this unbalanced current is to deflect the up galvanometer needle to the left and move or keep the tongue of the up relay to the spacing stop. The currents in above explanation have been considered as if each flowed independently of any other existing current, showing clearly, as is the case, that the deflection of galvanometer and "spacing" on relay are due to a spacing current being received from the down station, while the up marking currents do not affect their own instrument. We might describe the action perhaps more accurately by saying that the marking current to line from up station and spacing current from line from down station neutralize one another, leaving no current in the line branch, and the deflection of galvanometer needle and movement of relay tongue are produced by the up compensation (marking) current flowing unbalanced from D to U.

Case 2.—Suppose while up station is sending, down station also sends, *i.e.*, keys are pressed at both stations. The marking currents from up station produce as before no effect on up galvanometer or relay. The marking current from the down station enters the up station at Ⓤ, flows through the relay and causes it to mark, and through the galvanometer deflecting the needle to the right. As in the Case 1 we may consider the action from another point of view and say that the current in the line branch is double that in the compensation branch, and therefore the relay marks and the galvanometer is deflected.

The up station then receives signals at the same time that it is sending.

Case 3.—The down station only sending. Its marking current enters up station (as in Case 2) at Ⓤ, flows through coil to Ⓓ to line and through right coil of galvanometer back to down station. At the same time the up station is sending a "spacing" current dividing through up relay from U to D and from Ⓓ to Ⓤ and returning to zinc through the two coils of the galvanometer. These currents are equal and produce no effect on the instruments, while the down marking current, unbalanced, causes the relay to work and the galvanometer needle to deflect to the right, or as before we may say that the spacing current from up station neutralizes the marking current from down station, leaving no current on the line, while the compensation current unbalanced, from U to D, causes the relay to mark and the galvanometer needle to deflect.

The action at the up station only has been followed in the text, but by referring to Fig. 13 that at the down station can be similarly traced. The direction of the currents and the station from which they originate are shown by arrows marked U and D respectively.

D C duplex connections.

15. Fig. 14 gives the actual connections for D C duplex, up and down stations. In this diagram the condenser is shown connected up across the terminals of the rheostat, and D C keys are used; while working duplex the key switches are both kept at "send." A switch, single and duplex, is added to the circuit, as in the case of single current duplex, to allow of simplex working being employed if desired.

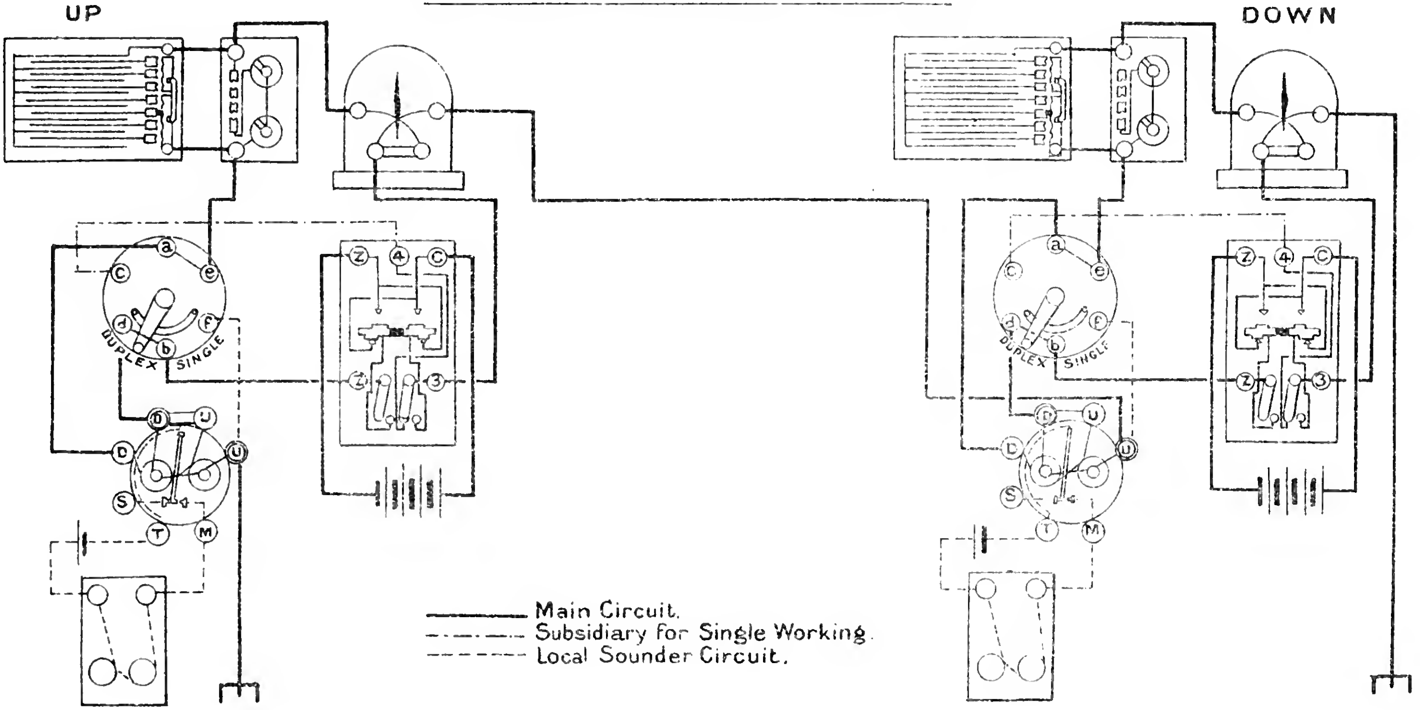
Tracing marking currents when up station is sending and working duplex, we have copper of battery to C of key (the switches in both keys must be at send), to 3, to galvanometer (Point X, Fig. 13) where it divides; half flows through right coil of galvanometer to line, enters down relay at Ⓤ, flows to Ⓓ, to *d* of switch, to *b*, to 7 of key, to Z, through battery to C, to 3 if down key is pressed, or from 7 to C through battery to Z, to 3 of key, if not pressed. From 3 it flows through coil of galvanometer to earth and returns to up station at Ⓤ to Ⓓ, (Point Y, Fig. 13). The other half of the current flows through the left coil of the galvanometer, through the rheostat to *e* of switch, to *a*, to D of relay, to U where it unites at the brass strap with the line portion of the current. The whole current then flows from Ⓓ to *d* of switch, to *b*, to 7 of key, to Z, to zinc of battery.

The spacing currents from up station flow in same circuits but in the opposite direction, and the down station is at the same time sending out a current (either marking or spacing). To understand the effect on any one relay or galvanometer the least confusing method is to trace each current as if flowing without reference to any other, and consider the resultant effect of the three on the instrument in question; thus three equal currents, one from U to D, one from Ⓓ to Ⓤ and one from Ⓤ to Ⓓ will cause the relay to mark.

If the single and duplex switch be moved to "single" the system works as an ordinary D C set. At up station

Chap. 7. Fig 14.

DOUBLE CURRENT DUPLEX.



1774

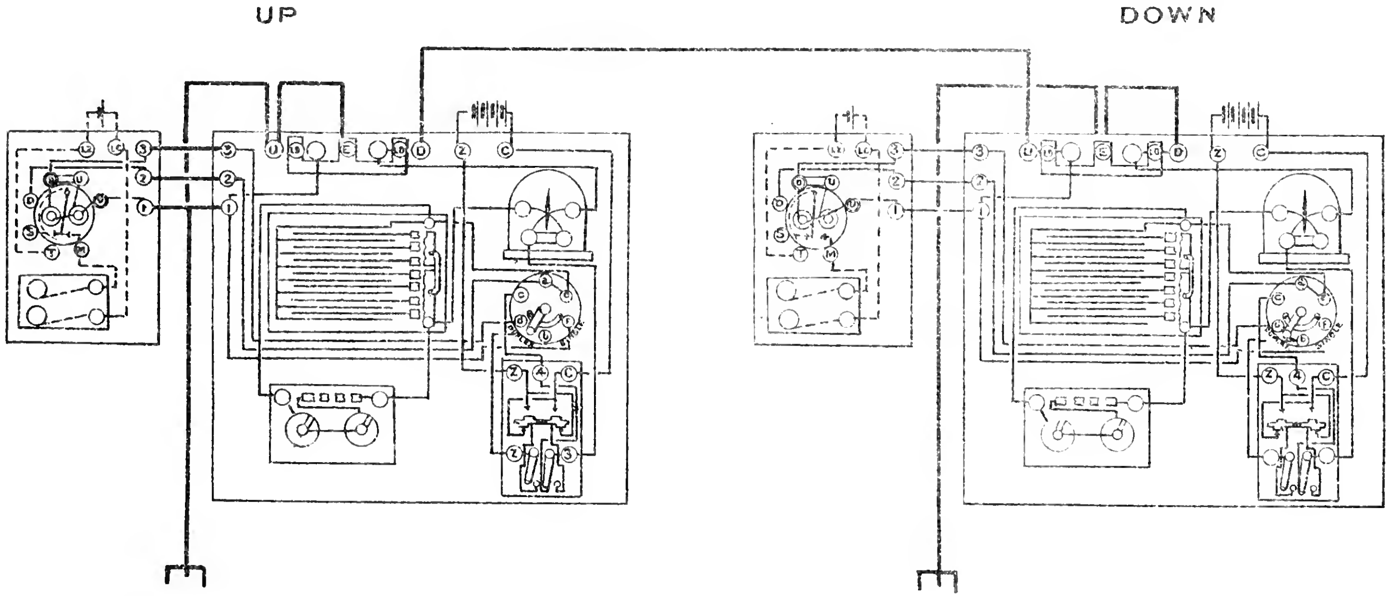
H. & C. GRAHAM LTD. LITHRS, LONDON, S.E

To Face p. 104.

Chap. 7. Fig 15.

TWO BASEBOARDS DUPLEX.

JOINED UP FOR DUPLEX WORKING.



To face p. 105

H & C. GRAHAM LTD, LITHRS, LONDON, S.E.

marking current flows from copper of battery to C, to 3, to galvanometer, to line (compensation branch is dis at *e* of switch) enters down station at Ⓤ of relay, to Ⓓ, to U, to D (circuit from Ⓓ through *d* is dis) to *a* of switch, to *c*, to terminal 4 of key, to general stud, to 3 (when working simplex the key switch must be used) from 3 to galvanometer, to earth, returns to up station at Ⓤ of relay, to *f*, to *b* of switch, to 7 of key, to Z, to zinc of battery. The spacing current can be similarly traced round same circuit in the opposite direction.

Adjustments of D C duplex.

16. The adjustments of sounder and relay are the same as for ordinary D C working. The galvanometer needle in D C duplex is always deflected as there is always an unbalanced current through one coil. One station must adjust at a time. The adjusting station alters the resistance in the compensation circuit until working the key causes no alteration in the deflection of the galvanometer. The condenser capacity may also require adjusting. A *momentary* kick of the galvanometer needle to the observer's right on pressing the key, or to the left when it is raised, indicates too little capacity in the compensation circuit, and more must be added by plugging between the bar and the blocks. A momentary kick to the left on "make" and right on "break" indicates too much capacity in the compensation branch.

The resistance and capacity of a long line may vary from hour to hour according to the weather, so that considerable experience may be required on the part of the operator to keep his instruments in proper adjustment when working duplex. Duplex telegraphy possesses one great disadvantage for military purposes, viz., that intermediate stations cannot be established. S C duplex translation is however easily effected and obviates this difficulty to a great extent.

Baseboard duplex.

17. A "baseboard, duplex," has lately been introduced into the service on which the necessary instruments for D C duplex working are mounted. It consists actually of two boards, a large and a small, which pack together for transport. Fig. 15 shows two of these sets connected up and gives their internal connections. By putting the switches over to single, ordinary D C working can be carried on. The small board has the receiving portions of the circuit mounted upon it, the large board the sending instruments, so that the two clerks may be seated a convenient distance apart.

S C duplex translation.

18. No military set is arranged for Duplex translation, but as it can be effected with the instruments already described and is simple to understand when the principles of duplex working and translation are known, a short description is included here.

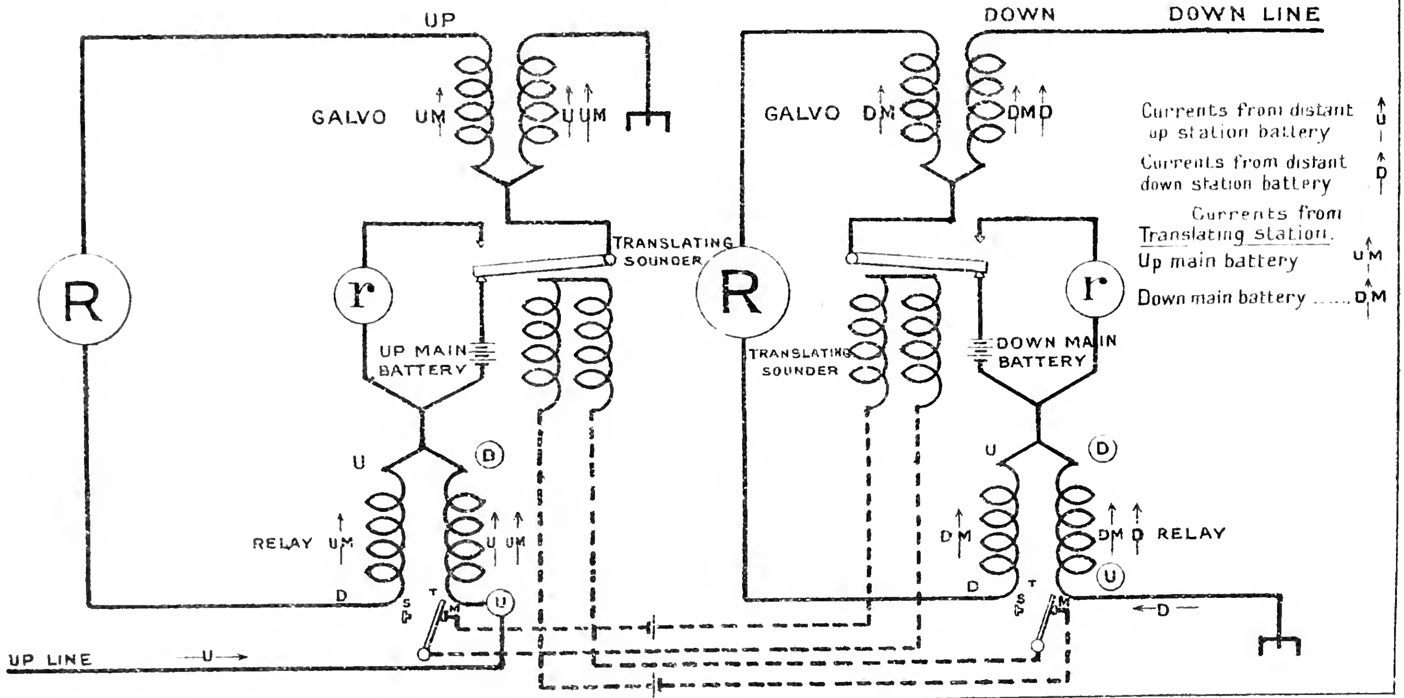
Fig. 16 gives a theoretical diagram of S C Duplex translation It is obviously only two S C duplex sets in which the keys are replaced by translating sounders, the sounder of one set being worked as a key by the relay of the other set. In the diagram translation in both directions simultaneously is shown, and it will be seen from the arrows representing the currents that the translation, say, from up station to down is unaffected by translation from down to up, and *vice versâ*. Fig. 17 is a diagram of the complete connections of a S C duplex translating station. There are three "S and D" switches in the circuit. The centre one divides the instruments into two sets, connected together for translation when this switch is at "Duplex" or working separately to up and down stations respectively when it is at "single." By means of the other two switches the two sides of the circuit may be joined up for either duplex or single working, either when they are connected for translation or are working separately. The condensers are omitted from the diagram for the sake of clearness.

Chap 7. Fig 16.

SINGLE CURRENT DUPLEX TRANSLATION.

THEORETICAL DIAGRAM.

TRANSLATING STATION—BOTH DISTANT STATIONS SENDING



H & C GRAHAM LTD. LITHRS LONDON S.E.

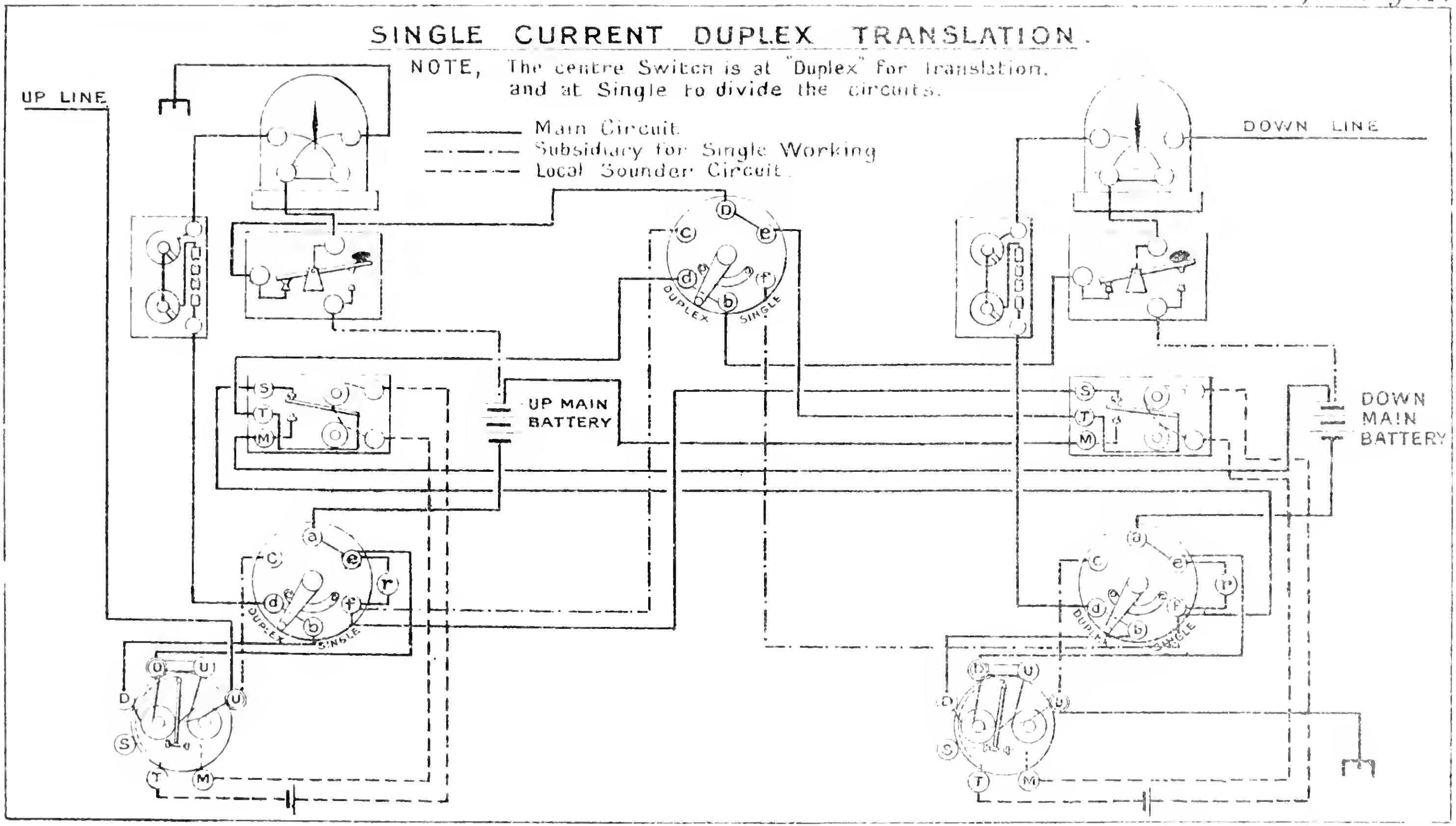
To face p 106.

Chap. 7. Fig 17.

To face p 106

SINGLE CURRENT DUPLEX TRANSLATION.

NOTE, The centre Switch is at "Duplex" for translation, and at Single to divide the circuits.



H & C. GRAHAM LTD, LITHRS, LONDON, S.E.

CHAPTER VIII.

QUADRUPLEX.*

Diplex.

1. Duplex telegraphy, as has been explained, means the transmission on the same wire of two messages at once in *opposite* directions. Sending two messages at once in the *same* direction on one wire is known as "Diplex" telegraphy, and by combining the two systems we get "Quadruplex" working, four messages being sent simultaneously, two in each direction.

Diplex working is effected as follows :—

A continuous current flows to line. At the receiving station are two relays, one an ordinary polarized relay which works when the *direction* of the current is changed, whatever its strength ; the other, a non-polarized relay which works whatever the direction of the current, but only when the *strength* of the normal current is increased. At the sending station is a double current key which reverses the direction of the current and thus works the polarized relay, and a single current key to increase the current strength and work the non-polarized relay. By working each of these arrangements on the *duplex* system already described, we get quadruplex working. The double current key and polarized relay at a station are known as the "A side" of the set, and the single current key and non-polarized relay as the "B side."

Special instrument required.

2. The only instrument actually necessary for quadruplex working, not already described in connection with other systems, is the non-polarized relay, but special forms of D C and S C keys, and also of polarized relay and translating sounders, are generally employed for good working, and will be shortly described.

Non-polarized relay.

3. The electro magnet coils of the non-polarized relay are wound in the same way as those of the ordinary Post Office standard relay and the ends brought to terminals U D and Ⓤ Ⓓ. There is no permanent magnet to polarize the cores, and these have pole pieces as shown in Fig. 1. The two soft iron armatures are pivoted at their centres, and are made in two parts (*see* Fig. 2). The two halves of each are brazed together so that the two cores and two armatures of the instru-

---

* The special instruments required for Quadruplex working are not service instruments, and would be obtained if required from the Post Office. "Quad" working is not suited to field lines, the insulation and resistance being, as a rule, too variable to permit the necessary fineness of adjustment.

ment shall not make a closed magnetic circuit, and the residual magnetism become too strong when the armatures touch the poles to allow of their release. When connected up for quadruplex working a (weak) current as mentioned above is always flowing in the circuit and the cores of the relay are magnetized, and attract the armatures. It is immaterial in which direction this current is flowing, as the armatures are not polarized, and the ends are attracted always to the nearer pole. A light tongue is fixed to the pivot of the armatures, and by means of a spring attached to it (*see* Figs. 1 and 2) the armatures are prevented from actually touching the poles when the attraction is only that due to the normal (weak) current. The tension of the spring can, however, be so adjusted that the pull of the magnets when the strong current flows round them is sufficient to overcome the spring and pull the armatures over. The end of the tongue plays between two contacts on a fixed carriage; normally it rests against the stop marked M in Fig. 2 (corresponding to the "marking" stop in a polarized relay), but when the armatures are attracted it is brought into contact with the insulated stop marked S. The tongue and "M" are connected to two (unlettered) terminals on the base. It will be seen, therefore, that since the tongue is normally against the marking stop, the current in the local circuit is continuous till *broken* by the working of the relay. The reason for this arrangement is that during the time the strong current sent by the S.C. key is flowing and actuating the non-polarized relay, the *direction* of the current may be changed by the movement of the D.C. key on the A side.

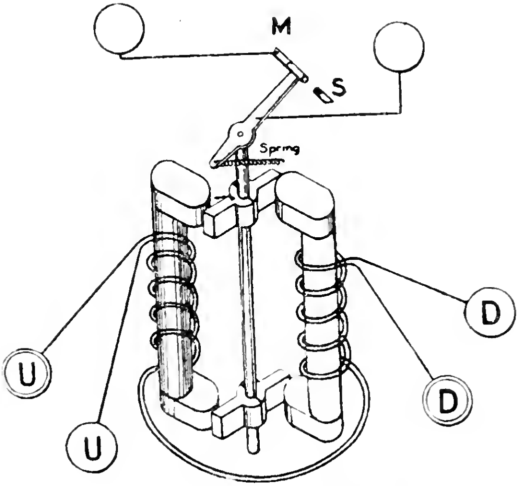


FIG. 1.—Non-Polarized Relay.

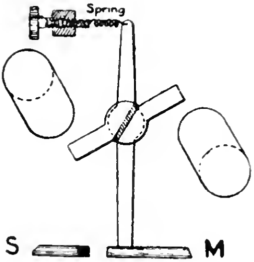


FIG. 2.

Such reversals cause momentary breaks in the current, and cause the tongue of the relay to "chatter" on the spacing stop. The local circuit, however, remains continuously broken during a signal, in spite of this, partly due to the inertia of the (comparatively) heavy armature of the sounder, and partly due to the relay tongue itself being somewhat sluggish, and not having time to make good contact with the marking stop. The slight kick in the relay is not, therefore, communicated to the local circuit. If the tongue was normally against the spacing stop and *completed* the local circuit when the armatures were attracted (as in ordinary relay working) the least movement of the armature and tongue would completely break the local circuit and the signals would be split. The sounder in this local circuit, therefore, works "reversed," that is its armature is normally down, and rises when a strong current is sent from the distant station.

Uprighting sounder.

4. The signals are not easy to read when it is working in this way, and a translating sounder (or an "uprighting" sounder as it is called when used for this purpose) is used in place of the ordinary pattern. To S and T of the translating sounder is connected a second local circuit containing an ordinary sounder, known as the "reading sounder," on which the signals are received in the usual way. The stops of the uprighting sounder are adjusted to give the lever very little play, and the sound does not interfere with the signals from the reading sounder. The Post Office pattern uprighting sounder (Fig. 3) differs a little from the military translating sounder, having a lighter lever, and the adjusting screw for the lower (marking) stop arranged as in the "recorder," *i.e.*, not fixed on the lever itself.

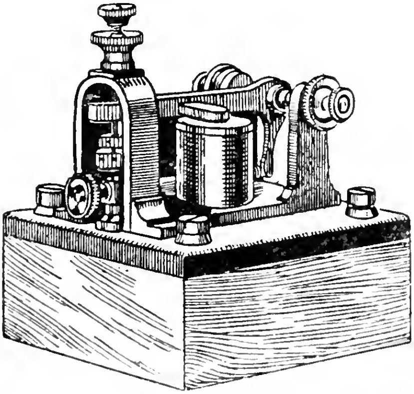


FIG. 3.—Uprighting Sounder (Post Office Pattern).

Fig. 4 gives a diagram of the non-polarized relay, uprighting sounder, and reading sounder connected up.

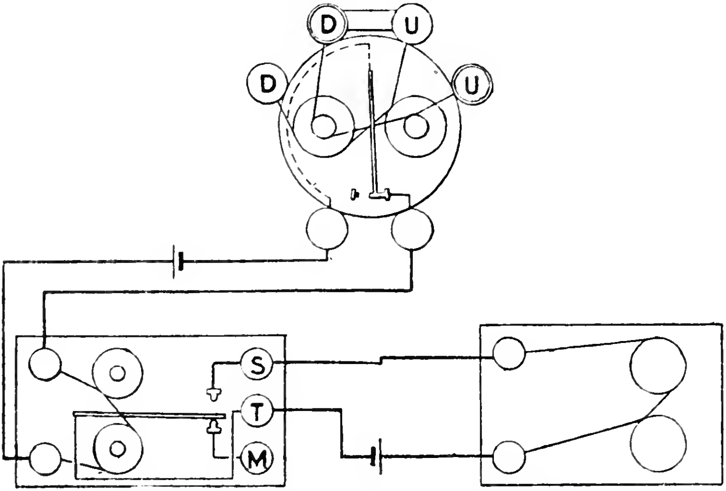


FIG. 4.—Non-polarized Relay and Local Circuits.

Increment key.

5. The special form of S.C. key is illustrated in Fig. 5. It is designed simply as one half of a D.C. key, the upper and lower springs corresponding to the "front" and "back" stops of an S.C. key respectively. The connections to the stops and bridge of the key are brought out to three terminals on the ebonite base. This pattern is better than the ordinary S.C. key, as the springs follow up the contacts on the lever, and by adjusting the lower stud, contact can be made on one spring at the moment it is broken on the other, while independent of this adjustment, the lever of the key can be given a suitable amount of play for convenient sending.

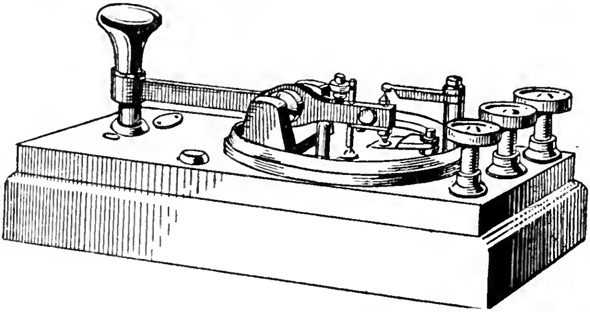


FIG. 5.—Increment Key.

Reversing key.

6. The reversing key, Fig. 6, is like an ordinary D.C. key from which the "send and receive" switch and its connections have been removed. Screw studs with capstan heads form the lower contacts on the lever, as in the increment key.* By adjusting the screws, contact between the lever and lower springs can be maintained when the key is pressed till the moment the top contacts of the lever touch the upper springs, and *vice versâ*, when the key is released. The object of this is to prevent there being any interval of disconnection when working the key; for as will be seen (Fig. 7) the increment and reversing keys are in series, and a dis in either will affect both the A and B sides.

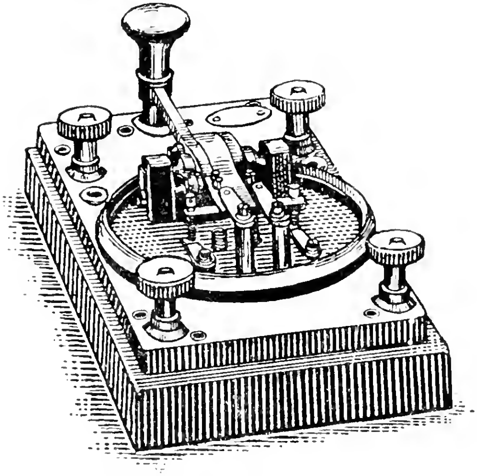


FIG. 6.—Reversing Key.

Polarized relay, Type B.

7. A pattern of Post Office standard relay, exactly similar in design to that already described, but with thicker wire in the coils, is generally employed for quadruplex working, since the current that flows when the B side is working is much greater than in other systems in which the relay is used, and might damage the finer wire of the ordinary pattern. This quadruplex relay is known as the Post Office standard, type B, its resistance is 200 ohms in series and 50 ohms in parallel.

Quadruplex.

8. Fig. 7 shows two stations connected up for quadruplex working. The instruments are shown diagrammatically and the local circuits omitted. The thin arrows represent "A" side currents, the thick "B" side currents; the case represented

---

* The "Key, double-current, Mark III," has such adjustable contacts, and can be used as a reversing key.

being that of both "A" and "B" sides sending at each station, *i.e.*, all four keys down.

The various conditions that arise when working may best be understood by marking on a diagram, similar to Fig. 7, the currents from the batteries and noting their combined effect on any particular relay or galvanometer.

Some of the different cases may be shortly summarized as follows :—

Case 1.—All keys at rest. Batteries E_1 only are working, sending out spacing currents. The "effective" or "unbalanced" currents through the A relays are from D to U or Ⓓ to Ⓤ. The same "effective" currents flow through the D U coils of the B relays, but are too weak to actuate them. None of the relays therefore work.

Case 2.—Both A keys depressed. The currents are the same as in Case 1, but reversed in direction. The effective currents therefore flow from Ⓤ to Ⓓ or U to D and work the A relays, but are still too weak to affect the B relays.

Case 3.—All keys depressed. Conditions are the same as in Case 2, but the strength of the currents are increased and the B relays respond as well as the A relays (Fig. 7).

Case 4.—Suppose A key depressed at up station and B key at down station. At the *up station* there will be weak currents from its own battery E_1 through Ⓓ – Ⓤ and U – D of each relay, the effects of which will neutralize one another. There will also be a strong current from the down station batteries E_1+E_2 through D – U of each up relay; this current will hold the tongue of the A relay to the spacing stop and work the B relay. At the *down station* there will be strong currents from the down batteries E_1+E_2 through Ⓓ – Ⓤ and U – D of both relays, and these produce equal and opposite effects. A weak current from E_1 at the up station also flows unbalanced through Ⓤ – Ⓓ of both relays, causing the A relay to work but not strong enough to effect the B relay. The general result, therefore, is that the *up B relay* and the *down A relay* work.

Other cases can be followed out in a similar way.

Compensation circuit, spark coil, &c.

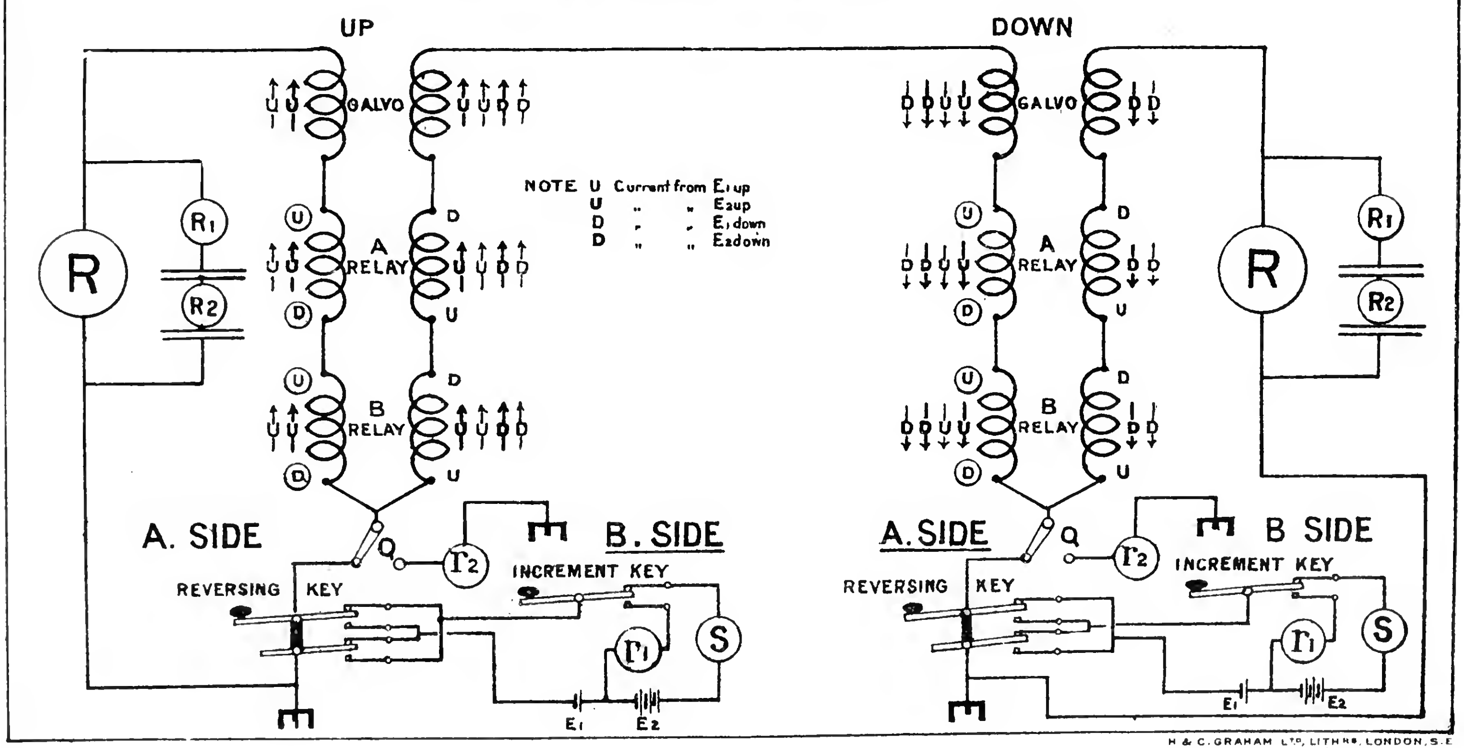
9. There are one or two other points to notice in Fig. 7. The compensation circuit is shown complete as in Fig. 12, Chapter VII, with condenser, condenser coils, and retardation coils, to balance the line as accurately as possible. S is a resistance of 100 ohms called the "spark coil" placed between the large battery E_2 and the front stop of the increment key to prevent a very large current flowing (followed by a heavy spark) if the contact springs of the increment key are momentarily short circuited by the lever when working.

r_1 is a resistance block made approximately equal to S+ internal resistance of E_2, so that the total resistance of the circuit may be unaltered whether the increment key be up or

Chapter 8. Fig 7.

QUADRUPLEX WORKING

SHOWING A&B SIDES SENDING AT BOTH STATIONS



H & C. GRAHAM LTD, LITHRS, LONDON, S.E

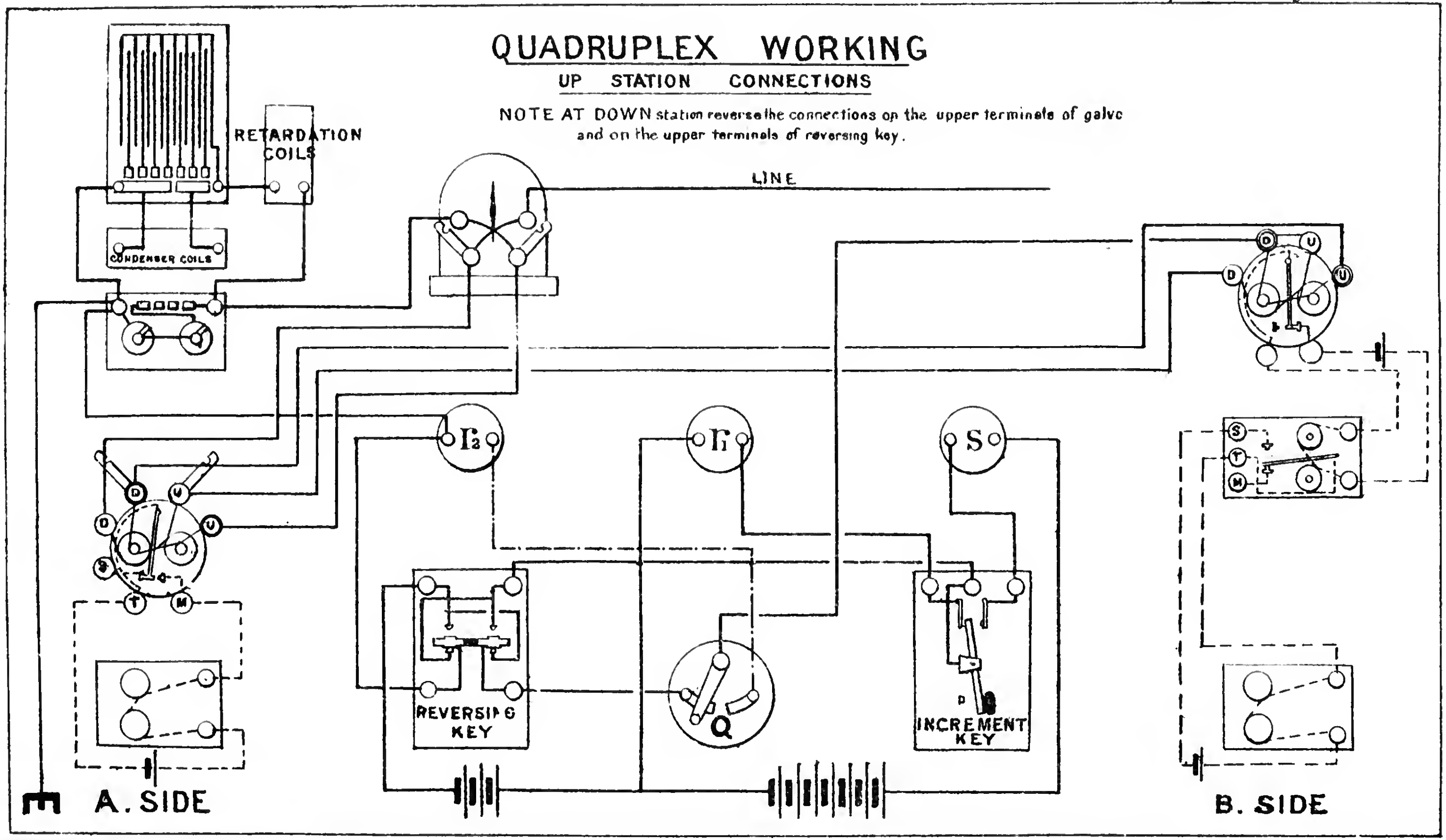
To Face p. 112.

Chapter 8 Fig 8.

QUADRUPLEX WORKING

UP STATION CONNECTIONS

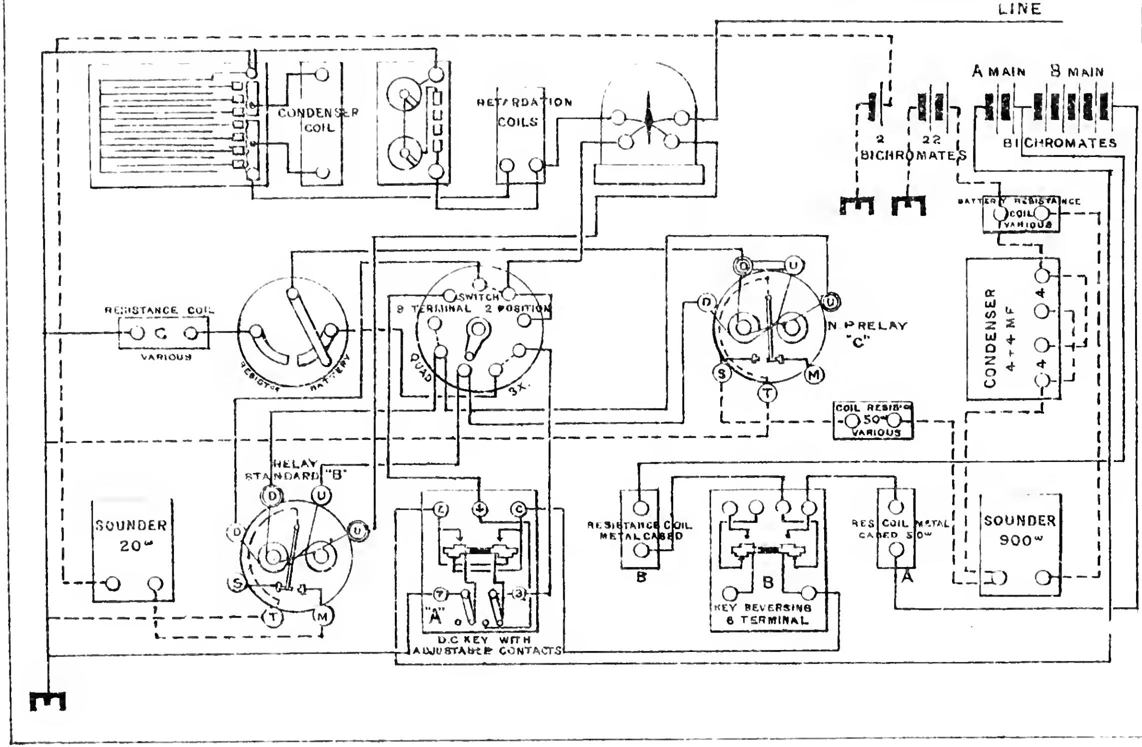
NOTE AT DOWN station reverse the connections on the upper terminals of galvo and on the upper terminals of reversing key.

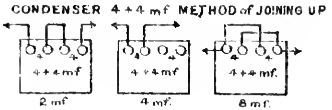


H. & C. GRAHAM LTD, LITHRS, LONDON, S.E

QUADRUPLEX WORKING

CONNECTIONS AT AN "UP" OFFICE WITHOUT USING UPRIGHTING SOUNDER





At a Down Office reverse the wires on the upper and lower terminals of the Galvanometer; the wires on D and U of the Standard Relay B; and the battery connections on the "A" Key

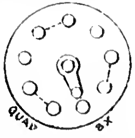
The D.C. Key with adjustable contacts used on the "A" side must be adjusted to short circuit the battery momentarily during reversal. "D.C. Key with adjustable contacts" will be the standard form issued in future.

On circuits under 100 miles in length 13 Bichromates may be used for the "B" local battery

The Coil "A" should have a resistance of 50ω. The Coil "B" should have approximately a resistance of 50ω plus the resistance of the "B" side battery, and the Coil "C" should have a resistance equal to that of "A" plus the total resistance of the whole battery.

If no Bichromate cells are available, use double the number of Daniell's cells

CONNECTIONS OF SWITCH AT SIMPLEX.



H & C GRAHAM LTD LITHRS, LONDON S.E.

T face p. 113

down. The connection in which r_1 is placed, viz., from the positive pole of E_1 to the back stop of the increment key is called the "tap wire."

The switch Q serves to put the line to earth through the receiving part of the circuit, cutting out the keys and battery, for convenience in balancing or for testing purposes. It serves also to prevent the main batteries working when the circuit is not in use; the relays being still in circuit the office can be called up if required. Between Q and earth is placed another fixed resistance, r_2, equal to S+internal resistance of the whole battery $E_1 + E_2$. For good working the E.M.F. of E_2 should be $2\frac{1}{3}$ times that of E_1, so that when the increment key is down the E.M.F. applied to the circuit is $3\frac{1}{3}$ times as great as when it is up. Batteries giving 30 volts and 70 volts respectively are commonly used for E_1 and E_2 on quadruplex circuits.

Complete Quad connections.

10. The complete connections for an "up" quadruplex station are shown in Fig. 8. The connections at the "down" office are the same as at the "up," except that the line and compensation connections are reversed on the terminals of the galvanometer, and the battery connections on the reversing key. The apparatus at an office should be arranged so that the two sending clerks sit together in the centre, the messages to be forwarded being placed between them. The two receiving clerks sit next them, one on either side. The section to the left of the switch is the A side, that on the right the B side.

The circuits in Fig. 8 can be traced with the help of the diagrammatic circuit, Fig. 7.

Note.—In quadruplex working, the straps on the galvanometer, and on the A side relay are not used.

Quadruplex working without uprighting sounder.

11. A system of working the B side without an uprighting sounder has recently been introduced (October, 1905) in the Post Office, and is shown in Fig. 9.

The connections on the S and M terminals of the B relay are reversed so that the local circuit is normally broken. A sounder of 900 ohms resistance is used in the local circuit, and an adjustable condenser of 2, 4, or 8 microfarads is joined across its coils with suitable resistances in the circuit to prolong the discharge. By this arrangement the magnetism in the coils of the sounder is kept up by a current from the condenser when the momentary breaks due to reversals in the line current by the A side key take place. Split signals on the B side are thus prevented.

Nine terminal switch.

12. A new pattern two-position switch with 9 terminals has also been introduced, and a D C key is used on the A side in place of the reversing key, but with adjustable contacts like those of the latter on the B side,* a six-terminal key, as described below, is used in place of the increment key—one side only being connected up.

---

* The "Key, double-current, Mark III," has these adjustable contacts.

Six terminal key.

13. This is a convenient place to notice shortly a pattern of key lately introduced in the Post Office which can be used in place of all other patterns, single or double current, except single current key with switch.* It is illustrated in Fig. 10. As the figure shows, it is constructed on the same lines as a D.C. key, or rather as a "reversing" key. It differs only from the latter in that its two bridges, front and back stops, are each connected direct to a separate terminal, and the instrument consists of two S.C. keys side by side unconnected with one another. For use as a S.C. key, one side only, with its three terminals, is employed. To use for D.C. working the top terminals must be cross connected, and a separate two-way switch used for sending and receiving, Fig. 11. As a "reversing" key the cross connections, as in Fig. 11, are required, and as an "increment" key, one side is used.

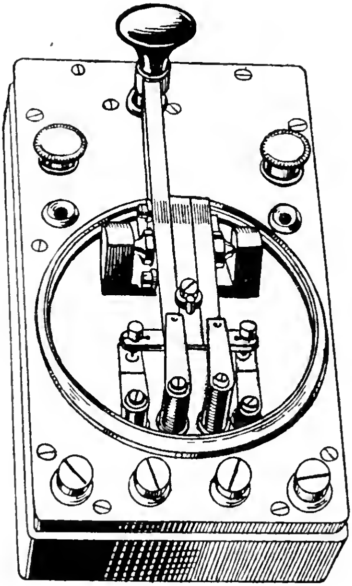


FIG. 10.

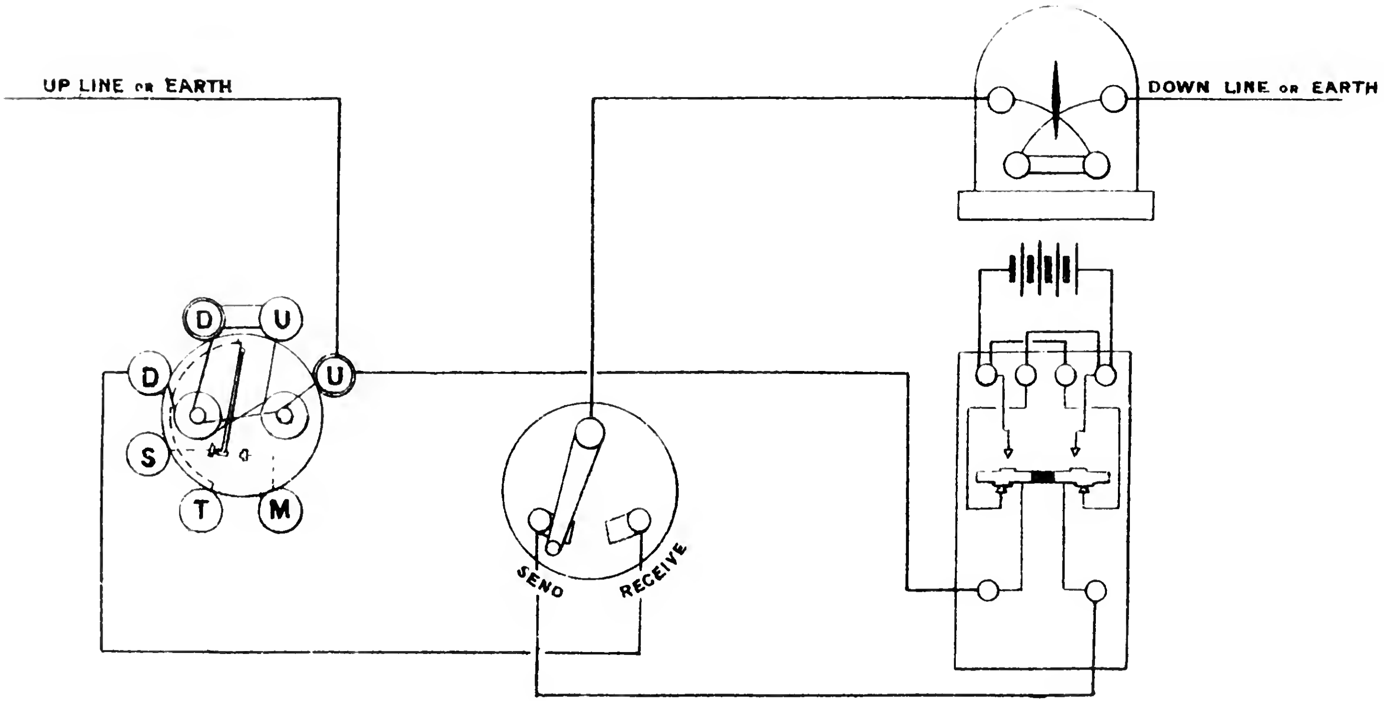
---

* Not described in this book, but used for D.C. sending with common battery working, and is practically a combined key and switch used as described in Chap. V, para. 9.

Chapter 8. Fig. 11.

SIX TERMINAL KEY

CONNECTED FOR DOUBLE CURRENT WORKING.



H & C GRAHAM LTD. LITHRS. LONDON S.E.

To face p 114.

CHAPTER IX.

THE HIGH-SPEED WHEATSTONE AUTOMATIC SYSTEM.

Automatic working.

1. When describing how the duplex system doubled the amount of work that could be done on a single line, it was explained that this method was often of little use for relieving the press of work on military lines, as such pressure, when it occurred, was usually in one direction. The quadruplex system, of course, is of more use in this respect, but requires experienced clerks and very careful adjustment. The automatic system increases the working capacity of a line by greatly increasing the rate at which messages can be sent. On all the circuits hitherto described, the signals are sent on the key by hand, and the maximum rate at which a good clerk can send is about 35 words per minute. The operator gets tired also, and is liable to make mistakes and lose time in making corrections. In the automatic system the hand-worked key is replaced by a machine capable of sending the dots and dashes at a maximum rate of from 200 to 400 words a minute, depending on the line conditions, and the messages are recorded at the receiving station on a tape by an instrument very similar to the ordinary inker. The dots and dashes composing the message to be forwarded must be represented in a particular way by holes punched in a paper slip before they can be sent by the automatic transmitter, but several clerks may be employed at this, and with good punchers messages can be dealt with on a single wire as fast as on six or seven separate hand-worked circuits. The automatic apparatus consists of somewhat delicate mechanism and is rather heavy, and, therefore, unsuitable for field work; but for more or less permanent offices on lines of communications it has been found exceedingly useful.

Instruments for military use would probably be obtained from the Post Office, or would, at any rate, be the same as used by that department.

The following description is taken from "Technical Instructions," published by the G.P.O.

Apparatus required.

2. The automatic apparatus consists of three parts, the perforator, the transmitter, and the receiver, but a double current key, a galvanometer, and a sounder are always required in addition, while a rheostat and a condenser are also necessary where speeds in excess of 300 words per minute are desired; the key and sounder enable the tele-

graphist in charge of the circuit to obtain and give corrections and acknowledgments, or to work by hand when there is not sufficient traffic to demand automatic working, and the galvanometer checks the condition of the transmitter and key and indicates the strength of the current arriving from the distant office.

Galvanometer.

3. The galvanometer should be supplied with a double-wound * shunt-resistance to carry off the extra current generated in the coils.

The perforator.

4. The perforator, which is shown in plan and front elevation by Figs 1 and 2, is purely mechanical in its action. Groups of perforations, corresponding to the letters of the alphabet, are made up by it in a slip of oiled paper, which is afterwards propelled automatically through the transmitter.

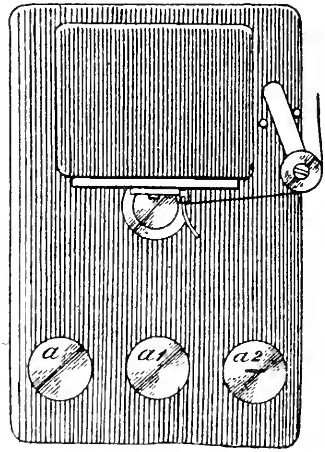


FIG. 1.

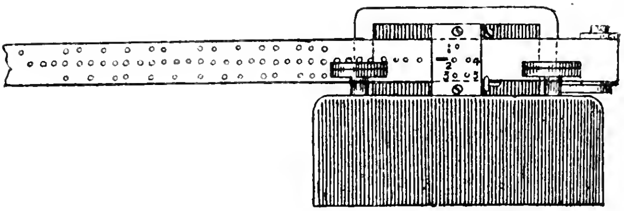


FIG. 2.

The keys or plungers a, a_1, a_2, Fig. 1, actuate five punches, 1, 2, 3, 4, 5, Fig. 2. When key a is depressed, it

---

* *I.e.*, wound "non-inductively"—resistance about 300 ohms.

causes 1, 2, and 3 to perforate the paper in a vertical line, thus: ◯ ○ ◯ ; the depression of a_1 causes 2 only to punch, thus: ○ ; and the depression of a_2 causes 1, 2, 4, and 5 to perforate, thus: ◯ ○ ◯ ◯ ; a corresponding with a dot, a_1 with a space, and a_2 with a dash. The centre row of perforations acts as a guide to keep the paper in its proper place in the transmitter, and as a rack by which it can be propelled. The perforations above and below the centre determine the number and order of the currents sent by the transmitter.

Fig. 3 shows the mechanism placed beneath the cover, and Fig. 4 shows the levers b, b_1, and b_2, which are pivoted in the block B under the base, and are connected respectively to the keys a, a_1, and a_2. The opposite ends of the levers project upward through the base and terminate at the back of the mechanism (Fig. 3) near the ends of the five punches. Above and below the punches are two small rods, one of which is shewn at c, Fig. 3. These rods are provided with steel spiral springs for withdrawing the punches after the depression of the keys. Spiral springs are also used to restore the keys and levers to their normal position after each operation.

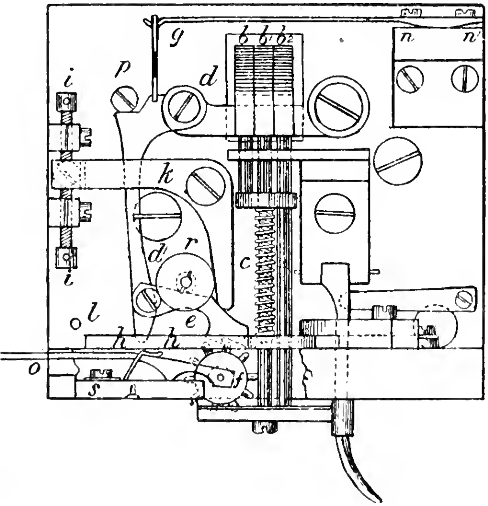


FIG. 3.

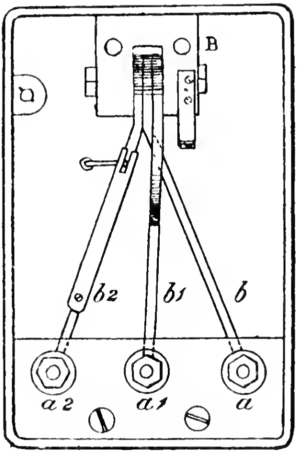


FIG. 4.

Action of perforator.

5. When key a is struck the corresponding lever b is depressed; the opposite end of this lever pushes forward the punches 1, 2, 3 (Fig. 2), and the lever d (Fig. 3), which carries

the smaller lever d_1 and the pawl *e*. By this movement the three punches are forced through the paper slip, and perforations representing a dot are produced; and also *d* draws forward d_1 (to which the pin *p* acts as a fulcrum) and causes the pawl *e* to move back over one tooth of the star-wheel. When the key rises the punches are withdrawn, as already explained by the spiral springs *c*, and the pawl *e*, and its connecting levers are made to resume their normal position by the action of the strong flat spring *g*, so that the paper is pushed forward one space by the pawl *e*, operating the star-wheel *f*. There are similar movements when the two keys a_1, a_2 are depressed, except that one punch only is actuated when a_1 is depressed to form a space, and four when a_2 is depressed to form a dash.

The lever *h*, Fig. 3, is connected by means of a small rod passing through the base of the lever b_2, and is only actuated when a dash is punched. Its function is to regulate the movement of the pawl *e*. When either a dot or a space is punched, the movement of lever d_1 is limited by the tail-piece of *h*, and the pawl moves over one tooth only of the star-wheel, pushing the slip one pace forward, but when a_2 is depressed, the lever *h* is raised so that the movement of d_1 is not limited by *h*, but by the pin *l*, and the pawl accordingly moves over two teeth of the star-wheel, so that when the key rises the paper advances two spaces.

Perforator adjustment.

6. The machine is adjusted by means of the two screws, *i*, *i*, which act upon the bent lever, *k*. It must be so adjusted that 120 centre guide holes and 120 spaces are produced in exactly 12 inches of paper. The adjustment of the screws, *i*, *i*, moves the lever, *k*, either inwards or outwards. If the end nearest the punches be moved towards them, then the perforations will be spread over a great length of paper; but if it be moved away from the punches, the perforations will be closer together and will occupy less paper. If a length of slip be taken containing 121 spacing perforations (which number may be obtained without counting, by punching the word "telegraph" three times, including the double space between the words, but no space after the last word), then the distance between the centres of the first and last holes must be exactly one foot. In other words, the distance between the centres of any two adjacent guide holes should be exactly one-tenth of an inch. Although a perforation more or less will not generally make any material difference to the working, it is important for high speed that the adjustment be accurate.

The flat spring, *g*, can be adjusted by means of the screws, *n*, n_1, and must exert sufficient force to propel the paper freely after each depression of the keys. The vertical spring which carries the small grooved roller, *r*, is adjustable in a similar manner by means of two screws under the base.

It should exert just sufficient force to cause the pawl, *e*, to drop between the teeth of the star-wheel. When the keys, *a* or a_1, are depressed, the pawl should move freely over one tooth, and when key, a_2, is depressed, it should be drawn back over two teeth of the star-wheel. If undue force be required to produce this action between the pawl and the star-wheel, then it will probably be found that the rubber ring under the head of the faulty key is a little too thick.

The star-wheel frame is provided with a tail-piece, which projects outwards through the vertical plate, *o*, *o*, on the left-hand side. When paper is inserted this tail is pulled towards the operator in order to move the star-wheel out of the way, and as soon as the tail is released the wheel resumes its proper position.

The covers of perforators are hinged to the instrument, and fastened by means of a spring bolt on the right-hand side of the cover.

The star-wheel mechanism may be removed by withdrawing three small screws in the plate *s* (Fig. 3), and carefully pushing the piece outwards. The star-wheel revolves in a groove filed in the brass piece, and it should be quite clear of the sides and bottom of the groove.

Where two screws are provided for adjusting, care should be taken always to release one before tightening the other, or the heads will probably be broken off or the cocks bent. Clamping screws also should be loosened before moving the adjusting screws which they clamp, and carefully tightened up again when the adjustment is made.

A gauge half an inch wide and nine mils thick should pass freely between the front plates. The standard width of perforator paper is from 472 to 475 mils, and its thickness 4 to $4\frac{1}{2}$ mils.*

The transmitter.

7. The electrical mechanism of the transmitter is shown in Fig. 5.

The contact-points marked C^d, C^u, and those marked Z^d, Z^u, are connected respectively to the positive and negative poles of the transmitting battery. Between these contacts plays the compound lever DU, the two parts of which D and U are insulated from each other, and are connected, as shown, respectively to "down line or earth," and to "up line or earth." The lever is so pivoted, and the contacts are so arranged that when D makes contact with Z^d, U is in contact with C^u; and when D moves against C^d, U is changed over to Z^u. Thus reverse currents are sent to line. So long as the upper part of DU is to the left, a "spacing" current is sent to line, and when it is to the right a "marking" current is being sent. There are platinum contacts on the levers DU, opposite the contact-points.

---

* A mil is $\frac{1}{1000}$th part of an inch.

A jockey wheel J, fitted at the end of a flat spring, presses against the upper end of the lever D, and so holds the compound lever firmly against the contacts; the lever cannot maintain the intermediate position shown in the figure.*

The bell-crank levers A, A¹, which are pivoted on the front of the transmitter, are the means by which the required movements of the compound lever DU are effected. At the ends of the vertical arms of these levers are hinged the rods H, H¹ respectively, and at the ends of the horizontal arms are hinged the vertical rods S, M. The free ends of the rods H, H¹ pass freely through holes in the lever D, and work in brass bearings, shown to the right of the lever, so that they do not interfere with the action of the lever. Upon the rods, but insulated from them, are screwed adjustable collets, K, K¹. These will be again referred to when the action is described.

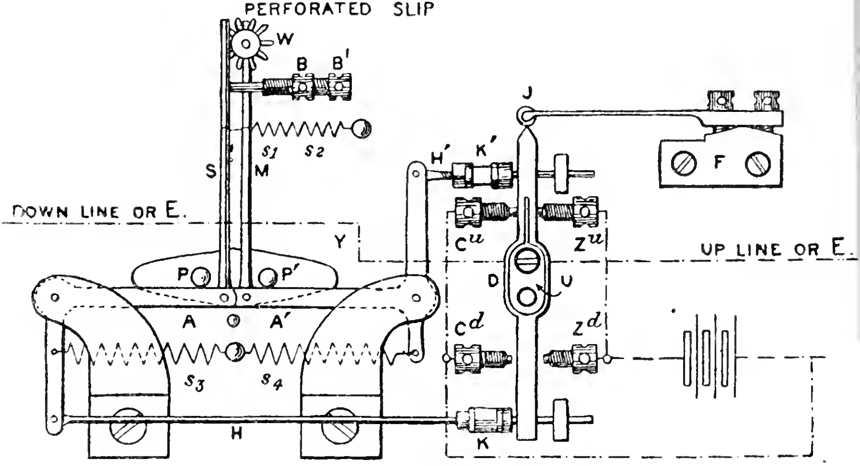


Fig. 5.

The rods S and M are kept in their normal position against the screws B, B¹ by means of light spiral springs s_1, s_2. The screws B, B¹ should be adjusted with special reference to the standard gauge of slip (*see* para. 6). The rods S and M pass on either side of a star-wheel W, which is of exactly the same description as that already referred to in the perforator. The wheel W is driven by the mechanism of the transmitter.

---

* The function of the jockey wheel and spring is superseded in the newer form of Wheatstone transmitter by a permanent magnet with pole pieces which attract and hold the compound lever to either side, exactly as in the case of the jockey wheel.

Y is an ebonite beam, pivoted at its centre, and caused to vibrate by means of a small crank driven by the clockwork. Projecting from Y are two steel pins P, P^1, against which the bell-crank levers A, A^1 are nominally maintained by the action of the spiral springs, s_3, s_4.

The two spiral springs attached to the crank levers A, A_1 are short, to prevent vibration being set up in the springs themselves.

The star-wheel revolves in a slot cut in a brass platform attached to the frame of the clockwork, and the two rods S, M work in similar slots on each side of that for the wheel.

The star-wheel is so geared that the upward movement of the rods S, M, if properly adjusted, takes place when the perforations in the paper slip come exactly opposite the ends of the rods.

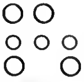
The perforated slip is kept in position on the star-wheel by a roller which is pressed into gear with the star-wheel by means of a spring. The position of this roller is so limited that it does not press upon the paper, but only prevents it from rising out of position. In it are gaps to keep it free of the rods S, M in their upward movement, and the central portion is toothed to gear with the teeth of the star-wheel.

Action of transmitter.

8. When the transmitter trainwork is started, the rocking beam Y is set into vibration, and the pins P, P^1 move alternately up and down. When P rises, the horizontal arm of A is free to rise also, and the spring s_3 causes it to do so. The rod H is thereby moved towards the right, and the collet K therefore pushes the lower end of the lever DU towards the right also. The pin P^1 simultaneously descends, pressing A^1 down, and moving the collet K^1 clear of the compound lever. The pressure of the jockey wheel J ensures smart and decided action of DU. When the pin P^1 rises in its turn, the reverse action takes place: H is moved to the left, so that K is clear of the lower end of the lever, and H^1 is moved to the right, so that K^1 pushes the upper end of the lever smartly to the right.

When the transmitter is running without slip, this alternate motion, which, as has been already indicated, reverses the current sent to line, takes place regularly without interruption, and simple rapid reversals take place, because the bell-crank levers, and the rods attached, are free to follow the alternate motion of the pins P, P^1.

When unpunched paper is inserted, both the rods S, M are pressed downwards and the pins P, P^1 in their motion do not actuate the bell-crank levers A, A^1; the lever DU, consequently, does not move, and a permanent current is therefore sent to line.

If now slip, perforated (say) with the letter  (*a*) be inserted, then when rod M rises it will be free to pass through the first upper hole, and the lever UD will be moved and will send a "marking" current; when the reverse movement of the rocking beam Y takes place, rod S will be free to pass through the first lower hole, and the current sent by DU will be reversed; a *dot* will therefore have been sent. On the next movement of the rocking beam, M will be free to pass through the second upper hole, and the length of the "spacing" current is consequently precisely equal to that of the previous "marking" current (*dot*). The marking current being now on, when the rocking beam leaves S free to rise, it is prevented from so doing by the paper, which is not perforated below the second upper hole. In this case, therefore, the marking current is kept on until the rod S is again free to rise, which it can do through the second lower hole, and the current is then reversed. It will be seen that the marking current is therefore kept on during movements equal to two dots and the space between, and this is the recognised length of a dash. It is thus clear that when properly perforated slip is run through the transmitter, any required Morse signals—dots, dashes, and spaces—can be automatically sent to the line.

Adjustment of transmitter.

9. One end of the flat spring, which carries the jockey wheel J, is attached to a brass piece F, Fig. 5, which is in turn screwed rigidly to the frame of the clockwork. The upper side of F is V-shaped, and the tension of the spring is adjustable by means of the two screws which fasten it to its support. It should have sufficient tension to enable it to push the lever DU suddenly to the right or left when either of the collets K or K^1 pushes it beyond the centre of the jockey wheel.

The collets K and K^1 can be adjusted by being screwed forward or backward; their correct position may be found by running the transmitter with a blank slip, when the bar should remain unaffected, whether resting in its right or left position. The collets must, however, be sufficiently close to push the bar over the centre when the slip is removed, so as to allow the jockey roller to complete the movement.

In order to ensure reliable action at high speed, it is essential that the spiral springs s_3 and s_4 be strong enough to easily overcome the tension of the flat spring acting through the jockey wheel upon the lever. The amount of play allowed between the contact screw C^d and the lever D when it is resting on Z^d, or *vice versâ*, is about 5 mils. The contacts C^u and Z^u should be adjusted to suit, so as to preserve similar distances with respect to the lever U.

The exact positions of the vertical rods S and M are regulated by the screw B, B^1, Fig. 5; each of the rods should be so adjusted that it commences to enter a perforation in the slip when the left-hand edge of the perforation is sufficiently clear of the left-hand edge of the rod to allow it to pass through freely. If the screws B, B^1 are screwed too much either way out of their correct position, the rods will catch against the edges of the perforation, and the mechanism will not act properly.

The springs s_1 and s_2 pull the rods S, M back against the screws P when they have become sufficiently withdrawn to be just clear of the strip. Although these springs are very light, they must be strong enough to cause the rods to return to their normal positions promptly.

The speed of slip should be capable of adjustment between not more than 7 and not less than 80 feet (400 words) per minute (see Speed table, p. 136). The thickness of the upper contact-arm U should not exceed 17 mils at the base and 12 mils at the top. The space between the paper roller and the platform, which is determined by the position of the stop-pin for the roller, should be from 8 to 10 mils wide. The tops of the vertical rods should be flat, and when in their lowest position they should be just level with the upper surface of the platform.

Good signals should be produced on the receiver with the coils joined in series (Fig. 15) when a punched slip is passed through at any speed from the lowest to the highest, the current employed being 17·5 milliamperes (see para. 14). Marking and spacing contacts of equal duration should be made for "reversals." This should be proved by the needle of an induced galvanometer temporarily placed in circuit remaining at zero or moving equal distances on each side whilst the instrument is running at any speed.

Speed regulator.

10. An important part of the mechanism of the clockwork is the "fly" and its regulator, by means of which the speed of running is determined. The fly is so designed that the clockwork shall start at as nearly as posible the required speed. Its construction may be seen from from Figs. 6, 7, 8, and 9. C is a toothed wheel fixed on an axle A, on which is also fixed the disc D (Fig. 6). One end of the spring S is pinned to the wheel C, the opposite end being pinned to a small ratchet collet R, which admits of adjustment of the spring, so as to oppose more or less resistance to the expansion of the fly wings F_1, F_2. The wheel C gears with two similar wheels, C_1 and C_2, to which the fly wings are attached, and these two latter wheels are free to turn upon the axes a_1, a_2 which are fitted in the cross-pieces b, b_1 rigidly fixed upon the axle A.

The action of the spiral spring S is to turn C_1, C_2, and their wings, to the position shown by Fig 8, in which position their motion is least retarded by the resistance of the air. When the clockwork is set in motion, the fly turns with the axle A, and the rapid rotation tends to cause the wings to extend in the direction of the arrows by centrifugal force, and to assume the position indicated in Fig. 9; the tendency being limited by the tension of the spiral spring S, and the speed of the fly being controlled by the increased or decreased resistance which the air offers to the motion of the wings consequent on the size of the circle which they describe; or, more correctly, the resistance offered by the air is proportional to the difference of the area of the two concentric circles described from the centre of axis A to the inner and outer edges of the fly wings, as shown by dotted lines in Figs. 8 and 9.

The regulator provides the necessary mechanical connection between the trainwork and the fly. It is shown in Figs. 6 and 7.

A solid steel disc D, the outer surface of which is an accurate plane, is rigidly attached to the fly-axle A. To the axle A_1, which is directly in gear with the clockwork train, is also fixed a similar steel disc D_1, and between D and D_1 is placed a small intermediate disc *d*, of German silver, having a polished periphery. The disc *d* is pivoted in a small brass frame, which can be shifted backwards or forwards by means of a lever projecting upwards from the back of the instrument; thus *d* can be made to gear with the edge of the disc D_1 and the inner surface of the disc D, as in Fig. 6, or it can gear with the inner surface of D_1 and the outer edge of D, as in Fig. 7. The disc D, and the intermediate *d*, are kept in close contact with D_1 by means of the jewelled spring J, Fig. 6, so that if the disc D_1 be turned by the clockwork, it will turn the connecting disc *d*, and the latter will turn the disc D and the fly-axle A to which it is rigidly fixed.

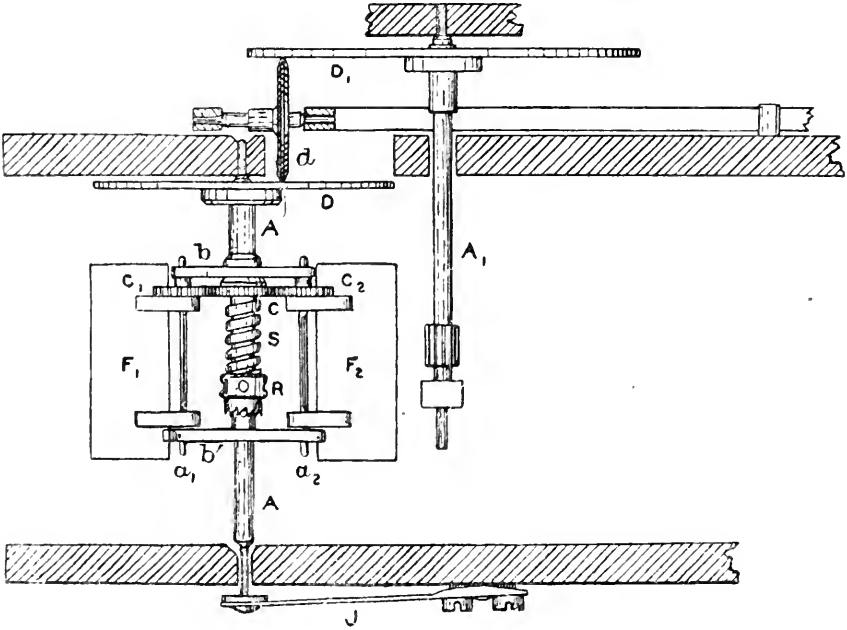


FIG. 6.

When the intermediate disc *d* is adjusted to the position indicated in Fig. 6, the disc D_1 tends to turn it rapidly, since there is a large circumference gearing against a smaller. Similarly the disc *d* tends to turn the disc D quickly; hence a comparatively slow motion of the axle A_1 will impart a quick motion to the axle A and the fly. When, however, the position of *d* is as shown in Fig. 7, then the smaller circumference of D_1, gearing by friction with *d*, and the latter gearing in the same manner with the larger circumference of D will cause even a quick motion of A_1 to impart a comparatively slow motion to A.

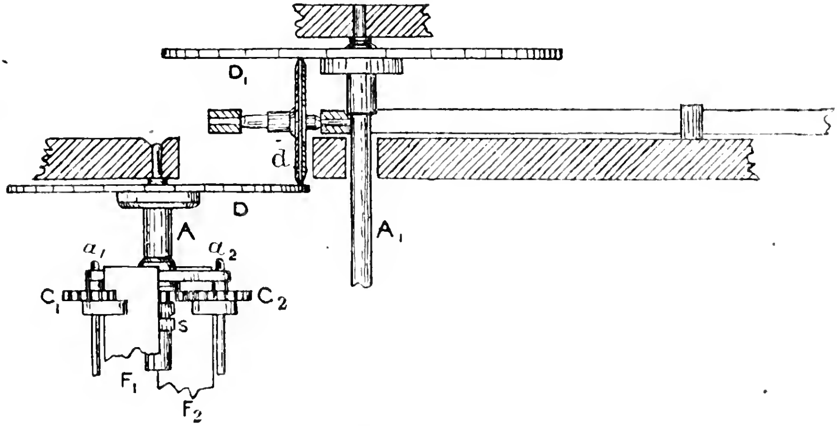


FIG. 7.

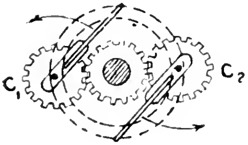


FIG. 8.

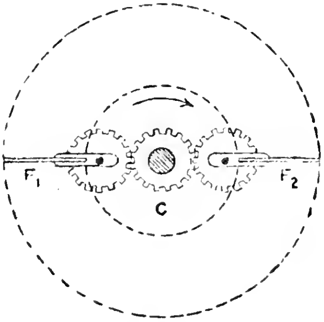


FIG. 9.

The instrument may be adjusted to run at any speed between the minimum and the maximum limits by means of the lever, which is pivoted to the framework of the instrument, and is connected to the movable frame in which the small disc is pivoted. It will be noticed from this description that the faster the fly is driven the slower is the motion of the train-work, and *vice versâ.* In fact, the expansion of the fly in consequence of the speed at which it is driven acts as a brake upon the driving gearing.

The surfaces of the discs must on no account be oiled, and, should they accidentally become so, must be carefully cleaned, as grease causes slipping and consequent irregularity in running.

The chains which carry the driving weight are made up of links, which, as shown by Fig. 10, are cut V-shaped at their openings. This device allows of any two links being snapped together when held as shown by Fig. 11. Before a chain is joined, care must be taken to see that it is not twisted, as when the links are snapped together they cannot be separated except by breaking.

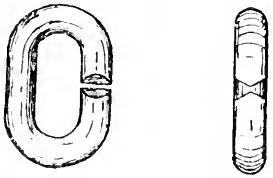


FIG. 10.

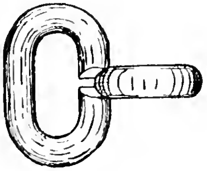


FIG. 11.

Connections.

11. A triple switch under the base of the transmitter cuts off the line and battery from the key when the transmitter train is running, and connects them to the electrical contacts of the transmitter. It is actuated by the starting and stopping lever. A plan of this switch is shown in the diagrams of connections, Fig. 12.

The battery is permanently connected, as shown in the figure, to the terminals which lead to two of the switch bars, and the down line or earth is connected to the third bar. The switch is shown in the position it occupies when the transmitter train is at rest. The connections made in the two positions of the switch can be easily traced from the figure.

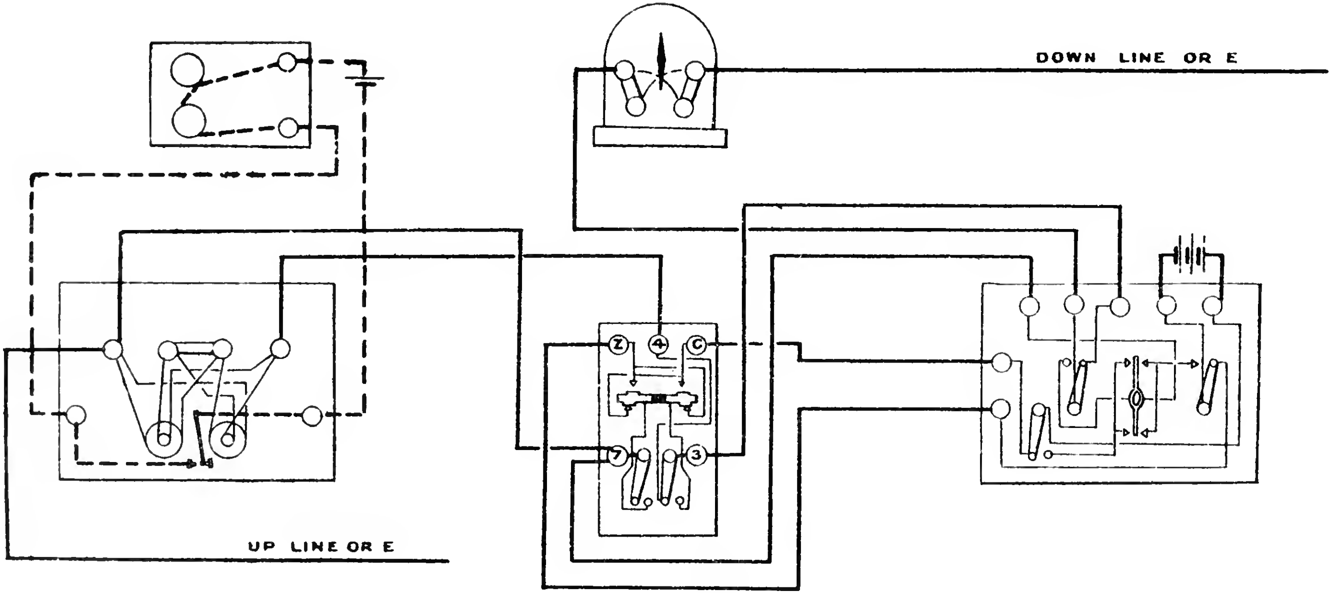
The receiver.

12. The receiver is shown in elevation by Fig. 13.

The upper portion contains the clockwork. The ink reservoir, the adjusting screw for the magnets (S), and the paper guides are attached to the front of the instrument. The lower portion contains the electrical mechanism. The instrument, practically, is an ordinary polarized relay, worked by the direct line current, and surmounted by a train of clockwork, which is driven by means of a weight; its speed of running is regulated by a fly, expanding through a rotary motion, similar to that of the transmitter.

The paper used in the receiver is the ordinary Morse slip. On leaving the drawer in the base of the instrument (not shown in the figure) the slip is passed over a guide P, and then

WHEATSTONE AUTOMATIC.



To face p. 126.

H & C. GRAHAM Lᵀᴰ, LITHRˢ, LONDON, S.E

between two steel projecting pieces, *a* and *b*, which keep it in the right position to be marked by the inking disc, *m*. It then passes between the two rollers, Q and Q^1, which are for carrying

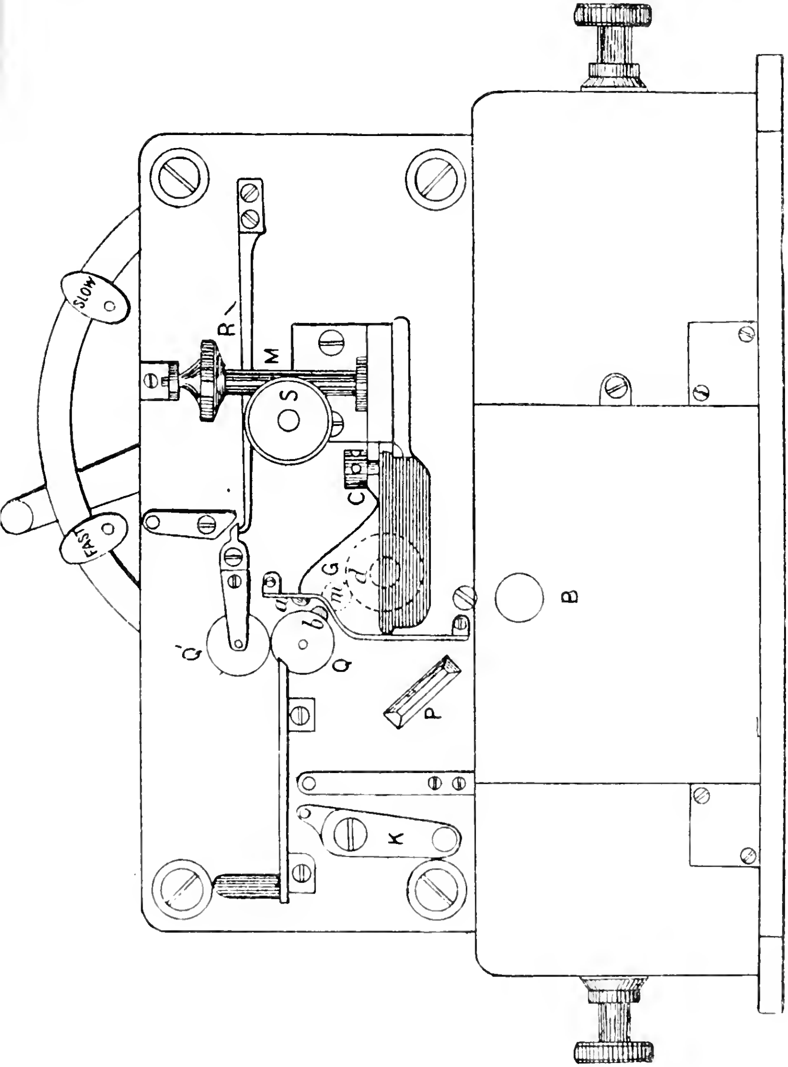


FIG. 13.

forward the slip when the receiver train is in motion. The roller Q is turned by the clockwork, and Q^1 presses upon the slip by means of the spring R.

The inking discs *m* and *d* are covered by a brass hood G, fixed in position by means of the screw C. If the latter be slightly unscrewed (not removed), the hood G may be slipped off and the discs *m* and *d* exposed for cleaning when necessary. The ink-well is secured in its place by the thumb-screw M.

The starting and stopping of the clockwork is effected by the lever K.

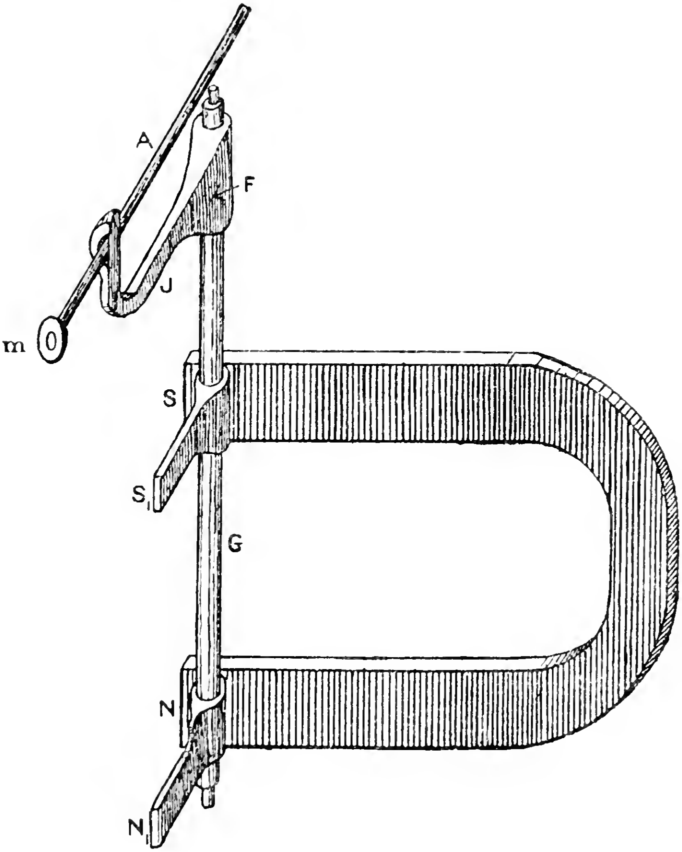


FIG. 14.

The clockwork gives rotary motion to the inking disc and its supply wheel, and also carries the paper slip forward at the required speed, the speed regulator being controlled by means of the lever shown above the clockwork. The large lower inking disc *d*, shown in dotted lines, serves the smaller marking disc *m* by capillary action. By this means *m* is kept supplied with ink, and is ready to mark the slip when pressed against it.

The electro-magnets which work the recording armature consist of two bobbins of fine silk-covered copper wire having cores of carefully annealed soft iron. If these cores were provided with a cross-piece they would then form what is generally known as a horse-shoe shaped electro-magnet. But greater rapidity of magnetic action is obtained by dispensing with the cross-piece and providing a second tongue or armature at the lower end of the axle, and polarized in the opposite direction to the upper one by means of the other pole of the inducing magnet. The arrangement of the tongues, armature, and inducing magnet is shown by Fig. 14. Near the top of the axle G a long bent tongue J is fixed in a similar direction to the tongues N^1, S^1. At the bent end of J a slot is cut in which the axle A revolves, being kept in position by means of the flat spring F, one end of which is screwed to the tongue J, near the axle.

The inking disc *m*, is fixed at the end of the axle A.

Adjustment of receiver.

13. The adjustment towards "marking" or "spacing" is effected by altering the position of the electro-magnet with respect to the tongues, by the turning of the upper edge of the screw S (Fig. 13) to the left for a spacing, and to the right for a marking bias. To produce a bias towards "spacing" the portion of the electro-magnet on the left-hand side of the tongues is caused to recede, while the portion on their right is made to approach. This movement of the electro-magnet is reversed if a bias towards "marking" is required.

The coils are each wound with two wires, each having a resistance of 200 ohms, which were then joined in parallel inside the instrument (Figs. 15 and 16), so that the resistance between U and D, and that between Ⓤ and Ⓓ is 100 ohms. When, therefore, by means of the links the coils are joined externally for series, the total resistance is 200 ohms.

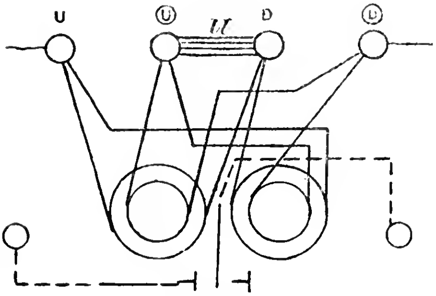


FIG. 15.

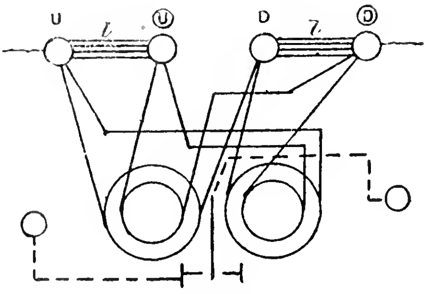


FIG. 16.

On reference to Fig. 15 where the coils are connected for series externally, it will be seen that a current entering at terminal U has a path open to it around each bobbin; but in

Fig. 16, where the links are connected in parallel, a current entering at terminal U also proceeds, by means of the link, to terminal Ⓤ and it therefore has two paths around each bobbin open to it. The effect of this is to reduce the resistance of the instrument from 200 ohms to one-fourth, or 50 ohms, and so make it suitable at simplex for short lines or lines with intermediate offices.

On the "simplex" lines in wet or foggy weather, when the leakage of the line is considerable, it may become necessary to revert to "series" externally in order to obtain sufficient magnetic effect to produce good marks at a moderately high speed, but this should never be done on lines having intermediate offices except by arrangement with all offices in circuit.

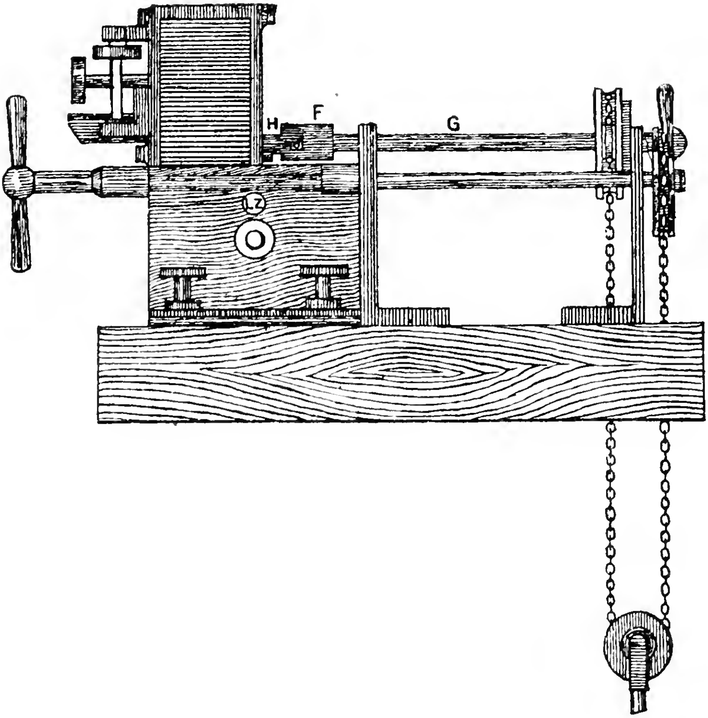


FIG. 17.

The receiver, like the transmitter, is driven by a weight, and is arranged to run Morse slip at any speed between 8 and 60 feet a minute.

The instrument possesses a mechanical combination of click-wheel and bayonet-joint, by means of which the clockwork and electrical portion (the "*Receiver Train*") may be detached from the driving part (the "*Receiver Motor*") without waiting for the weight to run down, or running the risk of damage by letting it down by hand. The construction of this arrangement is shown by Figs. 17, 18, and 19.

Fig. 18 shows the bayonet joint which gears the clockwork with the weight. The long axle G is provided with a socket F to receive the end of the axle H (Figs. 17 and 18), projecting from the clockwork; near the end of this axle is fixed a strong pin A (Fig. 18), which gears behind a projection, B, and is held in that position by the action of the weight, which keeps the flat surface of the slot pressed against the pin.

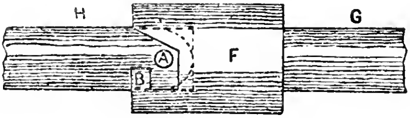


FIG. 18.

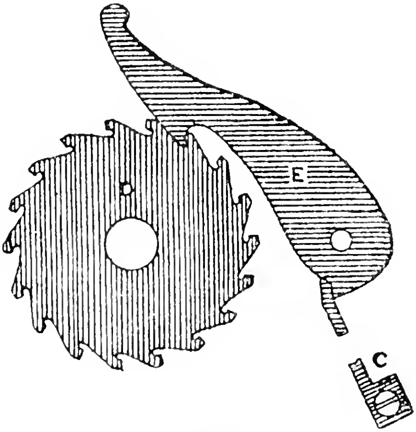


FIG. 19.

The detachable gear is represented by Fig. 19. The teeth of the click-wheel D into which the pawl E is made to engage when required, are undercut in such a manner that when the pawl is placed in gear with the wheel it becomes locked. The normal position of the pawl E is, of course, away from the click-wheel; but, in order to separate one portion of the instrument from the other, the clockwork is allowed to run, the pawl is thrown over, and is then pressed against the click-wheel by the spring C. By this means the weight is brought to a standstill and securely locked until the click-wheel is turned (by means of a handle, shown at the right-hand end of the axle, G, Fig. 17), into such a position as to permit of the pawl being easily disengaged.

After the weight is stopped by E acting upon the click-wheel D, the axle H is carried forward by the momentum acquired by the clockwork into the position shown in Fig. 18, so that the pin A is clear of the projection B, and then, if the binding screws on each side of the clockwork portion are released, the parts may be easily separated.

Owing to the facility with which the receiver train can in this way be separated from the motor, it is rarely necessary to remove the latter from the instrument table.

A mechanical alarm, which indicates when the weight requires winding up, is now fitted upon the motor.

Mechanical adjustment of receiver.

14. The permanent mechanical adjustment of the receiver is a simple matter and only requires a little care.

By partly turning the screw at the top of plate B, Fig. 13, the plate, which is hinged at the bottom, can be let down, thus exposing two small adjusting screws with a projection from the lower tongue playing between them. The easiest method of adjusting is as follows:—

Allow the slip to run at the rate of about 15 feet per minute, then keep the tongue pressed gently against the left-hand screw; if a line appear on the slip, advance the screw until it is broken into dots; then withdraw the screw slowly until the line appears unbroken, when a further very slight withdrawal will insure the necessary margin. The tongue should then be pressed gently against the screw on the right-hand side, the screw being advanced until a regular broken line (irregular dots) appears on the slip, when it should be slowly withdrawn until the slip runs out clean, and as in the first adjustment, a small margin should be given by a slight further withdrawal of the screw.

It sometimes happens that the tongue, owing to a dirty state of the inking discs, requires a great deal of play between the screws. The effect of this is to considerably reduce the speed of working when the current is weak, and it is therefore important to keep the inkwell and the discs as clean as possible.

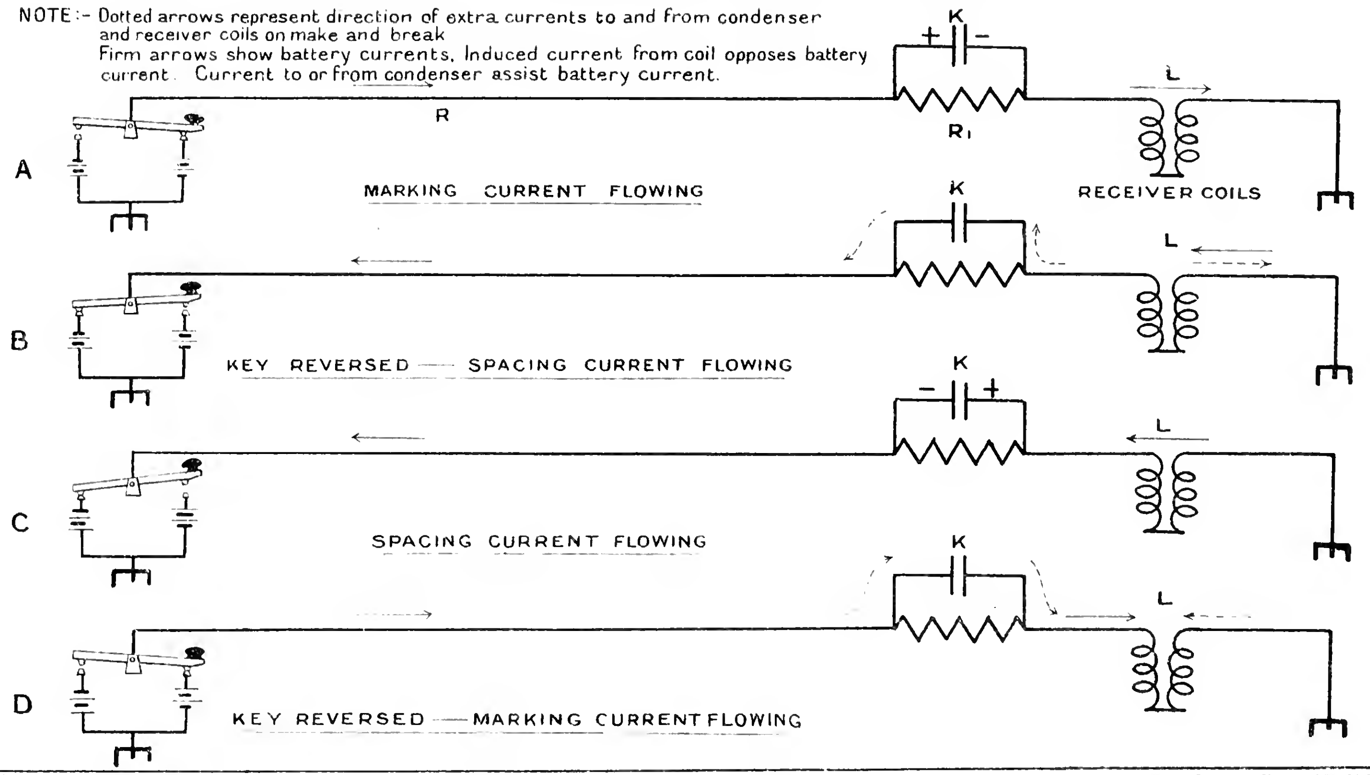
The inking-disc, being dry, should pick up ink promptly when the train is set running at lowest speed. The standard breadth of marks is 16 mils. The standard thickness of Morse paper—an important matter in connection with high speed apparatus—is 3½ mils. The coils of the magnets should be differential with 50 Daniell cells without external resistance, care being taken that the current is passed through the coils in both directions. With a properly adjusted transmitter, the receiver should work at a speed of at least 400 words per minute (the coils being in series), with 20 Daniell cells through 800 ohms external resistance, a condenser of 2mf. capacity being joined across the external resistance. (Figure of merit 17·5 milliamperes).

Fig. 12 is a diagram of an automatic set connected up.

Chap 9. Fig. 20.

THEORY OF COMPENSATING CONDENSERS.

NOTE:- Dotted arrows represent direction of extra currents to and from condenser and receiver coils on make and break
Firm arrows show battery currents. Induced current from coil opposes battery current. Current to or from condenser assist battery current.



H & C GRAHAM LTD. LITHRS. LONDON S.E.

An up station only is shown; the diagram is the same for a down station except that the line and earth connections are changed over. When the switch of the automatic transmitter is in the "off" position and the transmitter at rest, a D. C. key is in circuit, and for receiving the automatic receiver works as relay to a local sounder circuit, the clockwork train being at rest. This arrangement allows of the office being worked by hand as an ordinary D. C. set when there is no press of business. Currents flow of course in the local sounder circuit when the recorder is receiving signals from the automatic transmitter, but when the latter is running at any speed the reversals of current follow too rapidly for the heavy armature of the sounder to respond to them.

Compensation condenser.

15. On land lines where a speed of 300 words per minute and upwards is required, a shunted condenser must be used at the receiving end of the line. It is placed in the line in series with the receiving instrument and is known as a "compensating condenser."

The general principle involved in the application of condensers to the receiving end of a line as far as the receiving electro-magnets are concerned may be understood from the diagram, Fig. 20.

Diagram A shows a steady marking current flowing through line resistance R, shunt R_1, and receiving magnet coils L. The condenser is charged as shown.

Diagram B shows the currents flowing at the moment the battery current is reversed. The currents from and into the condenser, discharging it and re-charging it in the opposite direction, are shown by dotted arrows, as also is the "extra current" caused by the self induction of the coils. These "extra" currents of coil and condenser are in opposite directions, and by properly adjusting the capacity of K, and the resistance of R_1, the condenser current can be made to neutralize that from the coil which otherwise, as seen by the direction of its arrow, tends to keep the battery current flowing in the old direction, and stop it rising quickly to its full value in the new, thus preventing the reversals taking place at the very rapid rate required. The necessity for the shunt resistance R_1 will be obvious, as otherwise (the two sides of the condenser would be at the same potential, and it would hold no charge.

When the extra currents at the moment of reversal have ceased, the condition of affairs will be as shown in diagram C, and when the battery current is again reversed, the currents will be momentarily represented as in diagram D, and then again as in diagram A. The self induction of the receiver or relay may, however, be compensated for without using condensers, by joining the receiving instruments in series with a resistance the value of which is dependent on the self induction of the receiving instrument, and increases with the maximum speed required. For example, with an average receiver with coils in series, an added resistance of 12,000 ohms and a signalling voltage of 120 should give a speed of 400 words per minute, while the same receiver with coils joined in parallel, an added resistance of 3,000 and a voltage of 60 should be capable of recording signals at the same speed. The exact amount of resistance required differs with different specimens of the same form of receiving instrument, and also with different transmitters, the intervals of "break" in the transmitter and the resistance of the battery having a considerable influence.

The effect of capacity in the line is to increase the delay action produced by the self induction of the relay, and it cannot be overcome by increasing the line resistance; shunted condensers must be used. In cable circuits a shunted condenser is inserted at either end of the circuit.

Duplex.

16. Fig. 21 shows method of connecting up an automatic set for simplex and duplex working: up station. For a down station as in former diagram the line and earth connections are merely reversed. By means of the switches the circuit can be worked D. C. by hand or automatic, and either simplex or duplex. When receiving signals, working simplex, the "compensation circuit" (rheostat, condenser, &c.) is in series with the line between the galvanometer and receiving relay. The values to which the resistances and capacity have then to be adjusted may be different from those required when working duplex. The second switch marked "battery" and "resistance" is used to cut off the battery when working duplex, and insert in place of it a resistance *r* equal to its internal resistance. By this means the S battery is saved when no work is going on, while it is still possible to call up the station.

Adjustments of "Simplex" automatic.

17. On ordinary land lines the procedure for the attainment of maximum speeds should be as far as possible, as follows:

(*a*) The receiving office should request the sending office to turn his key switch to "send," for a minute, the voltage in use being as a general rule 100.

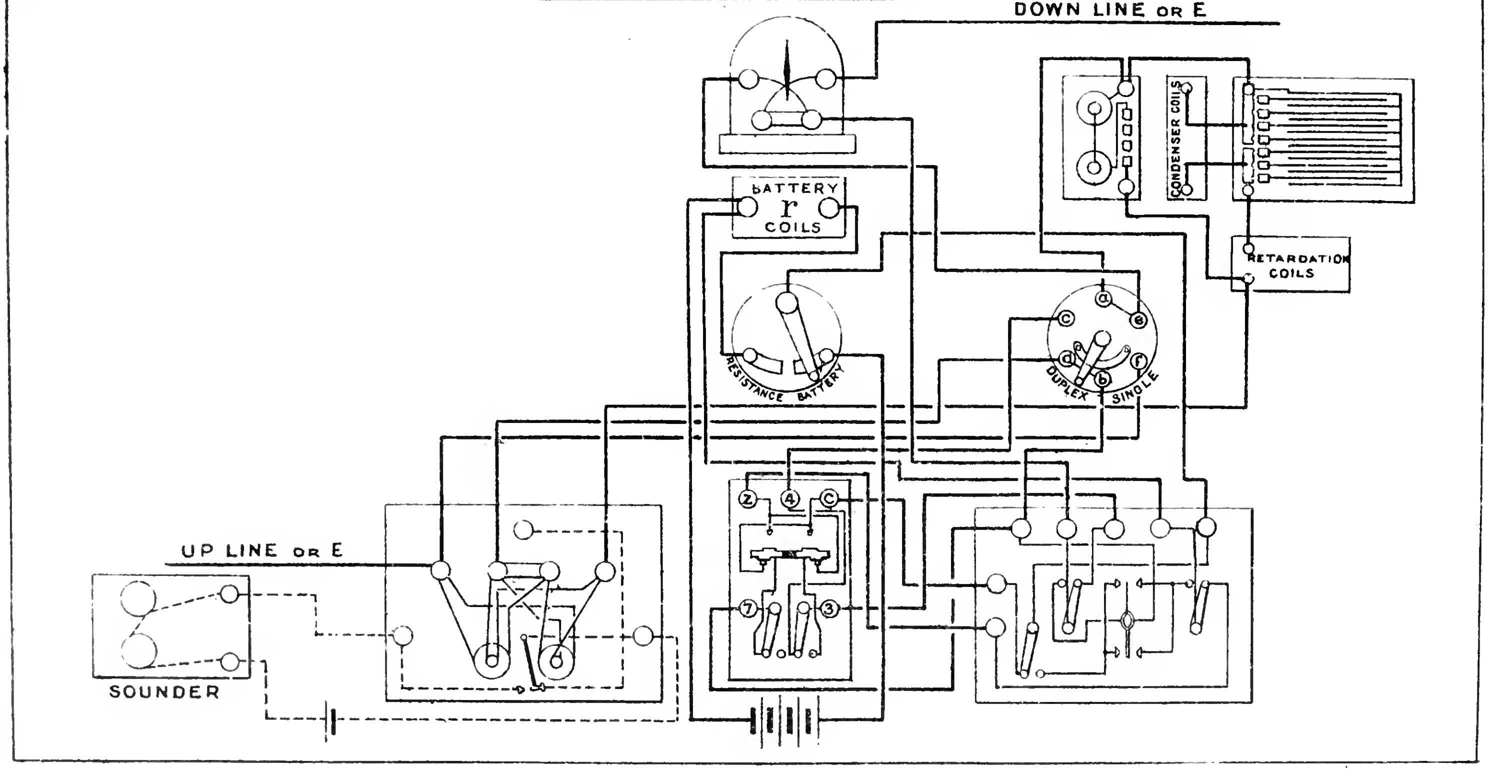
(*b*) The receiver or relay coils being connected in series, the receiving office should then raise or lower his resistance in the compensating shunt rheostat till 20° (or 8 milliamperes) is indicated on the half coil of the differential galvanometer.

(*c*) Slip should then be run through the distant transmitter, and the receiving office should alter his condenser values until the best results are obtained. The actual speed obtained with the most accurate compensation depends on the capacity, resistance, and self induction of the line, but generally speaking, the higher the unit capacity of the line, and the lower the compensating shunt, the greater the amount of compensating capacity which will be required.

(*d*) If the receiving relay or receiver have its coils connected in parallel, the deflection on the half coil of the

WHEATSTONE AUTOMATIC

SIMPLEX OR DUPLEX WORKING



H & C GRAHAM LTD LITHRS LONDON S E

To face p. 134.

galvanometer should be adjusted to indicate 35° (16 milliamperes) and the required compensating capacity will then be found for the same circuit to be greater than in the case of series connections.

(*e*) On circuits having a considerable amount of capacity in proportion to the conductor resistance, the addition of a shunted condenser at the transmitting end of the line, enables an additional increase of speed to be obtained. A condenser in this position is called a "signalling condenser," and its value in microfarads should be equal to the discharge value of the line at the sending end under its working conditions, the shunt being equal in ohmic resistance to the conductor.

The duplex speed on any line is practically slightly less than two thirds of the highest attainable "simplex" speeds obtained with the most advantageous compensating arrangements.

18. A table for ascertaining the actual speed of transmission on a Wheatstone circuit is given on next page. Speed table.

TABLE FOR ASCERTAINING THE ACTUAL SPEED OF TRANSMISSION ON WHEATSTONE AUTOMATIC CIRCUITS.

Direction—Pass 10 feet of perforated slip (representing 50 average words) through the transmitter, and observe the time occupied.

Time Occupied.	Number of Words per Minute.	Time Occupied.	Number of Words per Minute.	Time Occupied.	Number of Words per Minute.
Seconds.		Seconds.		Seconds.	
5	600	24	125	56	54
5½	545	24½	122	57	53
6	500	25	120	58	52
6½	462	25½	117	59	51
7	429	26	115	60	50
7½	400	26½	113		
8	375	27	111	Min. Sec.	
8½	353	27½	109	1 1	49
9	333	28	107	1 3	48
9½	316	28½	105	1 5	47
10	300	29	103	1 6	46
10½	285	29½	101	1 7	45
11	273	30	100	1 9	44
11½	262	31	97	1 10	43
12	250	32	94	1 12	42
12½	240	33	91	1 13	41
13	231	34	88	1 15	40
13½	222	35	86	1 17	39
14	214	36	83	1 20	38
14½	207	37	81	1 21	37
15	200	38	79	1 23	36
15½	195	39	77	1 25	35
16	188	40	75	1 28	34
16½	182	41	73	1 30	33
17	177	42	71	1 35	32
17½	172	43	70	1 37	31
18	167	44	68	1 40	30
18½	162	45	66	1 43	29
19	158	46	65	1 47	28
19½	154	47	64	1 51	27
20	150	48	62	1 55	26
20½	146	49	61	2 0	25
21	143	50	60	2 5	24
21½	140	51	59	2 10	23
22	136	52	58	2 16	22
22½	133	53	57	2 23	21
23	130	54	56	2 20	20
23½	127	55	55		

CHAPTER X.

THEORY OF THE TELEPHONE.

Elementary Telephone.

1. The elementary telephone is an instrument by means of which the mechanical energy of sound waves can be converted into electrical energy and *vice versâ*. It is applied, as we know, more particularly to the sound waves which constitute human speech, and the telephone enables us to transmit them over considerable distances in the form of variable electric currents which are again converted back into sound waves at the receiving end.

Elementary telephone.

2. Sound possesses three qualities, viz :—(*a*) pitch, which is dependent on the number of waves in a given time; (*b*) intensity of loudness, which depends on the size of the waves; and (*c*) quality, which depends on the shape and regularity of the waves.

Sound waves.

3. A simple musical note can be represented by a regular series of uniform undulations (Fig. 1) but the sound waves in human speech are of a much more complex character. Pitch and quality can be reproduced with remarkable fidelity by the telephone, but there is always a very considerable loss in the volume of sound or loudness.

FIG. 1.

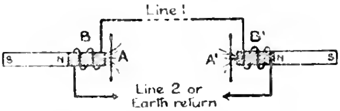


FIG. 2.—Bell's Telephone.

Simple telephone.

4. The principle of the elementary telephone is shown in Fig. 2. (B) and (B^1) are permanent bar magnets with soft iron pole pieces and coils of fine insulated wire wound round their ends; (A) and (A^1) are thin diaphragms of soft iron, usually tinned, or of ferrotype (to prevent rusting), and the coils are connected together as shown. Sound waves striking the diaphragm (A) cause it to vibrate in unison with those waves.

Action.

5. The movement of the diaphragm causes changes in the magnetic field due to the magnet (B), and there is consequently a current induced in the coil (*see* Chapter I, para. 50). This current passes through the coil on (B^1) and causes a variation

in the strength of the magnetic field. (A^1) is thus subject to a fluctuating pull, and is set into vibration, its movements corresponding with those of (A); (A^1) thus reproduces the sound waves. This arrangement, however, is only effective over short distances as the currents produced by the sound waves acting on the diaphragm are very minute. As the resistance of the line increases, the effects diminish rapidly.

Phelps-Edison transmitter.

6. Edison therefore devised his carbon transmitter with a view to securing greater energy. This transmitting arrangement consists of a transmitter and a battery arranged as in Fig. 3. (A) is the transmitter consisting of a case containing two platinum plates separated by a disc of compressed lamp-black. A diaphragm with a button in its centre presses against one of the platinum plates; (B) is a receiver similar to those shown in Fig. 2, and (C) a battery. The platinum plates are the terminals of the transmitter. The vibration of the diaphragm causes variation of the pressure between the platinum plates and so produces variation in the resistance in the transmitter, causing corresponding current variations. It was at that time believed that the current changes were due to variations taking place in the electrical resistance of carbon, when pressure is exerted upon it, but Hughes discovered that the explanation lay in the *quality* of the contact, demonstrating that a loose contact between the electrodes, whatever their material, is preferable to a firm one. He showed this experimentally with his nail microphone, which is illustrated in Fig. 4. This was extraordinarily sensitive but not practically useful. The loose contact principle being established, it only remained to devise a practical transmitter. For various reasons it was found that the best material to use for this purpose was carbon.

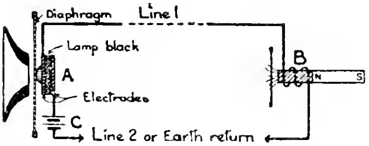


Fig. 3.

Hughes microphone.

7. Some forms of transmitters (or microphones) are described later. Hughes's arrangement (Fig. 5) consisted of two carbon blocks (B) secured to a diaphragm (D) between which a carbon pencil (C) was loosely secured in circular recesses as shown. There are other transmitters constructed on the same principle, the improvements on the original Hughes arrangement consisting principally in providing a larger number of contacts and in slightly damping the natural vibration of the diaphragm. Simple transmitters of this type are satisfactory for lines of low resistance, the transmitter being put directly in circuit with the battery, receiver, and

line wire as shown in Fig. 3, but with lines of considerable resistance the arrangement is unsuitable, as the following example will show. Assume the resistance of a transmitter to vary 1 ohm above or below the normal when it is spoken into, and the resistance (R) of the circuit to be 20 ω, then the resistance of the whole circuit varies between 19 ω and 21 ω ; and consequently the current variation is 5 per cent. If now (R) be increased to 1,000 ω, the current variations will only be 1/10 per cent. and the effect on the distant receiver will be correspondingly diminished. To get over this difficulty, it is necessary to make the variations in the microphone circuit independent of the line resistance and an induction coil furnishes the means of effecting this.

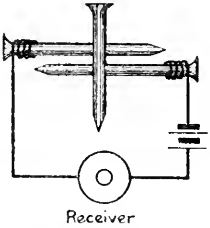


FIG. 4.—Hughes Nail Microphone.

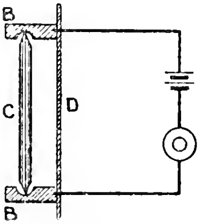


FIG. 5.—Hughes Carbon Microphone.

Induction coil.

8. The induction coil consists of a soft iron core (preferably a bundle of thin, soft iron wires) on which are wound a few turns of comparatively thick insulated copper wire. Over this is wound another coil, composed of a large number of turns of finer insulated copper wire. The thick wire coil is termed the primary and the fine wire coil the secondary (*see* Chapter I, paras. 53 and 63). The transmitting arrangement is then as in Fig. 6. It is obvious with this arrangement that the circuit in which the microphone is placed is of small resistance, and that consequently the current variations will be considerable and independent of line resistance. These current variations in the primary induce correspondingly varying E. M. Fs in the secondary, and by "stepping up," *i.e.*, by making the turns of

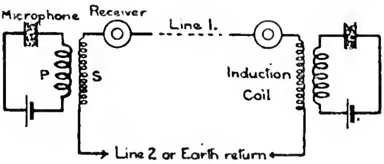


FIG. 6.

the secondary numerous compared with those of the primary, the induced E.M.Fs are of high voltage and therefore well calculated to secure transmission of energy over lines of high resistance.

9. It must be remembered, however, that the induction coil cannot CREATE electrical energy, but merely transforms the energy furnished by the battery into a form suitable for the purpose in hand, *i.e.*, high E.M.F. and small current instead of relatively large current and low E.M.F.

10. The arrangement illustrated in Fig. 6 provides for the transmission of speech, but it is also necessary to arrange for attracting attention at the distant station. The volume of sound produced in the receiver by the voice is seldom sufficient for this purpose, and other means have to be resorted to.

Methods of Calling.

Methods of calling.

11. The methods of calling in use with telephones are described under the following heads :—

(*a*) Push-piece, battery, and trembling bell.
(*b*) Magneto generator and polarized bell.
(*c*) Vibrating call.
(*d*) Visual call.

Battery and trembling bell call.

12. Trembling bells actuated by a battery were the first type of call to be adopted for telephone use. Their disadvantages, however, which consist in the weight and bulk, and the necessity for maintenance of the battery, and in the fact that more than two sets cannot be used on one circuit, have caused them to be generally superseded, and they are no longer used with telephones in the service. Since they may be met with outside the service, and since the same method is used for other purposes in the service, a description of their working is given. The details of service trembling bells will be found in Chap. XI.

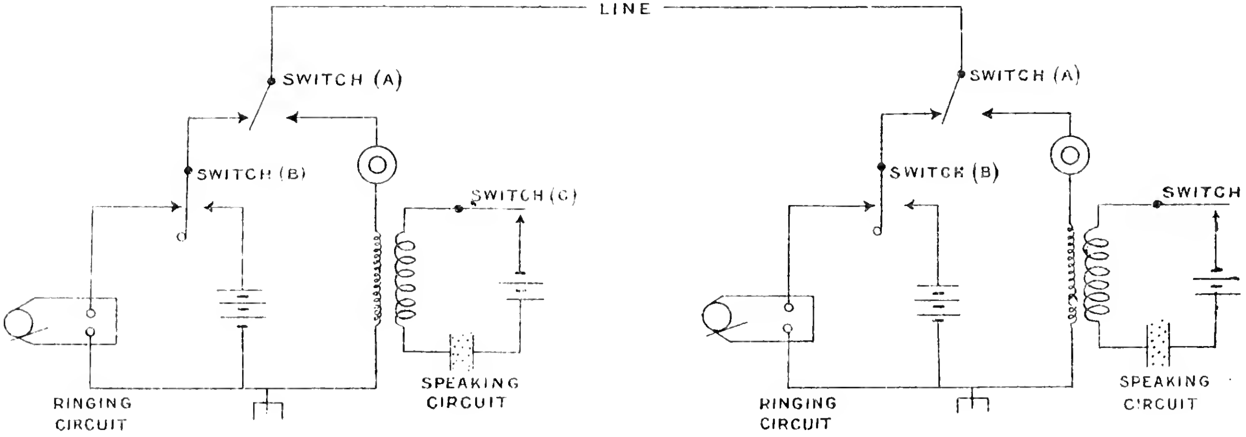
Trembling bells.

13. Trembling bells, of which there are endless varieties in use, consist of an electro-magnet (A) (*see* Fig. 7), an armature (C), pivoted at (B), and carrying a hammer (D), and a gong (H). The armature, when at rest, is held by a spring against the stop (E). This spring may be either a flat spring clamped at one end to the base of the instrument, and at the other to the armature, as shown in Fig. 7 ; or a spiral spring. The stop (E) is connected to one terminal (F), the pivot (B) of the armature to one end of the coil, and the other end of the coil to the other terminal (G).

A current entering at (F) flows *viâ* the stop (E) to the armature, and so through the coils and out to the other terminal. This current, however, in passing through the electromagnet attracts the armature away from the contact (E), and causes the hammer (D) to strike the bell. As soon as the armature moves, the circuit is broken at (E), and the current

Chap X Fig. 8.

COMPLETE TELEPHONE CIRCUIT.



To Face p. 141

H & C. GRAHAM LTD LITHRS LONDON S.E

ceases ; the coil ceases to be a magnet, and the armature flies back again to the stop (E). As soon as contact is made again at (E), the armature is attracted again, striking another blow : the armature therefore moves continually to and fro between gong and stop so long as the current flows.

It will be seen at once that the current which passes the bell will be of a very intermittent nature, and not at all suitable to actuate another bell. In some patterns, however, this is obviated by making the armature short circuit the bell each time it is attracted.

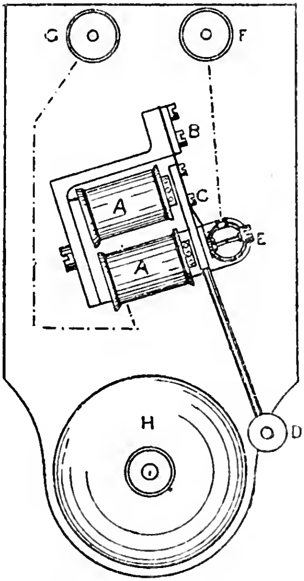


Fig. 7.—Trembling Bell.

Arrangement and switches.

14. The complete circuit of a telephone fitted with battery and trembling bell as a call is given in Fig. 8. It will be noticed that there are three switches, or keys, in each set :—

(*a*) To connect the line to the ringing or speaking circuit as required.

(*b*) To bring battery or bell into the ringing circuit as required.

(*c*) To break the microphone circuit when not in use, so as to prevent the battery from becoming exhausted.

The arm of switch (*a*) is frequently extended into a hook, or rest, to hold the receiver, and is so arranged that when the receiver is on the hook the ringing circuit is connected to the line, ready to send or receive a call ; but when the receiver is lifted to listen, a spring pulls the switch over, so that the speaking portion is in line.

Switch (*c*) is also sometimes worked automatically by the same switch.

Switch (*b*) generally takes the form of a push-piece, which normally puts the bell in the ringing circuit, but which, when pressed, substitutes the battery for it.

Magneto-generator and polarized bell call.

15. The system of calling by means of alternating currents from a small magneto-generator which actuate a polarized bell is that employed in most modern telephones both in and out of the service. The generator is comparatively light, and needs no attention, and the current is not interrupted in any way by passing through the polarized bell. The generator acts on the principle described in Chap. I, para. 50.

Polarized bells.

16. The polarized bell (*see* Fig. 9) consists of an electro-magnet (A), a centrally pivoted armature (B), to which is rigidly attached an arm (C) carrying a hammer (D), two gongs (GG), and a permanent steel magnet (NS). The south pole of the permanent magnet is placed directly over the centre of the armature, so that the centre of the armature has a north polarity, and both ends south. A current flowing through the electro-magnet causes its end to be of opposite polarity to each other; thus, one end attracts the armature, while the other repels it. As the current used is an alternating one, this polarity is quickly and constantly reversed, causing the armature to rock, and the hammer to oscillate between the two gongs.

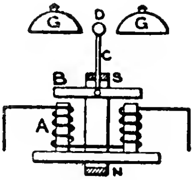


FIG. 9.—Polarized Bell.

Arrangement and switches.

17. The same three switches are essentially required in a telephone fitted with magneto ringing as were referred to in para. 14. They, however, vary somewhat in detail, and the circuit diagrams are differently arranged in almost every pattern of instrument.

The switch (*a*) for connecting line to speaking or ringing circuit is much the same as before in patterns designed for wall or table use. In the portable types, which are generally supplied with a hand telephone (*see* Chap. XI), this switch is frequently combined with the microphone switch in the handle of the hand telephone.

In most patterns the generator is arranged to ring the home bell, generator and bell being in series, so that switch (*b*) takes the form of an automatic cut-out actuated by the handle of the generator, which short circuits the generator except when the handle is turned. Thus the resistance of the generator is avoided when receiving a ringing current. This is the more important, as in some cases the secondary speaking circuit is in series with bell and generator.

As most of the newer telephones are fitted with hand receivers, the microphone switch (*c*) is placed in the handle of the hand telephone, where it can readily be pressed by the fingers when speaking or listening.

Vibrating call.

18. In very light portable telephones the generator is dispensed with, and a call is given by a small vibrator, working on the principle described in Chap. XV, the call being heard as a buzz in the receiver. This call is not very loud, and constant attention on the part of the operator is required. It has, however, the advantage common to all vibrators, that it will act through very leaky lines.

Arrangement and switches.

19. The vibrator is generally inserted in the microphone circuit, the battery and primary coil being common to both. A push-piece is provided to bring it into action.

Visual calls.

20. Visual calls are practically only used in exchanges. They are dealt with in Chap. XIII.

Number of Telephones on One Circuit.

Speaking.

21. As far as transmission of speech is concerned, there is practically no limit to the number of telephones which can be connected up in one circuit. For example, it is perfectly feasible for a news agency to distribute intelligence to a large number of subscribers simultaneously over a telephone wire, one transmitter being used at the head office. In such a case speech only is involved, as the subscribers are spoken to at certain fixed hours.

Calling.

22. Under ordinary conditions, however, the calling arrangements present difficulties when more than a strictly limited number of instruments are connected up on the same circuit.

Telephones may be connected up in two different ways (*see* Fig. 10), either in series ((*a*) single line, (*b*) metallic circuit),

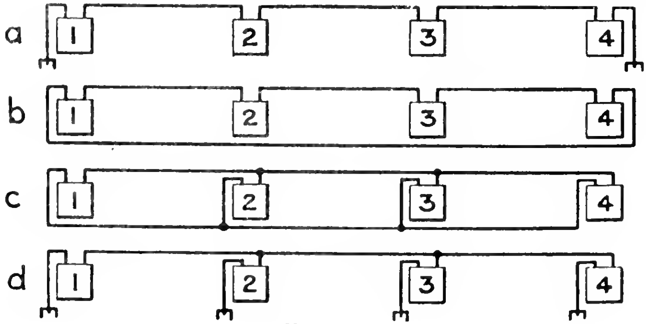


FIG. 10.

or in parallel, bridge for metallic circuit (*c*) and leak for single line (*d*).

Series.

23. The series arrangement shown in (*a*) and (*b*), Fig. 10, presents no difficulties about calling up when generators are used, but is inadmissable with trembling bells, since the current is interrupted by each instrument. It has, however, for generators the serious disadvantage that the bells at the disengaged stations are in the speaking circuit of any two stations who may be in communication. Furthermore, disconnection of the line breaks down the system altogether, whereas with the bridge system the breakdown is only partial. The series arrangement is one which is seldom or never adopted nowadays.

Parallel.

24. In the parallel arrangement the current generated at any station has a number of alternative paths open to it, and thus the distant station with which it was required to communicate will only receive a portion of the current, the amount depending on the respective resistances of the other outlets. In practice this can be got over with generator circuits by using powerful generators and high resistance (*i.e.*, sensitive) bells, but even then about six instruments on one circuit is about the limit for satisfactory results. With vibrator calls, the current required to produce a buzz in the receiver is so small that the amount lost at intermediate stations is of small consequence.

CHAPTER XI.

TRANSMITTERS, RECEIVERS, GENERATORS, AND BELLS.

Transmitters.

Ader and Gower transmitters.

1. All telephone transmitters now in use are microphones which are developments of the Hughes microphone described in Chap. X, para. 7. The first development consisted in increasing the number of carbon pencils to 8 or 10, and mounting them in carbon blocks attached to a thin diaphragm or sounding board of pine.

The Ader and Gower transmitters were both of this form, and are obsolete, though they may occasionally be met with.

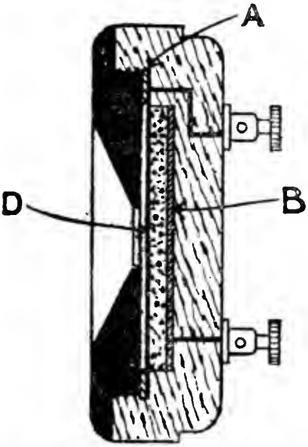


FIG. 1.—Hunnings' Transmitter.

Hunnings' transmitter.

2. In the Hunnings' transmitter (Fig. 1) the vibrating diaphragm (D) is of platinum foil, and about $\frac{1}{10}$ inch behind it is fixed a carbon or platinum plate (B), the space between being filled loosely with carbon granules. The diaphragm is held in place by a metal washer (A), on to which the mouthpiece is screwed down. A disc of wire gauze between (A) and the mouth-piece protects the diaphragm. The terminals of the microphone are connected to (B) and (D) through the washer.

This method of construction reduces the size of the microphone, and also, by adding largely to the number of loose contacts in the carbon granules, increases its efficiency. Its disadvantage lies in the fact that the granules are apt to pack tightly together, so that they require shaking up before good speaking is obtained.

Nearly all modern transmitters are modifications of the Hunnings; the varieties of form are numerous, but they are all alike in utilising carbon shot or granules. The improvements consist chiefly in devices to minimise the packing of the carbon.

Ericsson's transmitter.

3. Ericsson's transmitter, which is used in Telephones, Hand, A Mark I, C Mark I, and D, is illustrated in Fig. 2. It consists of a ferrotype diaphragm, to which is attached a brass cup, roughened to break up the granules if they pack. The caps fits loosely over a circular carbon block of the section shown in the figure, and strip of felt round the block prevents the granules from falling out. The springs shown in the figure have a slight damping effect on the diaphragm, which prevents it from vibrating more with one note than with another. The carbon block is screwed to the base, and the diaphragm is held at its edges by the cover of the microphone. The corrugations in the carbon block are designed to prevent the granules from packing. It has recently been decided to use carbon shot instead of granules in these microphones, as they are less likely to pack, especially in damp climates.

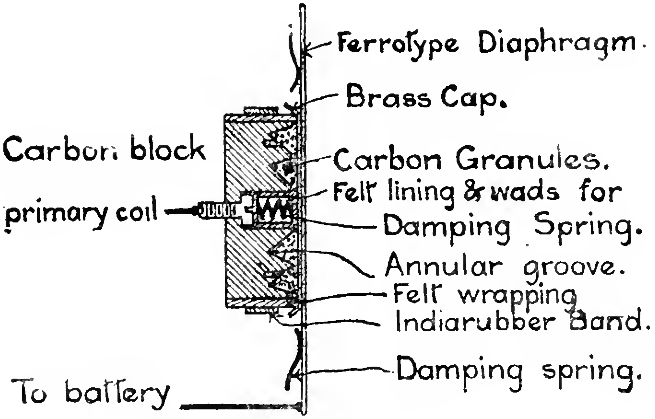


FIG. 2.—Ericsson Transmitter.

Capsule.

4. In the latest patterns of service transmitters a capsule is used, which contains the carbon shot sealed up into an air-tight metal case (*see* Fig. 3). This capsule fits into the case of the transmitter, the connections being made by the case of the capsule, and the platinum contact, shown in the figure, which is insulated from the case of the capsule. The sealing up of the

shot prevents damp from affecting them; when the capsule is damaged it is thrown away and a new one is slipped in.

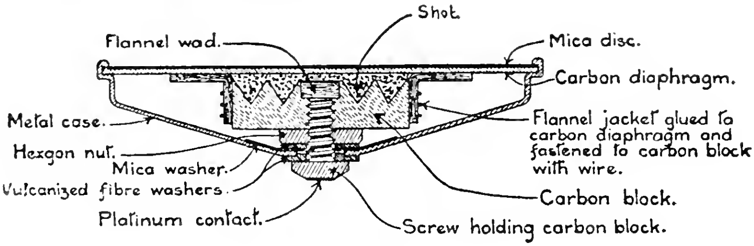


FIG. 3.—Capsule.

Telephone sets D, Mark II, transmitter.

5. The only transmitter in the service which does not form part of a hand telephone is the transmitter for Telephone Set D Mark II. This is a microphone of the capsule type, contained in a round aluminium case. It is provided with a spring contact inside the case, actuated by an ebonite button, which completes the circuit when pressed. The top of the case can be screwed off to give ready access to the capsule.

Receivers.

Ader receiver.

6. The Ader receiver was once very largely used in the service, and is still to be met with (*see* Fig. 4). It consists of a circular magnet (A), which at the same time serves as a handle. On the soft iron cores (B), fixed to the ends of the permanent magnet, two coils are wound with ·036-inch wire to a

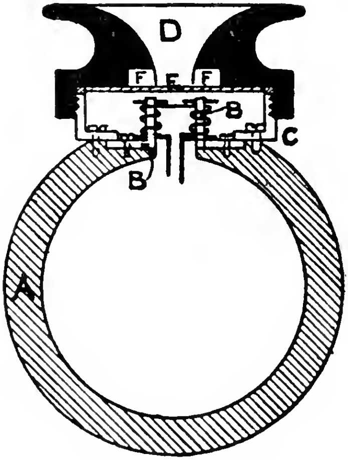


FIG. 4.—Ader Receiver.

resistance of 120 ohms, and the ends are made off to two terminals. These terminals are attached to, but insulated from, the cylindrical metal case (C), which, itself non-magnetic, is secured to the magnet (A). The mouthpiece (D), screwed on to (C), clamps between itself and (C), a thin ferro-type diaphragm (E), which touches (C) and (D) only at its periphery. Fixed in (D), and just clear of (E), is a soft iron ring (F), called a "sur-excitateur" separated from (E) by a brass washer. The diaphragm (E) is held about $\frac{1}{64}$ inch clear of the soft iron cores by a brass washer.

The object of the iron ring (F) is to act as a keeper to the pole-pieces, thus increasing the strength of the field through the diaphragm (E). The mouthpiece (D) is usually made of ebonite. A twin cord 2 feet 9 inches long is used with this receiver, known as Cord, telephone, Ader.

Double pole Bell receiver.

7. The Double Pole Bell receiver is a modification of the original Bell receiver. The construction varies somewhat according to the make, but the following description is fairly typical. It is not a service instrument, but is largely used by the Post Office.

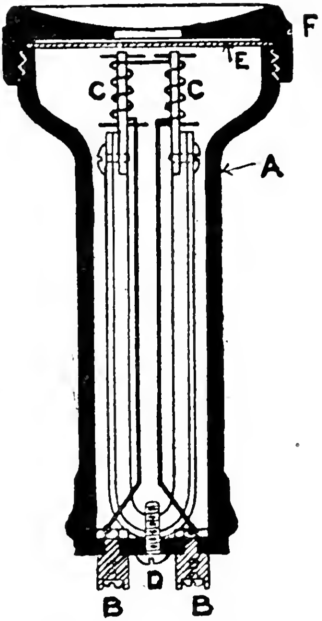


FIG. 5.—Double Pole Bell Receiver.

(A) in Fig. 5, is a brass or non-magnetic metal case, sheathed with ebonite. Within it is secured a long U-shaped permanent magnet, with soft iron pole-pieces, upon which are wound two coils of insulated wire. The two ends of the coils are led down the case to two terminals (B, B), in the base of the instrument. (D) is a screw by means of which the position of the magnet and pole-pieces can be adjusted in a longitudinal direction. (E) is a thin ferro-type diaphragm which is clamped between (A) and the ear-piece (F). (F) is threaded to screw on to (A), and is usually made of ebonite.

Watch receiver.

8. A great variety of patterns of watch receivers may be encountered, and the following description applies to the receiver forming part of Hand Telephone A; all other patterns are generally similar (*see* Fig. 6).

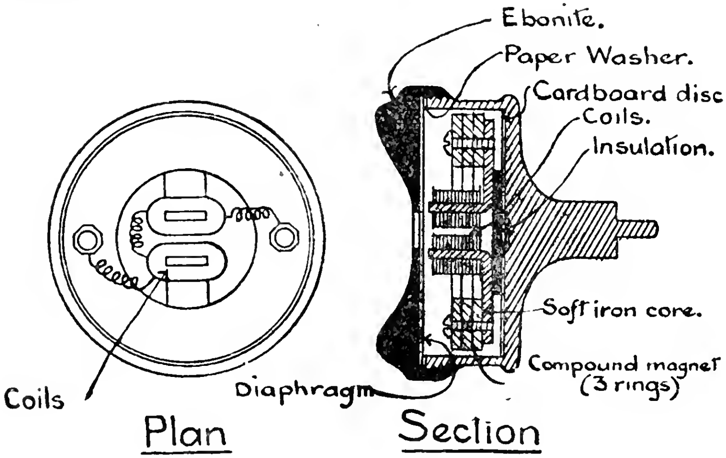


FIG. 6.—Watch Receiver.

The permanent magnet is ring-shaped, and consists of two or three separate steel ring magnets, fastened together by screws. The north and south poles lie at opposite ends of a diameter, and to these two points are screwed inwardly projecting soft iron pole-pieces, which, as they approach each other, are turned upwards through a right angle to an L shape. The upper portions, which are very close to one another, are wound with flat coils of wire to a resistance of 135 ohms. The whole of the above is contained in a case of non-magnetic metal, through which, at the back, but insulated from it by ebonite collets, pass two small bolts to which the ends of the coils are attached. Screwed to the top of the case is an ebonite earpiece; between the latter and the case the ferro-type diaphragm is clamped at a distance of about $\frac{1}{64}$ inch from the top of the pole-pieces.

With all receivers care must be taken to see that the ends of the coils are not short-circuited, and that the diaphragm is the correct distance from the poles of the magnet. In many patterns the rim of the case and the ends of the pole-pieces are in the same plane, and this clearance is obtained by inserting one or more washers, made of paper or brass. In service instruments the paper washers are saturated with melted paraffin wax, to render them damp-proof.

Telephone receiver, head, Mark I.

9. "Telephone receiver, head, Mark I" is a watch type receiver fastened to a circular steel spring, which is designed to pass over the head, and hold the receiver against the ear (*see* Fig. 7). The other end of the spring is fitted with a pad, to close the other ear. It is used on busy telephone exchanges, and with Vibrator telegraph. The receiver includes a 4 feet twin cord (Cords, telephone, Head receiver) for connecting it to the instrument.

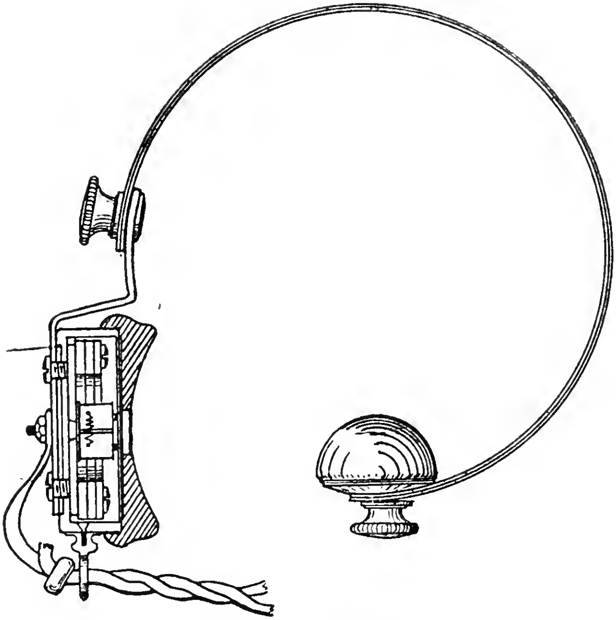


FIG. 7.—Head Receiver.

An ear-cushion of indiarubber is provided to fit over the ear-piece of the receiver for use in the field, or whenever it is necessary to exclude noise as much as possible. It is vocabularised as Telephone Receiver, Head, Ear-cushion. The cord is 4 feet in length, and is vocabularised as Cord, telephhone, Head receiver.

Telephone sets, portable D, Mark II, head receiver.

10. The head receiver for Telephone sets, Portable, D Mark II is a receiver of watch type, of aluminium, with a top covering of leather and wire gauze. The coils are wound with ·003-inch wire to a resistance of 200 ohms, and are adjustable from the

back by means of a screw. It is contained in a leather case, which is fitted with web bands for fastening round the head with a buckle.

Hand Telephones.

Patterns of hand telephone.

11. A variety of names have been applied to the now familiar combination of transmitter and receiver in one piece of apparatus, which is connected by flexible conductors to the telephone instrument. Among them "micro-telephone," "operator's telephone," and "converser" may be mentioned. The vocabulary name for the service patterns is "Telephones, Hand."

No less than six patterns exist in the service, viz.: Telephones, Hand, A Mark I, A Mark II, B, C Mark I, C Mark II, and D, which are very similar in general design. A feature common to them all is the switch, which projects from the handle, and is pressed by the fingers when speaking or listening. All hand telephones are issued complete with flexible cords, the latter can also be obtained separately.

Hand telephones, A Marks 1 and II, and D are electrically the same, and can be used with any telephone sets except C Marks I and II, which require hand telephones of the same letter and mark as themselves; for Transmitter, vibrating, Mark IV; for Switches, telephone, 5 and 10-line; and for Vibrator, telegraph. Hand telephone C Mark II is intended for use with Vibrator, telegraph, and by joining up in a special manner, for Transmitter, vibrating, Mark IV.

Telephone, Hand, A, Mark I.

12. "Telephone, Hand, A Mark I" is intended for use with office telephone sets, Telephone, Portable, A, and Switch-boards telephone exchange. It was also used with Transmitter, vibrating, Mark IV. It is now obsolescent, being superseded by Mark II.

The instrument is of Messrs. Ericsson's design, and is illustrated in Fig. 8. The receiver is that already described in para. 8, and illustrated in Fig. 6, and the coils are wound with ·004-inch wire to a resistance of 135 ohms. The transmitter is described in para. 3 and illustrated in Fig. 2. The switch is a simple contact maker for the microphone circuit, and the flexible cord has four conductors, two for the receiver and two for the transmitter. The cord is known as "Cord, telephone, A," is 4 feet long, and quadruple.

Telephone, Hand, A, Mark II.

13. "Telephone, Hand, A Mark II" is generally similar to Mark I, and is used for the same purposes. The alterations are intended to make it more durable, and are as follows:—

(*a*) The receiver leads are entirely enclosed in the case instead of coming through the handle and being attached to terminals outside the receiver.

(*b*) The ear-piece comprises a threaded metal collar with a removable ebonite disc, instead of being wholly of ebonite screwed direct to the body of the receiver.

(*c*) The transmitter is of the capsule type.

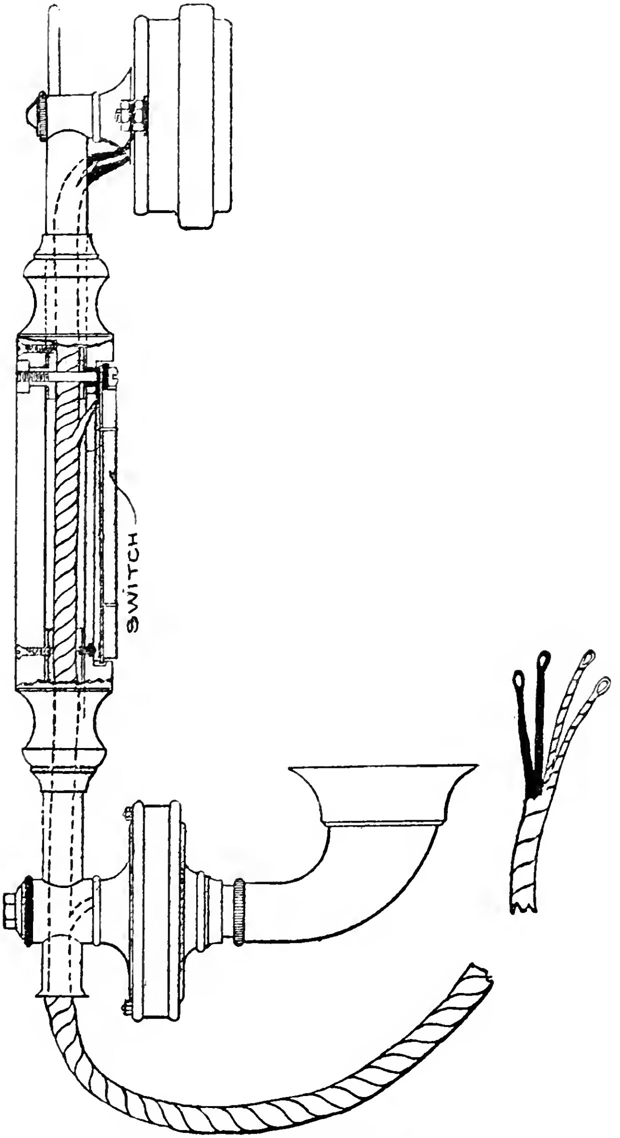


FIG. 8.—Telephone, Hand, A, Mark I.

Telephone, Hand, B.

14. "Telephone, Hand, B" is used only with "Telephone set, Portable B," which is practically obsolete, and will not therefore be described in detail.

Telephone, Hand, C, Mark I.

15. "Telephone, Hand, C Mark I" is also of Ericsson's design, and is generally similar to A Mark I. It is used with "Telephone sets, Portable, C Mark I," and is equipped with Cord, telephone, C. The mouthpiece is of rubber to avoid damage from rough usage. For diagram, *see* Chap. XII, Fig. 5.

The chief point of difference lies in the switch, which has an additional contact, for the purpose of short-circuiting receiver and secondary of induction coil when at rest. The conductors are therefore, two for receiver, one for transmitter, and one for switch. Care must be taken in joining up this instrument to get the conductors on the right terminals of the telephone.

Telephone, Hand, C, Mark II.

16. "Telephone, Hand, C Mark II"* is intended for use with "Telephone sets, Portable, C Mark II," and "Vibrator, telegraph, Mark I" (*see* Fig. 9).

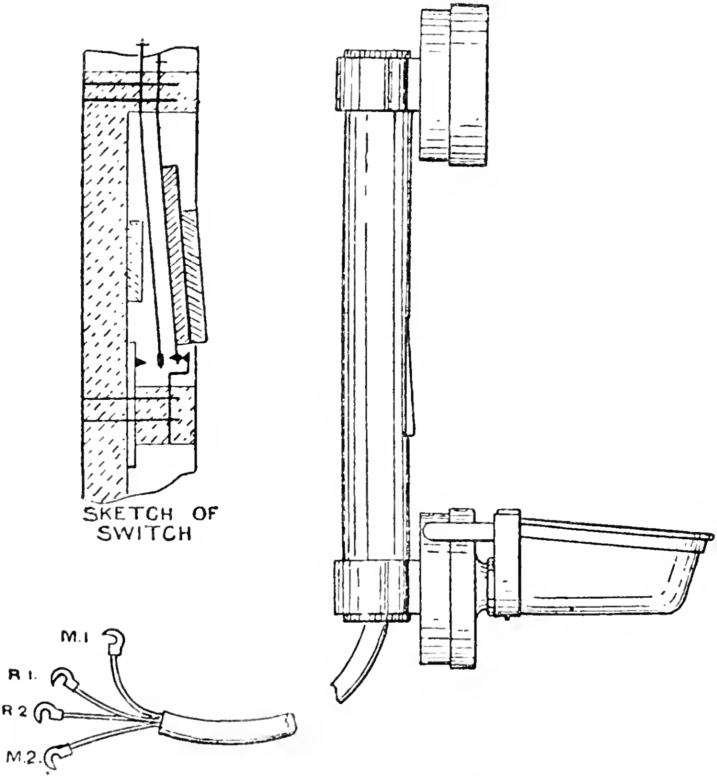


Fig. 9.—Telephone, Hand, C Mark II.

It is made of aluminium, the handle consisting of a tube covered with leather, which is prevented from pressing the

---

* Now obsolescent.

switch when shrunk with wet by an ebonite collar. The ends of the tube are closed by screw plugs, and the collars carrying the microphone and receiver cases can be removed by taking out a screw.

The receiver is wound with ·003-inch wire to a resistance of 120 ohms, and the microphone is of the capsule type. The mouth-piece is a leather hood, and is hinged to lie flat along the handle. The cord used is "Cord, telephone, C Mark II," which terminates in hook-shaped contacts, labelled M1, M2, R1, R2. The connections of these are shown in Fig. 6, Chap. XII. When used with Telephone set, Portable, C Mark II, M2 is spare.

Telephone, hand, C, Mark III.

16A. The Mark III Telephone, Hand, C, differs from Mark II as follows :—

(*a*) A fibre push fitted outside the leather cover over the pressel switch.

(*b*) A fibre ear-piece fitted to the receiver in place of the pattern in Mark II.

(*c*) A metal deflector fitted to transmitter as in Telephone, Hand, D Mark I, in place of the present leather one.

Telephone, hand, D.

17. "Telephone, Hand, D," is used with Telephone set, portable, D, Mark I, and, though electrically similar to A Mark I, is mechanically of a special construction, in order to decrease its length and bulk when packed in its leather case. This is effected by mounting the transmitter and receiver on a telescopic instead of a rigid tube, and by using a hinged plate instead of the ordinary mouth-piece. The switch is a simple microphone switch, and the cord is "Cord, telephone, D," length 3 feet.

17A. Telephone, Hand, D Mark III, is of a telescopic pattern, and is for use with Telephone Sets D Mark III (*see* para. 54A, Chap. XII); when this is not opened out, a pin keeps the pressel switch open.

Generators.

Nomenclature.

18. The magneto generators which form part of the various telephone sets are described in Chap. XII. There are, however, in the service two marks of a generator which is used by itself for alarm circuits, known as "Generator, magneto, A," Mark I and Mark II.

Generator, magneto, A, Mark I.

19. Generator, magneto, A, Mark I (*see* Fig. 10), is of the ordinary type, with three magnets, and is contained in a walnut box with a door, fitted for screwing to a wall. The armature is wound with ·006-inch wire to a resistance of 300 ohms. It is capable of ringing Bell electric, P, Mark I, through a resistance of 20,000 ohms. The driving gear is 140 : 37.

Generator, magneto, A, Mark II.

20. Generator, magneto, A, Mark II, is generally the same as Mark I, but differs in the following particulars :—

(*a*) The resistance of the armature winding is 700 ohms.

(*b*) It is fitted with a cut-out (*see* Fig. 6, Chap. XII), which disconnects the instrument except when in use. Care must therefore be taken to join them up in parallel and not in series. When the handle is turned the spindle revolves freely until a pin on it enters a V-shaped slot in a washer fixed to the driving wheel; the spindle then moves to the left, and causes the driving wheel to rotate, at the same time completing the circuit by closing a spring contact at the other end.

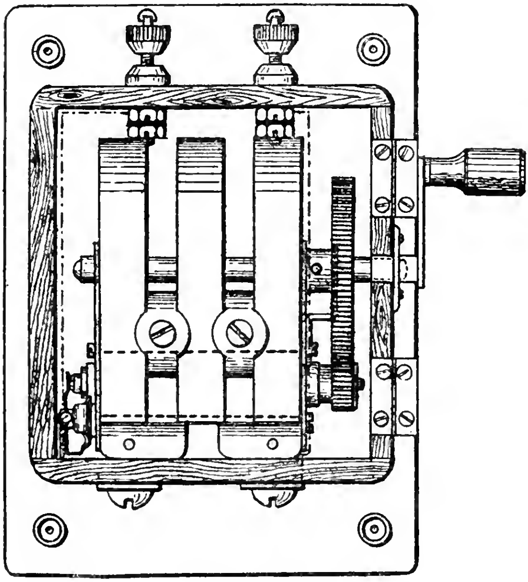


FIG. 10.—Generator Magneto A, Mark I.

Bells.

Classification.

21. A general description of the principles involved in the working of electric bells has already been given in Chap. X, paras. 13 and 16. Details of the instruments used in the service will now follow. Bells are classed under two heads, bells electric, battery, and bells electric, magneto.

Bell electric, battery, Mark III.

22. "Bell electric, battery, Mark III," previously known as "Bell, chattering, Mark III," is similar in principle to the trembling bells described in Chap. X. The magnet has two coils of 50 ohms resistance each, wound with wire of ·0076 inch

diameter, the ends of which are brought to connecting blocks, so that they can be joined in series or in parallel as required The armature is held against the contact pillar by means of an adjustable helical spring. The gong is three inches in diameter (*see* Fig. 11).

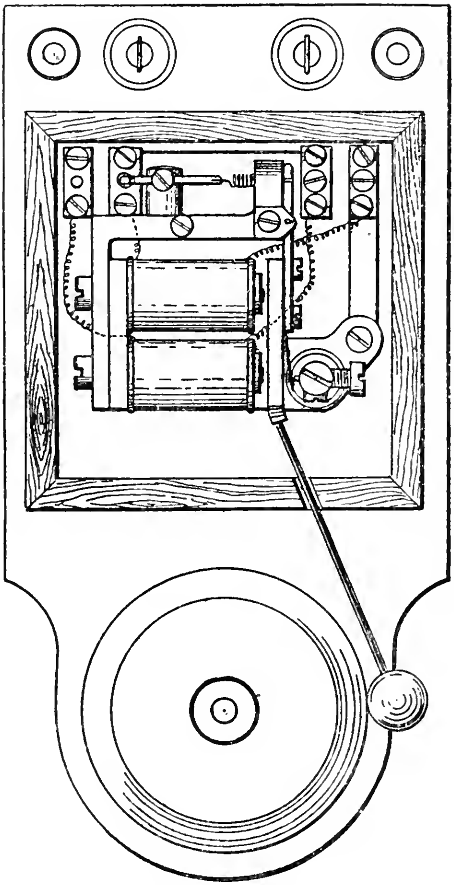


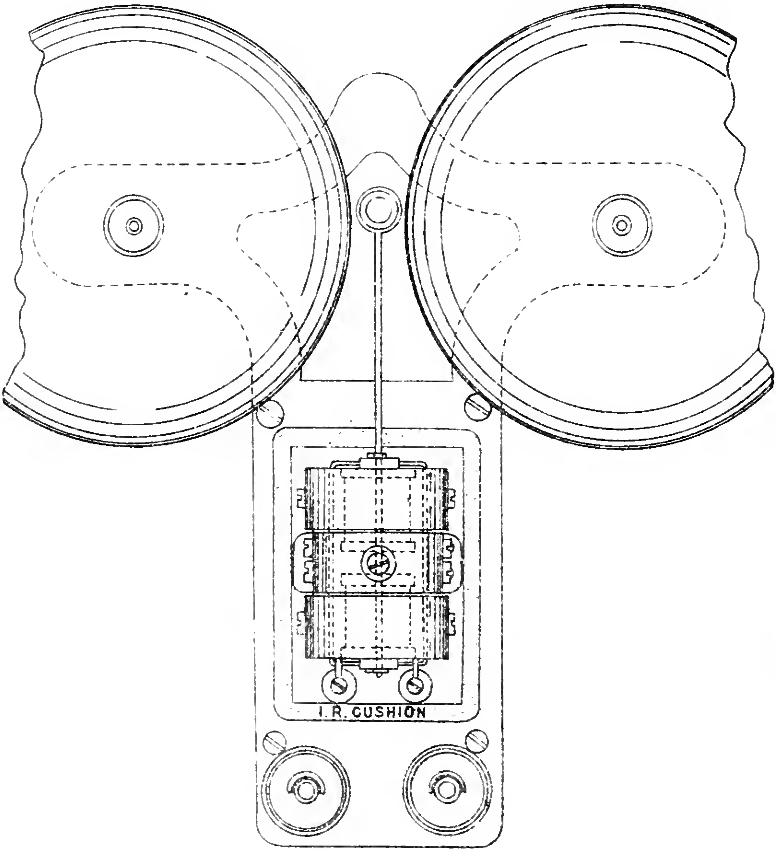
FIG. 11.—Bell Electric Battery, Mark III.

When used on local circuits the coils should always be connected up in parallel, giving the minimum resistance of 25 ohms. Even this is large for the purpose, and consequently a Mark IV has been produced.

Bell electric, battery, Mark IV.

23. "Bell, electric battery, Mark IV," is a low resistance trembling bell, designed for use on local circuits, and for general purposes. It is of a less elaborate and cheaper type

BELL, ELECTRIC, MAGNETO. "P" Mk I.



To face p. 157.

H & C. GRAHAM LTD, LITHRS, LONDON, S.E.

than Mark III; the armature works with a flat steel spring, and the coils are wound with ·018 inch wire to a resistance of 4 ohms for each bobbin. It has a 3-inch gong, and should ring through 30 ohms resistance with two Leclanché cells.

Bell, electric, magneto, P, Mark I.

24. "Bell electric, magneto, P, Mark I" (Fig. 12), formerly termed "Bell alarm," is designed for alarm circuits. It is a polarised bell, for use with alternating currents. The coils, wound with ·004-inch wire to a resistance of 500 ohms on each of the two bobbins, are fixed on the arm which carries the hammer, and lie between two horse-shoe permanent magnets. The coils and magnets are enclosed in a cast-iron cover, standing on an indiarubber cushion, to keep the wet out, and the two gongs are of 6-inch diameter.

Bell, electric, magneto, P, Mark II.

25. A new pattern of this bell is under consideration, which will be more watertight, and easier to adjust.

Bell, electric, magneto, Q.

26. "Bell electric, magneto, Q," formerly known as "Bell extension," is a polarised bell designed for use as an extension bell with magneto telephones requiring a low resistance bell. It is of the ordinary pivoted armature type, and is fixed to the bottom of the lid of a box, the two 2-inch gongs being outside the lid. The two coils are wound with ·006-inch wire to a resistance of 200 ohms. The terminals are on the outside of the box, and are provided with a small serrated lightning discharger.

Bell electric, magneto, R.

27. "Bell electric, magneto, R," is a polarised bell of high resistance designed for use as an extension bell with the newer types of magneto telephone. It is similar to the Q type except that the coils are wound with ·0048-inch wire to a resistance of 1,000 ohms.

CHAPTER XII.

TELEPHONE SETS.

Service patterns.

1. A telephone set is a complete instrument (but without battery), needing only two lines, or a line and earth, for use. Very many varieties exist in commercial use; the Service patterns are as follows:—

Telephone sets, Office:—

- *Mark II, magneto, low resistance bell.
- *Mark III }
- *Mark IV } Table type, magneto, high resistance bell.
- Mark V }

Telephone sets, Wall:—

- *Mark I }
- Mark II } Wall type, magneto, high resistance bell.

Telephone sets, Portable:—

- *A, magneto, low resistance bell, for coast defence purposes.
- B (obsolete), magneto, low resistance bell.
- *C, Mark I, magneto, low resistance bell.
- C, Mark II, magneto, high resistance bell.
- *D, Mark I, vibrator call.
- *D, Mark II, vibrator call.
- D, Mark III.

Telephone sets, Phonopore, for railway purposes.

A list of the constants of the various patterns will be found at the end of the chapter.

**Telephone sets, Office, Mark II.*

Telephone sets, Office, Mark II.

2. Telephone sets, Office, Mark II, formerly known as "Bell, Polarised," was the earliest type of magneto telephone to be introduced into the Service. They are now obsolete for any purpose but working on the short lines of exchanges, where the weakness of the magneto, and the low resistance of the bell are not disadvantageous.

The set, except for Telephone, Hand, A, which forms part of it, is enclosed in a box, with a handle at the top, and the terminals and the handle of the generator projecting from one side. The battery must be separately provided, and may consist of any two Leclanché or dry cells, preferably large ones. A diagram is given in Fig 1.

Generator.

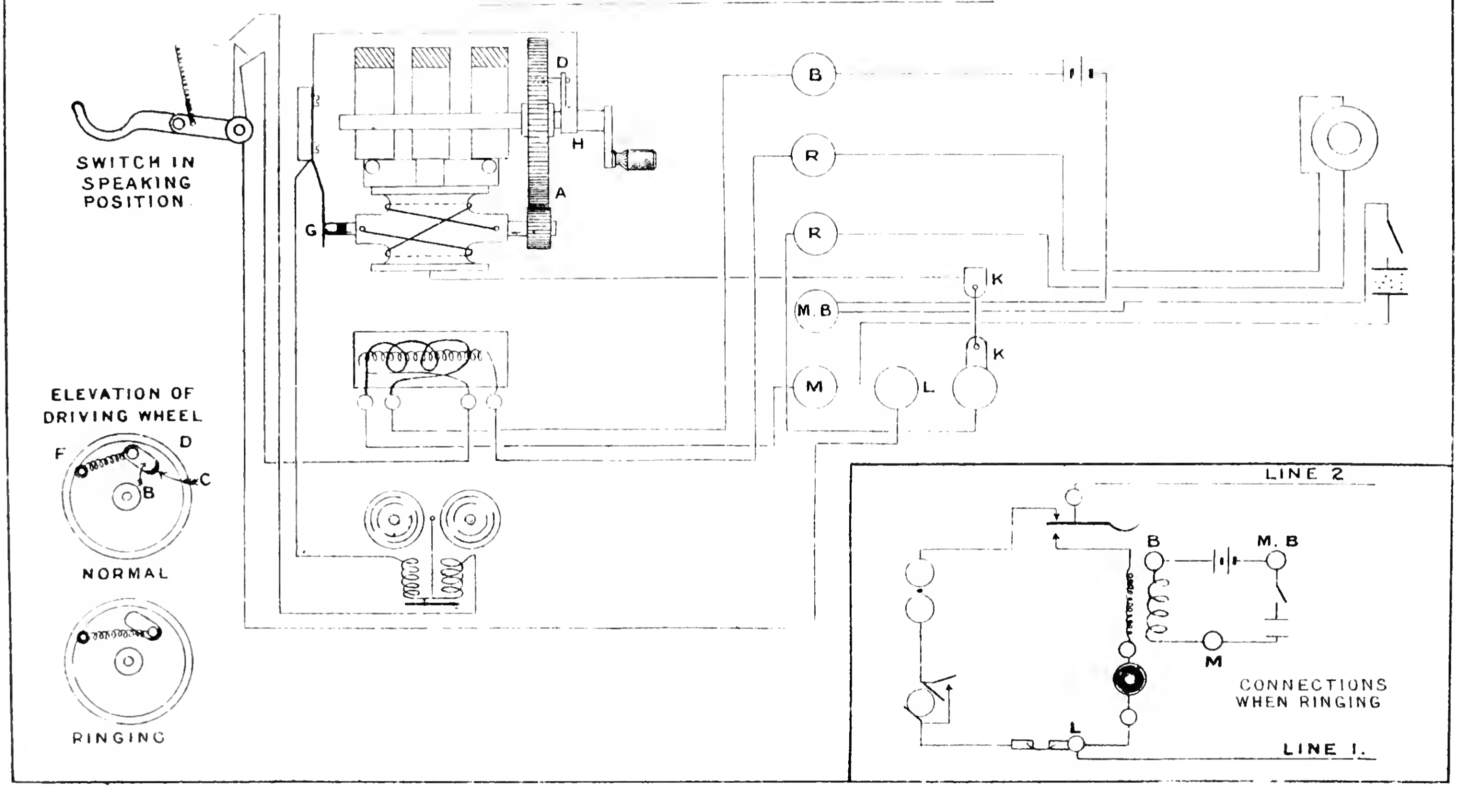
3. The generator has three magnets, and an armature wound with ·004-inch wire to a resistance of 700 ohms, and it is capable of ringing its own bell through a resistance of

---

* Obsolescent.

Chap. XII. Fig. 1.

TELEPHONE SET, OFFICE Mk II.



To face p 158

H & C GRAHAM LTD, LITHRS LONDON, S.E.

12,000 ohms. When the generator is at rest, an automatic cut-out removes its resistance from the circuit. This is arranged by a shunt between the spindle spring (G) and the crank bearing (H), which is in metallic contact with the crank and crank pin (D), which touches the driving wheel (A), which is in contact with the armature through the bearing; the two ends of the armature windings are therefore short-circuited. When the handle is turned clockwise the pin (D) moves in the slot (B) against the pull of the spring (F) till it touches the insulating block (C); the crank and driving wheel then turn together, but the shunt is broken at the pin.

4. The bell is of the ordinary pivoted armature type, the coils are wound with ·007-inch wire to a resistance of 140 ohms; the gongs are 2 inches in diameter. Provision is made at the brass straps (K, K) for the insertion of an additional bell, which may be required at a distance. This bell would be in series, and the straps must therefore be joined by a piece of wire if no extra bell is used. Bell electric, magneto, Q, is a suitable pattern for the purpose.

Induction coil.

5. The primary of the induction coil is wound with ·018-inch wire to a resistance of 2·6 ohms, the secondary with ·005-inch wire to a resistance of 290 ohms.

Internal arrangements and switches.

6. A line switch, in the form of a hook on which the hand telephone hangs, puts L2 either to secondary speaking, or to ringing circuit. The generator, as before stated, is shunted when at rest. The microphone switch is in the handle of the hand telephone. The hook for the hand telephone is awkwardly placed, as to hang the hand telephone on it it is necessary to place the set at the edge of a table or shelf.

Lightning dischargers

7. Protection from lightning must be provided separately.

Simple tests.

8. Ringing portion :—

Short circuit the lines, and turn the handle of the generator (switch down). The bell should ring, as generator and bell are in series. If not, the generator may be tested by short circuiting the lines with the tips of the moistened fingers and turning the handle, when a current should be felt.

Speaking portion :—

Short circuit lines (switch up), and move handle of microphone switch. Clicks should be heard in the receiver. If no sound, fault is probably in—

(*a*) Line switch.
(*b*) Battery.
(*c*) Receiver.
(*d*) Microphone switch, or cords.

For (*a*), examine line switch. For (*b*), disconnect at (B) and MB, and use detector. For (*c*), disconnect at R and R, and touch B and MB, when clicks should be heard.

To test microphone, short circuit lines (switch up), and blow into microphone; sounds should be heard in the receiver.

**Telephone sets, Office, Mark III.*

Telephone sets, Office, Mark III.

9. This instrument is of the pattern usually known as desk, or table, and has superseded Mark II for general purposes. The hand telephone rests in a cradle at the top, which actuates the line switch; and a six-fold cord, 6 feet 3 inches long (known as "Cord, telephone, Office") from the table portion, carries the connections for the two lines, the battery, and for an extra bell, to a rosette, which can be fixed at a distance along with the battery. Telephone, hand, A, is included in the set; any two large Leclanché or dry cells can be used as battery. A diagram is given in Fig, 2.

Generator.

10. The generator has four magnets, and the armature is wound with ·006-inch wire to a resistance of 500 ohms. It can ring its own bell through a resistance of 25,000 ohms. The generator and bell are joined in series, but the cut-out in the generator short circuits the bell when calling as well as the generator when at rest. When the generator is at rest, the incoming current passes through the bell to the spring (FGH), and through the contact (H), to the spindle (A); when the handle is turned, the pin (P) works in a V-shaped groove (S), and forces the spindle to the right, thereby disconnecting at (H), which removes the short circuit from the generator, at the same time allowing the spring (FGH) to make contact at (J), which short circuits the bell.

Bell.

11. The bell is of the pivoted armature type, with two $2\frac{9}{32}$-inch gongs. The two coils of the magnet are wound with ·0036-inch wire to a resistance of 1,000 ohms.

Induction coil.

12. The primary of the induction coil is of ·0175-inch wire, wound to a resistance of 1·2 ohms, the secondary of ·0084-inch wire to a resistance of 76 ohms.

Internal arrangements and switches.

13. The ringing, and secondary speaking circuits are in series, and either is short circuited by means of the line switch, which is actuated by the weight of the hand telephone resting in a crutch at the top of the instrument. The cut-out device of the generator short circuits either generator or bell. The microphone switch is in the handle of the hand telephone.

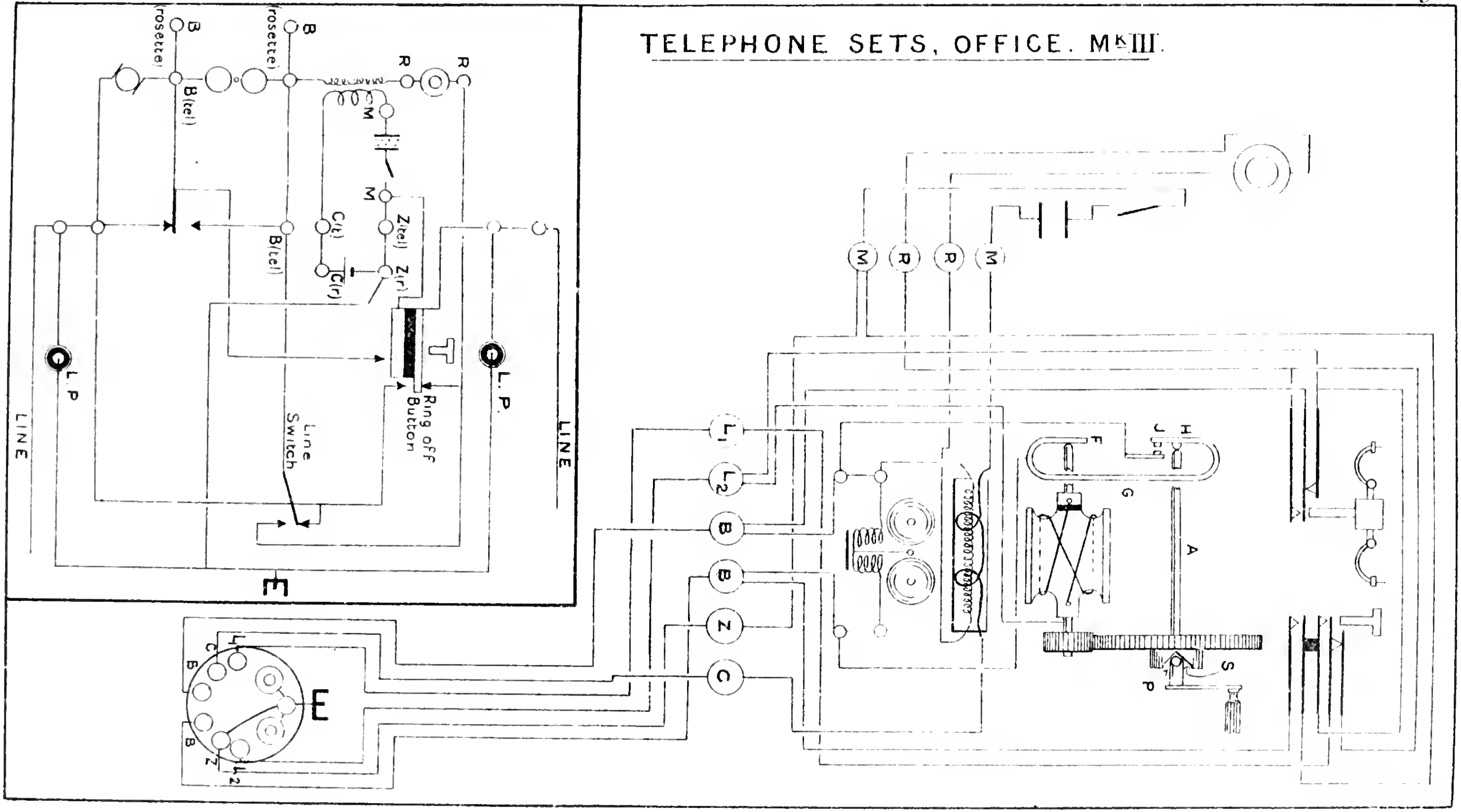
The ring-off button, when pressed, actuates a double switch. The top part, through which the connection from Line 1 to the secondary circuit and line switch passes when at rest, is arranged to bunch the lines when pressed. The bottom part is disconnected when at rest, and, when pressed, connects the bunched lines through the generator to earth; for this purpose Z is connected to E on the rosette. Thus by pressing the ring-off button and working the generator a current can be sent out on the two lines in parallel for a ring-off signal; or by pressing the button alone the bunched lines are earthed (for

---

* Obsolescent.

Chap.XII. Fig 3.

TELEPHONE SETS, OFFICE. Mk III.



H & C GRAHAM LTD LITHRS LONDON S.E

To Face p 160.

use, *see* Chap. XIII, para. 17). The hand telephone must be on the crutch when the ring-off signal is sent.

Lightning dischargers.

14. Two small dischargers of the plate type are provided in the rosette, but these are hardly sufficient for complete protection.

Simple tests.

15. Ringing portion :—

Generator and bell may be tested in series in either up or down position of the line switch, by disconnecting at (J) with a piece of doubled paper, and turning the handle, when the bell should ring. When the switch is down, L1 and L2 must be joined; when it is up they should not be joined. This tests the line switch also in both positions.

The generator may be tested separately by short circuiting L1 and L2 with the moistened tips of the fingers (switch down), when a current should be felt if the handle is turned.

Speaking portion :—

Move handle of microphone switch, with line switch *down*, clicks should be heard. This tests line switch, receiver, battery, and microphone switch. Battery can be tested with a detector by disconnecting at C and Z of rosette, or C and Z of telephone. Receiver by disconnecting at R R and putting leads to C and Z.

Microphone can be tested by blowing, when sounds should be heard in the receiver (microphone switch pressed, line switch *down*).

Ring-off button :—

Press ring-off button (switch down), and turn generator handle. A current should be felt if either L1 or L2 is joined to E by the moistened tips of the fingers. If the bell shunt be disconnected at (J) as before described the bell should ring when either L1 or L2 is joined to E and the handle is turned.

Telephone sets, Office, Mark IV and V.*

Telephone sets, Office, Mark IV* and V.

15A. These are later patterns with high resistance bell, 1,000 ohms. The Mark V differs principally from previous patterns in having the cradle, cradle switch, and ring-off key fixed on a removable base to facilitate access thereto.

The exposed metal work is bronzed.

*Telephone sets, Wall, Mark I.**

Telephone sets, Wall.

16. Telephone set, Wall, is an instrument of Ericsson's make which was bought in large quantities for use in South Africa; many are still available, and are to be issued in lieu of Telephone sets, Office, until the stock is used up. They include a special hand telephone, provided with a four-point plug, but

---

* Obsolescent.

without any switch, which is not suitable for service pattern instruments, although "Telephone, hand A" can be used with these sets. Some of them are equipped with a push button, which, when pressed, connects both lines to earth. Terminals are provided for a second receiver. These are in series, and should be bridged with a piece of wire if not in use. A cupboard is situated under the instrument which will take one "Cell, electric dry, A," or one "Cell, electric, Leclanché J." A diagram is given in Fig. 3.

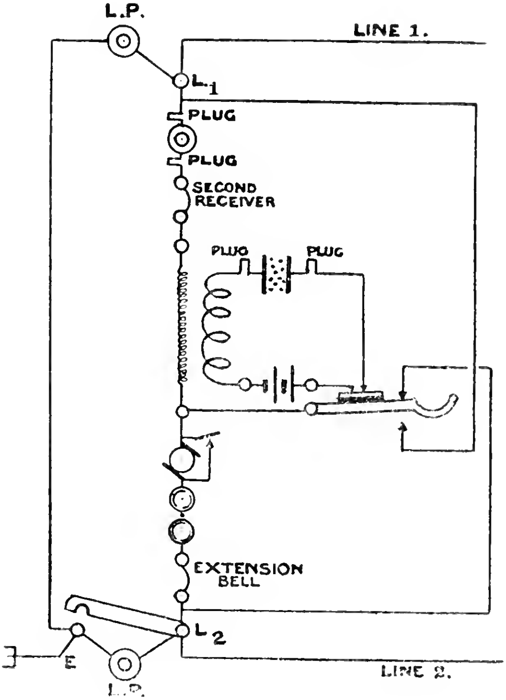


FIG. 3.—Telephone sets, Wall.

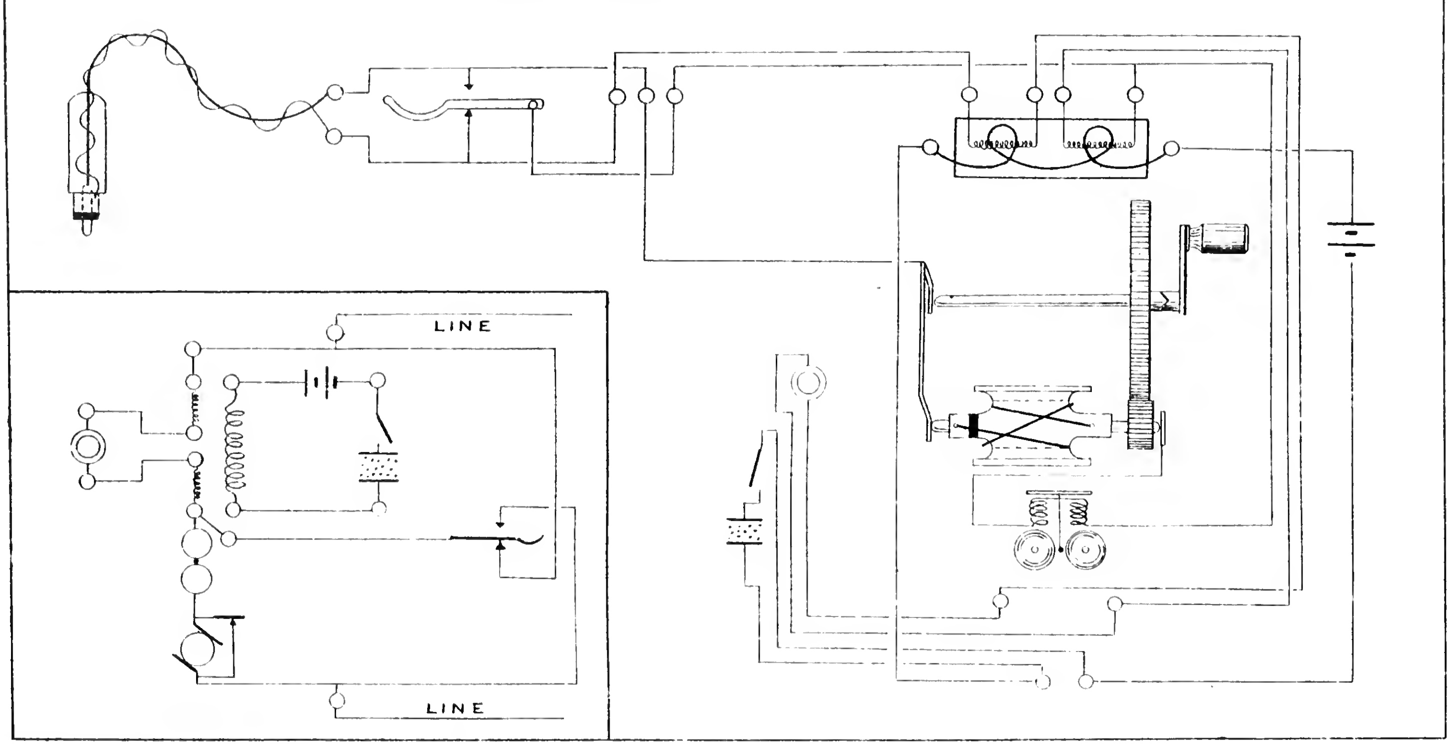
Generator. 17. The generator has three magnets, with a centrifugal cut-out, and will ring its own bell through a resistance of 20,000 ohms.

Bell. 18. The bell is of the ordinary type, and has a resistance of 300 ohms. Spare terminals are provided for an extension bell if required; they are in series, so that they must be bridged with a piece of wire if a second bell is not used. Bell electric, magneto, Q, would be a suitable pattern to use.

Internal arrangements and switches. 19. The speaking and ringing portions are joined up in series, and a hook switch short circuits either portion as required. The same switch, when up, completes the micro-

Chap XII. fig. 4

TELEPHONE SET, PORTABLE "A".



H & C GRAHAM LTD, LITHRS, LONDON, 3 E

phone circuit. The generator is short circuited when the handle is not being turned.

Lightning dischargers.

20. Two plate lightning dischargers are provided, one on each line.

Simple tests.

21. Ringing portion :—

The generator should ring its own bell with L1 and L2 short circuited and switch down, or with switch up at any time.

Speaking portion :—

Move handles of microphone switch, with line switch *down;* clicks should be heard in the receiver. This tests line switch, receiver, battery, and microphone switch. Battery can be tested with a detector by disconnecting it at its terminals, receiver by joining the two centre plugs to the battery terminals.

Microphone can be tested by blowing, when sounds should be heard in receiver (microphone switch pressed, line switch *down*).

Telephone sets, Wall, Mark II.

Telephone sets, Wall, Mark II.

21A. This pattern has a high resistance bell of 1,000 ohms, and differs from the Mark I in the following respects :—

The cradle, cradle switch, and ring-off key are fixed on a removable base facilitating access thereto.

The exposed metal parts are bronzed.

**Telephone set, Portable, A.*

Telephone set, Portable, A.

22. This instrument was designed as a portable set for coast communication work; it is contained in a 1′ 3″ × 10″ × 1′ 1″ case, and weighs 40 lbs., so that its portability is somewhat questionable. Telephone, hand, A, is included in the set, and two Cells, electric, dry A are used with it, space for them being provided in the case, but must be demanded separately. The set includes a plug and double flexible cord 6 feet long (Plug, jack, W.D., *see* Chap. XIV, para. 3) connected to the line terminals, which is carried on a small drum on the side of the case. The case is fitted with a shelf for writing a message. For diagram, *see* Fig. 4.

Generator.

23. The generator has three magnets, and the armature is wound with ·0052-inch wire to a resistance of 500 ohms. It is capable of ringing its own bell through a resistance of 12,000 ohms. The armature winding is short circuited through the spindle of the driving wheel when at rest; when the handle is turned, the spindle is free to revolve in the driving wheel until a V-shaped cut in the pipe has caused it to move slightly to the right, and so to disconnect the shunt at its other end.

Bell.

24. The bell is of the usual pivoted armature type, and is wound with ·0092-inch wire to a resistance of 50 ohms for

---

* Obsolescent.

each of the two bobbins. It is fitted with a small serrated lightning discharger, and a plug-hole for short circuiting plug.

Induction coil.

25. The induction coil is carried in a small box with a glass front. The primary is of ·028-inch wire, wound to a resistance of ·5 ohms; the secondary is in two halves, wound with ·007-inch wire to a resistance of 90 to 95 ohms in each half.

Internal rrangements and switches.

26. The secondary speaking and ringing circuits are in series, and the line switch short circuits either as required. The generator is shunted when not in use. The microphone switch is in the handle of the hand telephone.

Lightning dischargers.

27. Protection from lightning must be provided independently.

Simple tests.

28. Ringing portion :—

The generator should ring its own bell with switch *up*. The generator itself may be tested by taking off the desk and short circuiting the two inside terminals in the top left hand corner of the box with the moistened fingers.

Speaking portion :—

Move handle of microphone switch with line switch *down;* clicks should be heard. This tests line switch, receiver, battery, and microphone switch. Battery can be tested with a detector after taking desk off, receiver by joining a battery to the upper two terminals at the bottom of the front of the box.

Microphone can be tested by blowing, when sounds should be heard in the receiver (microphone switch pressed, line switch *down*).

**Telephone set, Portable, C, Mark I.*

Telephone set, Portable, C, Mark I.

29. This is a portable instrument, designed by Messrs. Ericsson, and was bought in large quantities for use in South Africa. It is very handy and portable, but not suitable for use in rain, nor are the parts easy of access for the lineman. Its weight is about 18 lbs. The set includes hand telephone C, Mk. I, and two P size dry cells are used with it, space for them being provided in the box. For diagram, *see* Fig. 5.

Generator.

30. The generator has three magnets, and the armature is wound with ·006-inch wire to a resistance of 500 ohms. It is short circuited when at rest, but, when the handle is turned, the shunt is broken by a centrifugal arrangement on the end of the armature spindle.

Bell.

31. The bell is of the pivoted armature type, and the two gongs have a diameter of $2\frac{1}{16}$ inch. The coils are wound with ·0066-inch wire to a resistance of 200 ohms.

Induction coil.

32. The primary is of ·018-inch wire, wound to a resistance of 1·6 ohms, the secondary of ·0084-inch wire, to a resistance of 70 ohms.

Internal arrangements and switches.

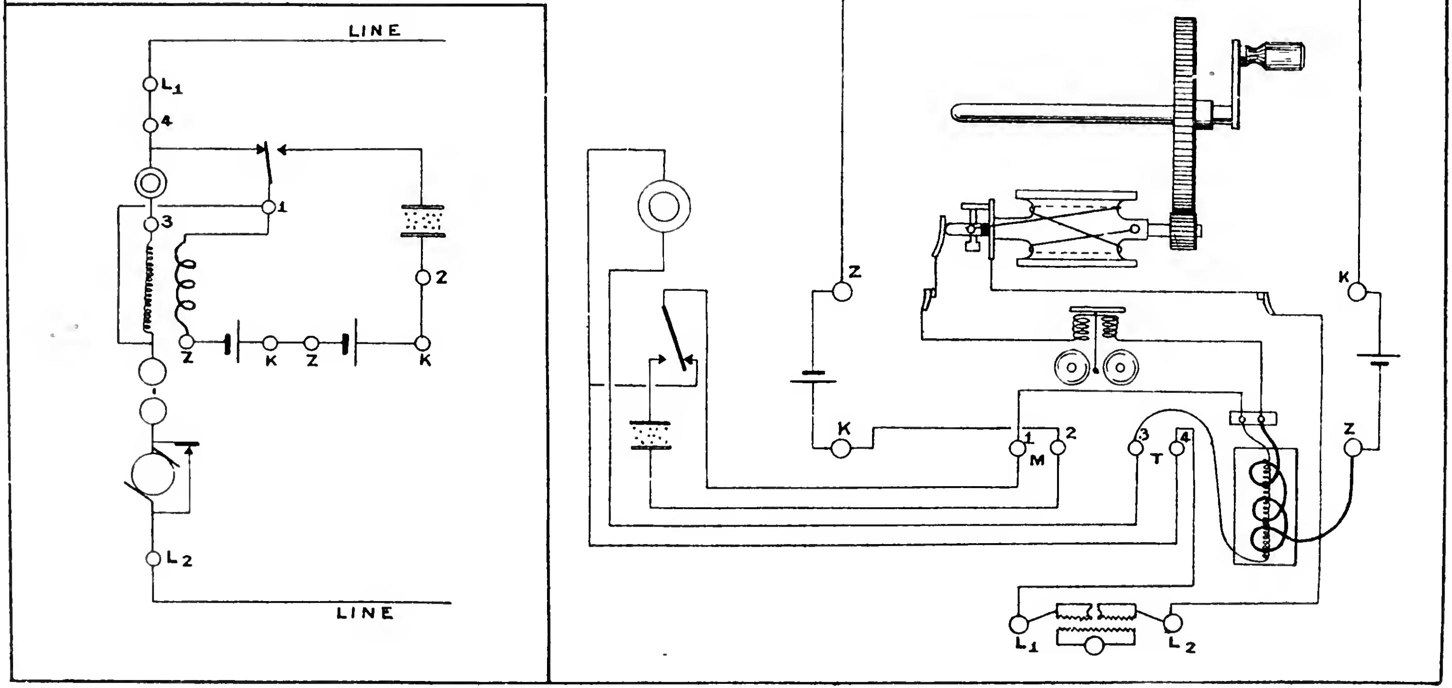
33. The secondary speaking, and ringing circuits are connected up in series. A switch in the handle of the hand telephone shunts the secondary speaking when at rest, and

---

* Obsolescent.

Chap. XII. Fig. 5.

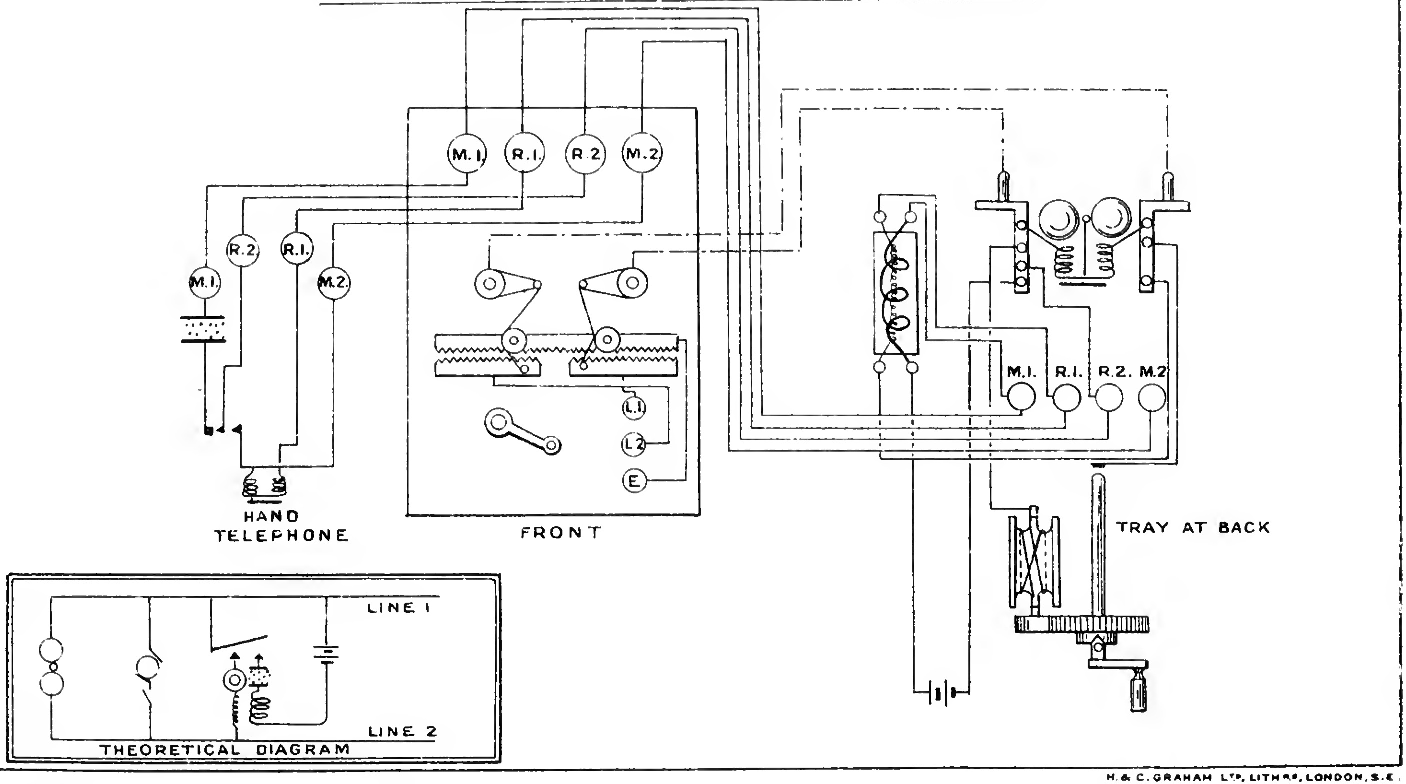
TELEPHONE SET, PORTABLE "C" Mk I.



H. & C GRAHAM LTD, LITHRS, LONDON, S.E.

To Face p. 164.

TELEPHONE SETS, PORTABLE "C" MARK II.



H. & C. GRAHAM LTD, LITHRS, LONDON, S.E.

To face p. 165.

completes the microphone circuit when pressed. Care must be taken in joining up the hand telephone to connect terminal 1 to tongue of switch, terminal 2 to microphone, terminal 3 to receiver direct, and terminal 4 to the receiver lead which is connected to the contact made by the switch when at rest. The generator is shunted when at rest.

Lightning dischargers.

34. A discharger of the comb or serrated type is provided, but this would be insufficient in a locality subject to thunderstorms. A plug is supplied for earthing either line.

35. Ringing portion :—

Simple tests.

Short circuit L1 and L2, and turn generator. Bell should ring whether the switch is pressed or not. If the switch is pressed the current should be heard in the receiver. The generator cannot be tested alone without removing the screwed down cover.

Speaking portion :—

Short circuit L1 and L2, and move switch. Clicks should be heard in the receiver. This tests receiver, battery, and switch. The ends of the two cells are visible for testing with detector.

To test microphone short circuit L1 and L2, and press switch If the microphone is blown into, sounds should be heard in the receiver.

Telephone set, Portable, C, Mark II.

Telephone set Portable, C, Mark II.

36. This instrument has been specially designed to obviate the difficulties experienced with Mark I. The case has a lid at each end : one, fixed with a simple hook, gives access to the hand telephone, generator handle, &c., and is for the use of the operator ; the other, fixed with screws, gives the lineman a convenient means of testing the internal arrangements. The weight is about 20 lbs., and the box is fairly waterproof whether open or shut. Its dimensions are 11¾ inches high by 10⅜ inches deep by 5¾ inches wide. Hand telephone C, Mark II, and C telephone ear cushion forms part of the set, and two "Cells, electric, dry 'P'" are used with it. For diagram *see* Fig. 6.

Generator.

37. The generator has four magnets, and the armature is wound with ·0052-inch wire to a resistance of 700 ohms. It is capable of ringing its own bell through a resistance of 12,000 ohms, and is provided with a cut-out which leaves the generator disconnected when at rest. When the handle is turned the spindle revolves freely inside the driving wheel until a pin on it engages in a V-shaped slot in a washer fixed to the driving wheel ; the spindle then moves to the left, and causes the driving wheel to rotate, at the same time completing the circuit by closing a spring contact at the other end.

Bell.

38. The bell is of the pivoted armature type, and is wound with 0·0044-inch wire to a resistance of 1,000 ohms.

Induction coil.

39. The primary is wound with ·018-inch wire to a resistance of 1·5 ohms, and the secondary with ·0084-inch wire to a resistance of 75 ohms.

Internal arrangements and switches.

40. The generator and the bell are each in bridge between the two lines, the generator being disconnected when at rest. One end of the secondary speaking circuit is to line 2, the other to the switch in the hand telephone, and is disconnected when the switch is not pressed. When this switch is pressed it also puts the primary circuit to line 1 : the other end of the primary circuit is permanently joined to line 1. The lead of the hand telephone marked M2 is not required for use with this instrument : M2 is therefore a dummy terminal.

Lightning dischargers.

41. Four bobbin lightning dischargers are provided with each set.

Simple tests.

42. Ringing portion :—

When L1 and L2 are disconnected, the generator should ring its own bell on short circuit. If L1 and L2 are joined with the tips of the moistened fingers, and the handle turned, a current should be felt.

Speaking portion :—

Clicks should be heard in the receiver when the switch is moved, whether L1 or L2 are joined or not. The battery may be tested with a detector if the back is opened.

The microphone may be tested by blowing on it, when sounds should be heard in the receiver, switch being pressed.

**Telephone set, Portable, D, Mark I.*

Telephone set, Portable, D, Mark I.

43. This is another instrument of Ericsson's design, for use on occasions when extreme lightness and portability are required. The heavy generator and bell are dispensed with, and a call is given by means of a small vibrator, and received in the receiver of the hand telephone. The action of the vibrator is described in Chap. XV. This method of calling is very useful on field lines, which are apt to be leaky and of high resistance, as the receiver responds to a very small amount of current ; a line of high capacity, however, such as a cable, causes the fluctuations of the volume of sound to be rapidly diminished, owing to their high frequency. The weight of the set is 5 lbs. 10 ozs., and "Telephone, hand, D," forms part of it. One special double cell is used with it, but does not form part of the set. (For diagram, *see* Fig. 7.)

Vibrator.

44. The vibrator is of the ordinary type, the coil of the electro-magnet being wound with ·0068-inch wire to a resistance of 2·33 ohms. It is actuated by the same battery as is used for the microphone circuit. Sparking at the contact is diminished by a condenser of $\frac{1}{20}$ microfarads placed in shunt across the make and break. The armature and its adjusting device are of rather fragile make.

Induction coil.

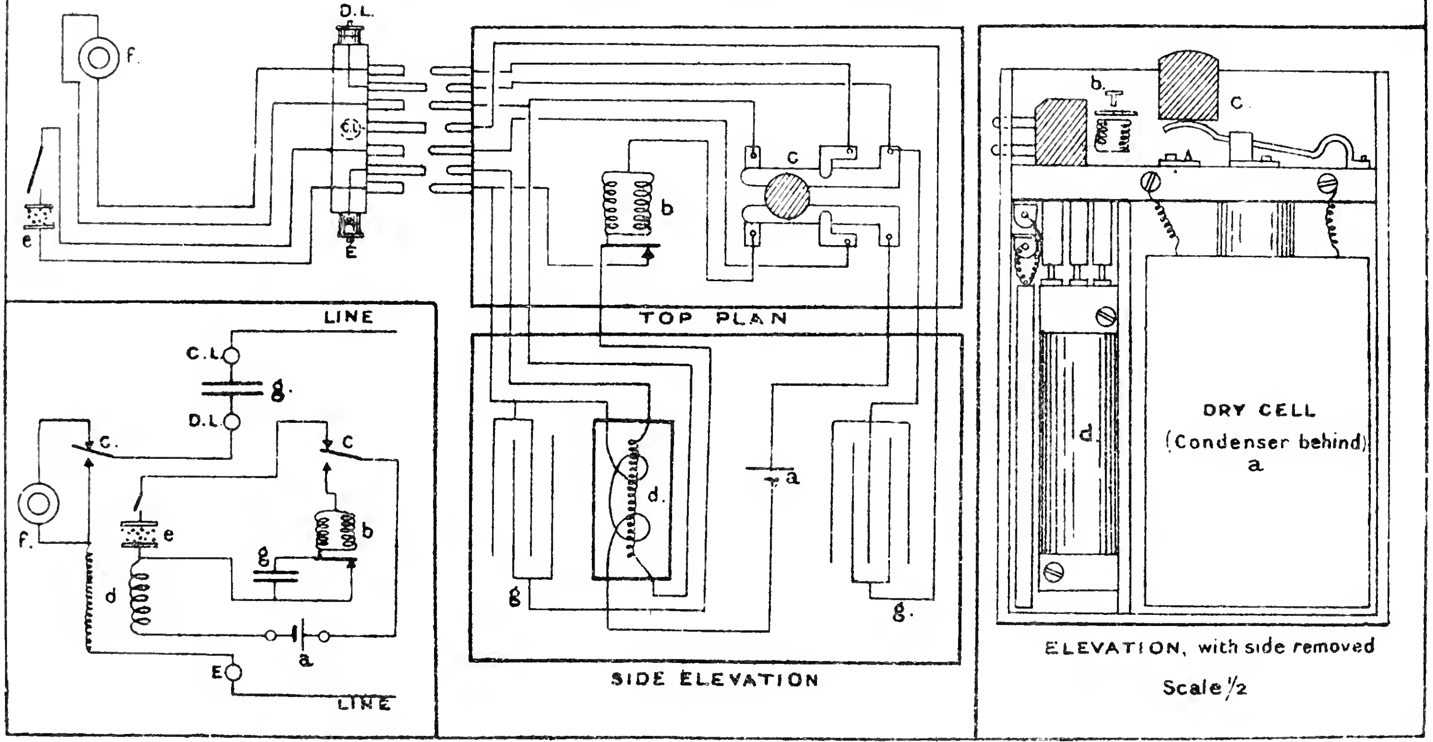
45. The primary is wound with ·0175-inch wire to a resistance of 1·5 ohms, and the secondary with ·007-inch wire to 100 ohms.

---

* Obsolescent.

Chap. XII. Fig. 7.

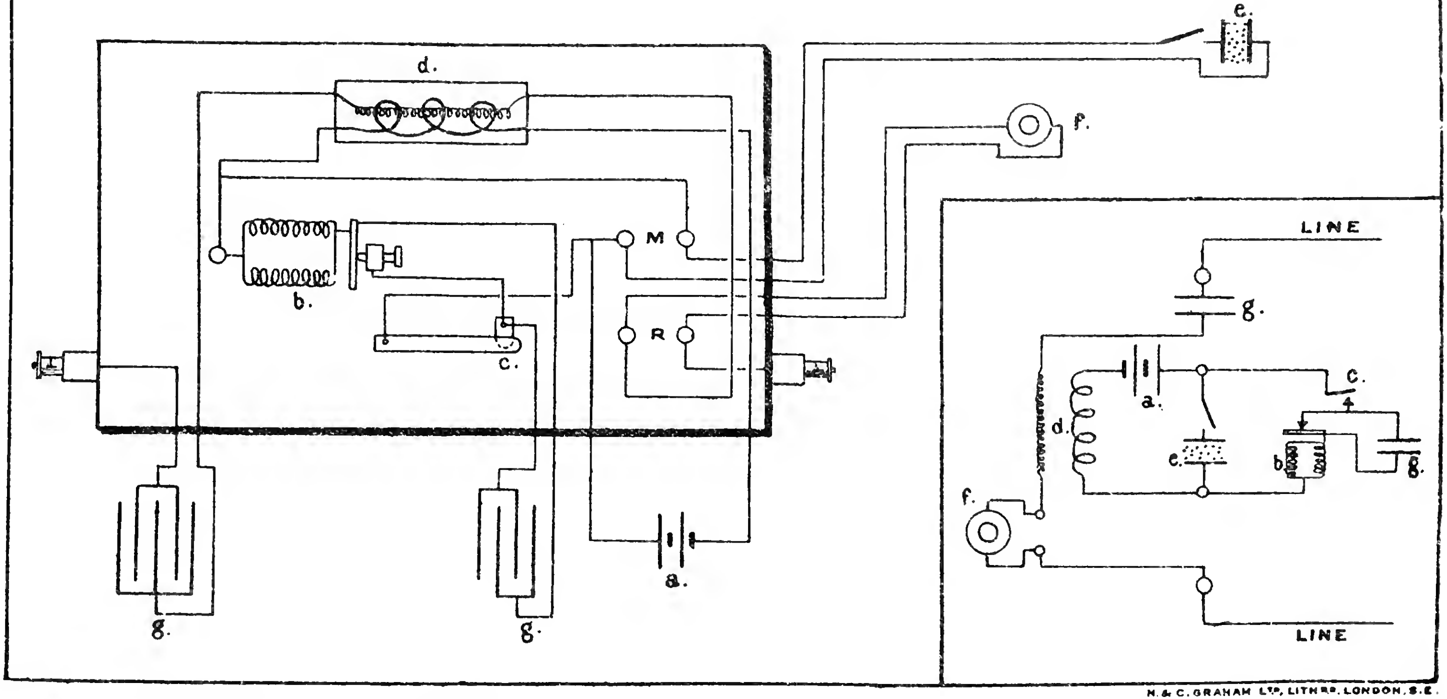
TELEPHONE SET, PORTABLE "D" Mk I.



H & C. GRAHAM LTD, LITHRS, LONDON, S.E.

To Face p. 166.

TELEPHONE SET, PORTABLE "D" Mk II.



H. & C. GRAHAM LTD, LITHRS, LONDON, S.E.

To face p. 167.

Internal arrangements and switches.

46. The only parts of the instrument that are in the line are the receiver and the secondary coil of the vibrator. The receiver is shunted by means of one part of the double switch in the top of the instrument, which is actuated by a press button. A condenser of $\frac{3}{20}$ microfarads is provided in line, which is brought into circuit if terminal CL is used instead of DL.

The primary circuit is divided into two alternative circuits by means of the other part of the switch already referred to; the primary of the induction coil and the battery are common to both. The one includes, in addition the microphone and microphone switch in the handle of the hand telephone; the other the vibrator, whose contact is shunted by a condenser as described above.

The four leads from the hand telephone are made off to a 7-hole plug, which fits to the body of the instrument. This plug also includes the three terminals CL and DL, mentioned above, and E.

Lightning Dischargers.

47. Protection from lightning must be provided separately.

Simple tests.

48. Vibrator :—

Press key, vibrator should buzz. If not, fault may be :—

(1) Weak battery.
(2) Armature out of adjustment.
(3) Disconnection in vibrator, primary, or leads.
(4) Short circuit in vibrator condenser.
(5) Dirty back switch.

Speaking :—

Move microphone switch, with CL and E joined. Clicks should be heard in the receiver. If not, fault may be :—

(1) Weak battery.
(2) Microphone switch dirty.
(3) Front switch faulty.
(4) Disconnection in primary, secondary, or leads.
(5) Faulty receiver.

To test microphone blow on it with CL and E joined, and microphone switch pressed. Sounds should be heard in the receiver.

A battery and detector between CL and DL should give no deflection.

*Telephone set, Portable, D, Mark II.**

Telephone set, Portable, D, Mark II.

49. This instrument has been designed as an improvement on Mark I. The vibrator and its adjusting device are of stronger make, the cells are larger (S size), and a head receiver and watch transmitter form part of the set in place of the hand telephone. Its weight is 5 lb. 6 ozs. For diagram, *see* Fig. 8.

Vibrator.

50. The vibrator is strongly made, with a powerful and accessible adjusting screw. Each coil of the electro-magnet is wound with ·018-inch wire to a resistance of 1·95 ohms ; sparking

---

* Obsolescent.

at the contact is diminished by a condenser of $\frac{1}{50}$ microfarads in shunt.

Induction coil.

51. The primary is of ·0164-inch wire, wound to a resistance of 2 ohms, the secondary of ·0084-inch wire, to a resistance of 75 ohms.

Internal arrangements and switches.

52. The receiver, secondary of the induction coil, and a condenser of $\frac{1}{36}$ microfarads are always in circuit between the line terminals. There are two primary circuits, with the battery and primary coil common to both. The one contains in addition the microphone, and the microphone switch in the edge of the transmitter case: the other the vibrator and its shunting condenser, which are brought into circuit by a switch in the top of the instrument actuated by a push-piece.

Lightning dischargers.

53. Protection from lightning, if required, must be provided separately.

Simple tests.

54. Vibrator :—

Press button, vibrator should buzz. If not, fault may be :—

(1) Battery.
(2) Armature out of adjustment.
(3) Disconnection in vibrator, primary, or leads.
(4) Short circuit in vibrator condenser.
(5) Dirty switch.

Speaking :—

Connect the two line terminals, and move microphone switch. Clicks should be heard in the receiver. If not, fault may be :—

(1) Weak battery.
(2) Dirty microphone switch.
(3) Disconnection in primary, secondary, or leads.
(4) Faulty microphone.

To test microphone blow on it, with microphone switch pressed, and line terminals short circuited. Sounds should be heard in the receiver.

A battery and detector between the line terminals, or between the left line terminal and the left terminal marked R. should give no deflection.

Telephone set, Portable, D, Mark III.

Telephone set, Portable, D, Mark III.

54A. This instrument has superseded the Mark II. The important improvements in the Mark III. are :—

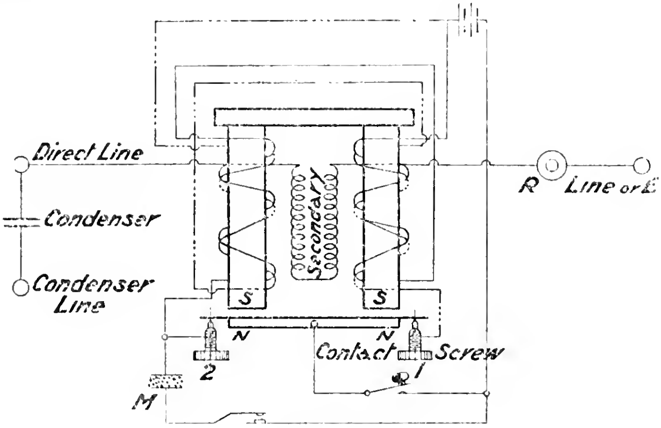
(*a*) An adjustable key for transmitting instead of a button.
(*b*) A combination polarized buzzer and induction coil which has an oscillating armature capable of fine adjustment.
(*c*) A telephone, hand, D, Mark III (telescopic), with pressel switch in addition to watch receiver with bonnet.
(*d*) The buzzer, condenser, and two cells are contained in an ebonite case.

(*e*) The line, earth, and condenser terminals are mounted outside the ebonite case.

(*f*) One condenser instead of two, the condenser being placed in the line circuit.

The brass base of the ebonite case is connected to the earth terminal, which enables the instrument to make earth when placed on the ground without an earth pin.

The whole is contained in a leather case of two compartments, one taking the telephone hand and head receiver, the other the instrument.



Constants.

Current required, 55 m.a. to give a good note in receiver through 10,000 ohms, line R.

Resistance of each primary winding 3·2 ohms.

Resistance of each secondary winding, 62 ohms.

Gauge of primary, 29 S W.G.

Gauge of secondary, 35 S.W.G.

The armature and cores are magnetized by a permanent magnet, one end of which forms the yoke-piece of electro-magnet, and extends to the front face of armature.

The adjustment of the buzzer is made as follows :—

Withdraw both contact screws. Advance No. 1 contact screw until a good note is obtained, then tighten clamping screw. Advance No. 2 contact screw until keenest note is found, clamping as in No. 1.

Each limb of the electro-magnet is wound with three coils, these three coils being each in series with the corresponding coil of three wound on the other limb.

The three coils are one secondary and two primaries.

One primary forms part of the microphone circuit, and with the secondary forms the "induction" coil for speaking.

When the key is pressed each primary in turn energizes the electro-magnet according to which tongue of the armature is against its adjusting stop.

Telephone sets, Phonopore.

Telephone sets, phonopore.

55. This instrument is used on railway circuits, for telephone working on a telegraph line. It is type "R.E." of the Phonopore Company, and patterns vary according as the Company make slight improvements and alterations. It includes two phonopore receivers, and a special "hooter" for calling, but no battery. For diagram see Fig 9.

Vibrator.

56. In the earlier patterns the induction coil is used to actuate the vibrator. In the later patterns a separate one is provided. The vibrator is specified to give clear and audible signals when short-circuited by a resistance of 30 ohms, with a low resistance battery of 5 cells. The spark is shunted by a condenser.

Induction coil.

57. The induction coil is of the ordinary type with a secondary having a resistance of 150 ohms.

Receivers.

58. The receivers are wound on the phonopore principle with two coils, the inside of one being connected to one terminal, and the outside of the other to the other terminal. In consequence the actual resistance between the two terminals is several megohms, and the two conductors act as a small condenser.

It appears that the capacity of these two windings is so small that ordinary E.M.Fs due to induction are insufficient to affect the diaphragms, whereas speaking currents have sufficient E.M.F. to do so. The effect is that inductive disturbances are to some extent eliminated.

Hooter.

59. A receiver of the Collier-Marr type is provided as a loud call. This is a double-pole receiver, in which only one coil is used. This coil, with its core, is altogether detached from the magnet, the latter being used to polarize the core. The coil is fixed in a central block of ebonite, and two soft iron diaphragms are clamped very close to the two ends of the core. The two magnet poles are fixed in contact with two adjusting screws brought very near to the outer faces of the diaphragms. The trumpet communicates with the diaphragms by small holes.

Internal arrangements and switches.

60. Three positions must be considered :—

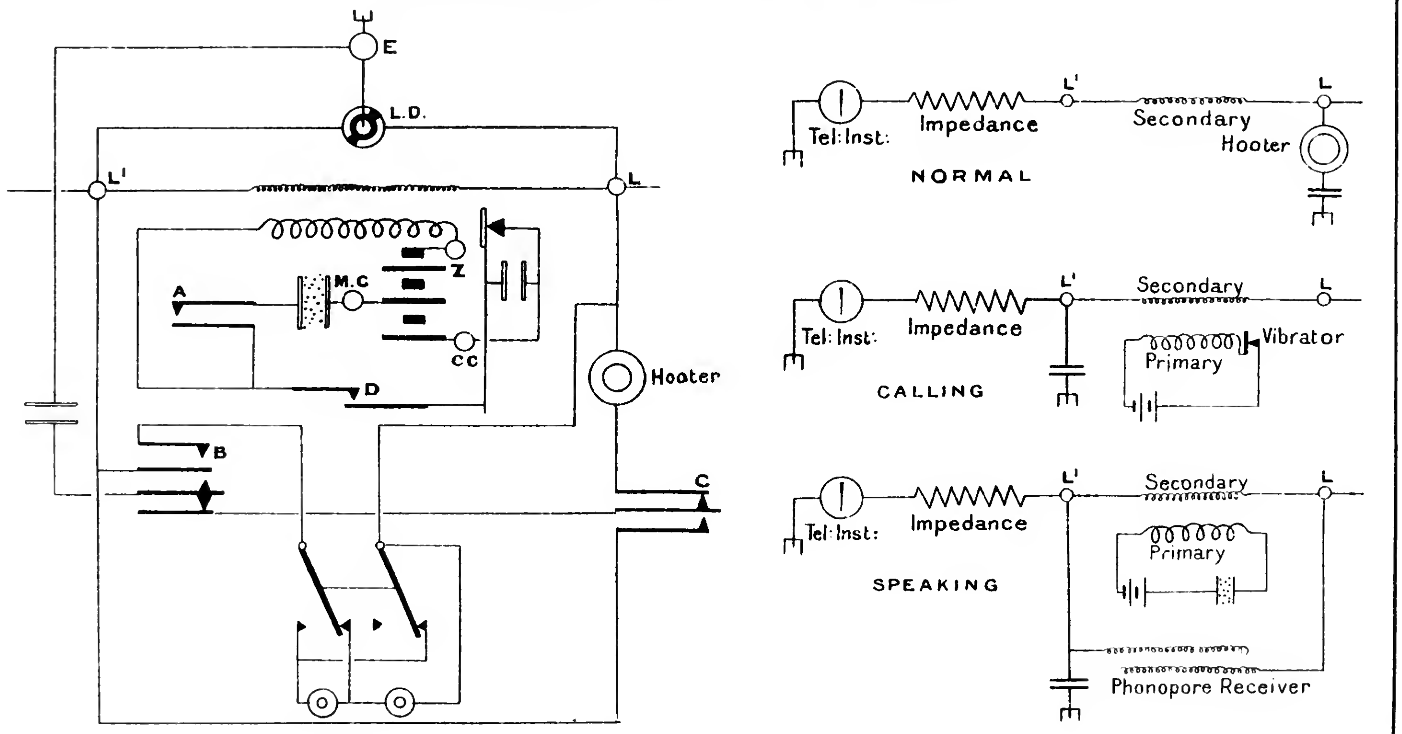
(*a*) Receiver on hook and key at rest.
(*b*) Receiver on hook and key depressed.
(*c*) Receiver off hook and key at rest.

In addition to these there are in the earlier patterns a switch for placing the receivers in series (switch, left) or parallel (switch, right) as required.

(*a*) L and L^1 are directly connected through the secondary coil. The hooter is joined to L, and is in this case connected to earth through the top part of the key switch (*c*), the bottom part of the hook switch (B), and a 1-microfarad condenser. It is then in a position to receive a call.

(*b*) Here the hooter is dis, the top part (C) of key switch being pressed, and putting earth through the condenser and the

TELEPHONE SETS, PHONOPORE



H & C GRAHAM LTD. LITHRS. LONDON S.E.

To face p 170

the bottom part of hook switch (B) to L^1 instead of to hooter. The bottom part of hook switch (D), which is also pressed, completes the local vibrator circuit through the primary coil. This is the calling position.

(*c*) When the receiver is off the hook the top part of hook switch (A) completes the local microphone circuit through the primary coil, and the bottom part (B) connects the receivers in shunt between L and L^1, L^1 still being to earth through the condenser. This is the speaking position.

External connections.

61. At a terminal station a "Coil, compensating," should be inserted in the line between the phonophore and the telegraph instrument, as an impedance coil. It will be noticed at once that this is practically the same arrangement as is described in Chap. XV for the vibrator and separator. At an intermediate station the instrument is joined up in leak, L being joined to line, and L^1 left disconnected. Intermediate telegraph instruments should be shunted by a "carrier."

Carrier.

62. The carrier consists of a wooden reel on which are wound inductively two coils of ·009-inch wire, each coil being of 241 ohms resistance. Each coil is terminated on two small brass plates on the opposite cheeks of the reel, one end of each coil is connected to a stout leading-in wire, which are in turn connected to two terminals on the outside of the containing case. The capacity of the carrier is about ·091 microfarad.

Lightning dischargers.

63. The two lines, L and L^1, are brought to the two sides of a carbon plate protector.

Simple tests.

64. *Calling.*—With press button pressed, and hook switch *up*, a call should be heard in the receivers. To hear your own call in your own hooter it is necessary to actuate the bottom part (D) of press button switch only, hook switch *up*.

Speaking.—Move hook switch up and down, clicks should be heard in the receivers. To test microphone blow into it, with hook switch up—sounds should be heard in the receivers.

Name of Telephone Set.	Generator.			Bell.	Induction Coil.		In circuit when			Pattern of dry cell.	Weight.	Pattern of extension bell.	Pattern of hand tel.	Remarks.
					Primary.	Secondary.								
	Number of Magnets.	Res.	Res. through which it will ring own bell.	Res.	Res.	Res.	Calling.	Receiving call.	Speaking.					
Office, Mark II ...	3	700	12,000	140	2·6	290	Generator bell.	Bell	Receiver, secondary.	Any	—	Q series.	A.	Obsolescent.
Office, Mark III ...	4	500	25,000	1,000	1·2	76	Generator	Bell	Receiver, secondary.	Any	—	R parallel.	A.	
Wall	3	—	20,000	300	—	—	Generator bell.	Bell	Receiver, secondary.	Any	—	Q series.	Special or A.	
Portable A ...	—	500	12,000	100	0·5	185	Generator bell.	Generator bell.	Receiver, secondary.	A.	40	—	A.	
Portable B ...	—	500	6,000	120	0·8	160	Generator bell.	Generator bell.	Receiver, secondary.	P.	18	—	B.	Obsolete.
Portable C, Mark I	—	500	12,000	200	1·6	70	Generator bell.	Bell.	Receiver, secondary (bell).	P.	18	—	C., Mark I.	Obsolescent.
Portable C, Mark II	4	700	12,000	1,000	1·5	75	Generator (bell in parallel).	Bell.	Receiver, secondary (bell in parallel).	P.	20	—	C., Mark II.	
Portable D, Mark I	—	2·33 (Magnet)	—	—	1·93	75	Secondary	Receiver, secondary.	Receiver, secondary.	Special	5 lbs. 10 ozs.	—	D.	Obsolescent.
Portable D, Mark II	—	1·95 (Magnet)	—	—	2·0	75	Secondary receiver.	Secondary receiver.	Secondary receiver.	S.	5 lbs. 5 ozs.	—	—	obsolescent.
Portable D, Mark III.	—	—	—	—	3·2 each	6·2	Secondary receiver.	Secondary receiver.	Secondary receiver.	S.	8 lbs. 5 ozs. (complete in case).	—	D., Mark III.	

CHAPTER XIII.

THE TELEPHONE EXCHANGE.

1. The requirement of a complete telephone system is that any office on the system can "call up" and converse with any other office on the system, with the minimum of trouble, and without disturbing any third office. Connecting up a number of telephones on one circuit does not generally meet the case, as, apart from the fact that any office on the line can interrupt a conversation, the number of telephones that can be connected to one circuit is limited. A code of rings has to be arranged for the different offices, and it is difficult to distinguish between, say, five and six rings. It may be considered, therefore, that more than four, or at most six, should not be joined to one circuit.

Intercommunication system.

2. There are two methods of arranging for intercommunication between a number of offices. If a circuit is brought from every office on the system to every other office with which it may require to communicate, and arrangements are made by which any of these circuits can be connected at will to the office telephone, the requirements are met. This method, however, entails the erection of a very large number of wires, and is only suitable for use when the offices are all close together (as in a block of offices) and when the number of offices is small. It has the advantage, however, that no exchange attendant is required. This system is called the "Intercommunication system," and instruments containing suitable switches for connecting the telephone to the different lines, are made by many manufacturers, but they are not used in the service and will not be further considered here.

Exchange.

3. The method usually adopted in the service is by a telephone exchange which consist in bringing a circuit from each office to a central position, and connecting these circuits to a suitable switchboard. One or more exchange operators are then required to make the necessary connections at the switchboard.

Requirements of switchboard.

4. The following requirements must be provided for at the switchboard :—

(i) Each station must be able to "call up" and speak to the exchange, independently of the other offices.

(ii) The exchange must be able to ring up and speak to any station independently of the other offices.

(iii) It must be possible to connect the line from any station to that from any other station, and this connection must be independent of all other connections and circuits.

(iv) The offices must be able to indicate to the exchange when a conversation is finished, and the connection between the offices no longer required.

(v) The exchange must be so arranged that the above can be carried out with the minimum expenditure of trouble, and therefore time, on the part of all concerned.

(vi) The switchboard itself must be as simple as possible, and not liable to get out of order.

In addition to the above, arrangements should be made for rapidly testing the circuits; these arrangements may be included as a part of the switchboard, but usually a testboard is provided separately (*see* Chap. XVIII).

Unfortunately requirements (v) and (vi) above are not easily combined, and the simpler the operating the more complicated the switchboard.

In large exchanges (v) is more important than (vi), as in such cases skilled linemen are available for maintenance; on the other hand (vi) is of great importance in the field and for portable exchanges, while (v) is not so important owing to the small number of offices usually connected to such an exchange.

Junction lines.

5. Where, owing to the large number of subscribers to an exchange system, or owing to the position of their offices, it is necessary to connect them, some to one exchange and some to another, circuits must be provided between the exchanges to enable the offices on one exchange to communicate with those on the other exchanges. Such circuits are called "junction" circuits. The multiplication of exchanges is to be avoided where possible, but is sometimes inevitable owing to the expenses involved in connecting all the offices to one place. Exchanges can be made for 10,000 subscribers, but such large switchboards are never required for military purposes.

Trunk lines.

6. Where connections are required between two telephone systems the lines between the exchanges are called "trunk" lines, the difference between trunk and junction circuits being chiefly one of length. In England all the trunk lines are owned and worked by the Post Office.

Patterns of switch-boards.

7. There are very many different patterns of switchboards in use, and it is beyond the scope of this book to attempt to describe them all. The methods of calling up, &c., will first be described generally, and then the details of some switchboards that are likely to be met with; if these are understood it should not be found difficult to understand the construction and method of operating other patterns.

Methods of calling.

8. Visual calls are always adopted in exchange working, though an audible call is usually arranged so that it can be used as well, if required, *i.e.*, during hours when the exchange

is not busy enough to necessitate an operator being constantly on the look out for calls. This audible signal usually takes the form of a battery ringing bell, the visual indicators acting as relays and closing a local circuit. Only one such bell is, as a rule, provided for the exchange, this bell therefore only indicates that some office has called and does not show which. In large exchanges a "pilot" signal is also provided for each section of the board, this signal operating as long as any call or clearing signal on that section has not been attended to.

Drop shutter line indicator.

9. The indicator adopted in most service exchanges at the present date (1907) is illustrated in Fig. 1. It consists of an electro-magnet with a pivoted armature, A, to which is attached a light lever, D, the weight of which holds the armature away from the core of the magnet. The lever terminates in a detent, which holds up a flap, S. When a current passes through the coils the armature is attracted, and the lever attached to it lifted. The flap, S, then falls forward by its own weight and reveals the number of the calling office, which is painted on the indicator behind the flap. When the flap falls it presses the light spring, B, against the contact screw, C, this contact completes the circuit of the bell. As all the springs, B, and all the screws, C, are connected together, any indicator falling will ring the bell until it is replaced. The shutter is replaced by hand. One indicator is provided for each line connected to the exchange, and the coil of the electro-magnet is normally connected to its line so that when the office rings up either by a generator or by a battery the shutter drops and gives the necessary signal to the exchange operator.

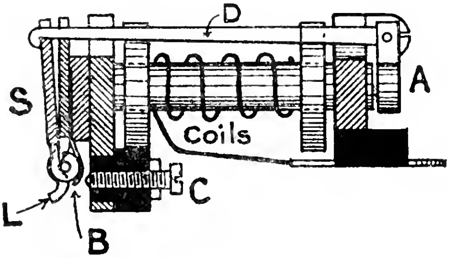


FIG. 1.—Drop Shutter-line Indicator.

Switchboard Telephone Exchange, 12-line, Field.

10. The Mark I field switchboard is arranged for circuits working with an earth return, and cannot be used with metallic circuits. This simplifies the board, and is sufficient for all ordinary field requirements, as there is seldom time available to run metallic circuits. The construction of the switchboard

is shown in Fig. 2. The lines are attached to the terminals at the top of the board. Each terminal is connected to one of 12 vertical brass bars. Behind these bars are five horizontal brass bars, and by means of pegs any horizontal bar can be electrically connected to any vertical bar, in much the same way as in the "Commutator, telegraph" (Chap. XVIII, para. 4). The four upper horizontal bars are for switching purposes, and the fifth is connected to a telephone set (T) for the operator's use. Each terminal is also connected through a line indicator, similar to that described in para. 9, to a short vertical bar below the one already mentioned, and behind these short vertical bars is another long horizontal bar connected to earth. The pegs are normally in the bottom holes, thus connecting each line through its indicator to earth.

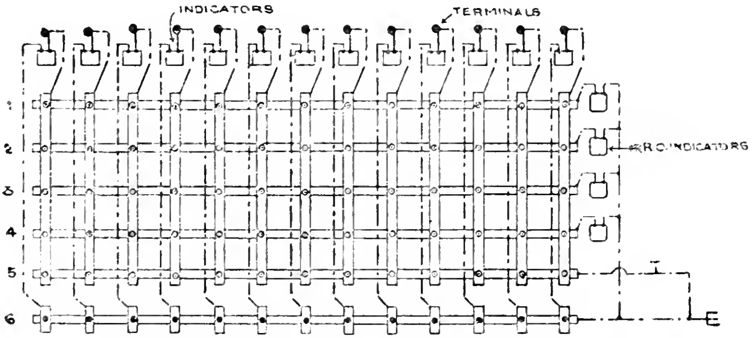


FIG. 2.—Switchboard, Telephone Exchange, 12-line Field, Mark I.

Method of operating.

11. The method of operating is as follows:—When a station rings up the current passes through the line indicator coils to earth, causing the shutter to drop. The operator then removes the corresponding peg from the lowest hole, and places it in the hole immediately above. This connects the line to the operator's instrument, and he then speaks to the office calling and ascertains which station is wanted. He then places the pegs of the two offices in holes in the same horizontal row (any of the four top rows will do provided it is not already in use). The two stations are then directly connected, and can call up and speak independently of the other lines, and the two line indicators are disconnected.

Each of the four top horizontal bars is connected to earth through a "ring-off" indicator. These ring-off indicators are similar to the line indicators, only of higher resistance and greater self-induction. This self-induction (as explained in Chap. I, para. 61) prevents the speaking currents from leaking to earth, but a battery current, or one of low frequency such as is furnished by the generator of a telephone set, will pass through it and drop the shutter. The object of this indicator is to enable the office to inform the exchange when the conversation is finished. The usual procedure is for the exchange operator to inform the station originating the call that the line required is disengaged before putting him through; the calling station then rings up the other station. It will be noticed that when a station is ringing in this manner the ring-off indicator will drop, and to avoid this being taken as the signal to disconnect, it is usual to arrange that the clearing signal is given by four distinct rings; these rings can be distinguished from a steady ring by the operator, and he disconnects the lines and replaces the pegs in the bottom row of holes.

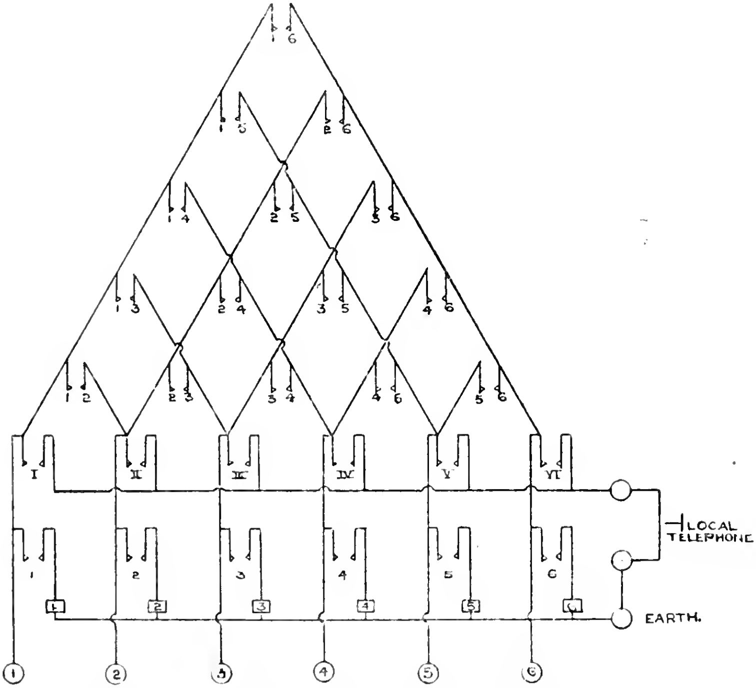


FIG. 3.—"Pyramid" Type Switchboard for Earthed Circuits.

If the exchange operator wishes to call an office, he removes the peg corresponding to that office from the bottom hole to the next one above, and rings up with his own instrument.

The indicators are provided with contacts to complete a local bell circuit when the shutters drop.

It should be noticed that if the resistance of the exchange earth is high, a portion of a current from a station ringing up may pass along one of the other lines to its earth, thus dropping one or more indicators and ringing up one or more other offices. It is thus very important for single line exchanges that the earth at the exchange should be as good as possible.

This pattern switchboard must always be used in a vertical position.

The details of the indicator are given in para. 21.

Mark II. 12. The Mark II field switchboard was introduced in 1906, and is similar in construction to the Mark I. It is rather more compact, and the indicators are constructed to work in any position. A "Discharger, lightning, bobbin" has been added for each line, and a local bell is included in the board, together with a plug for disconnecting it when not required. A separate telephone is required for the operator and a local battery for the bell, as in the Mark I.

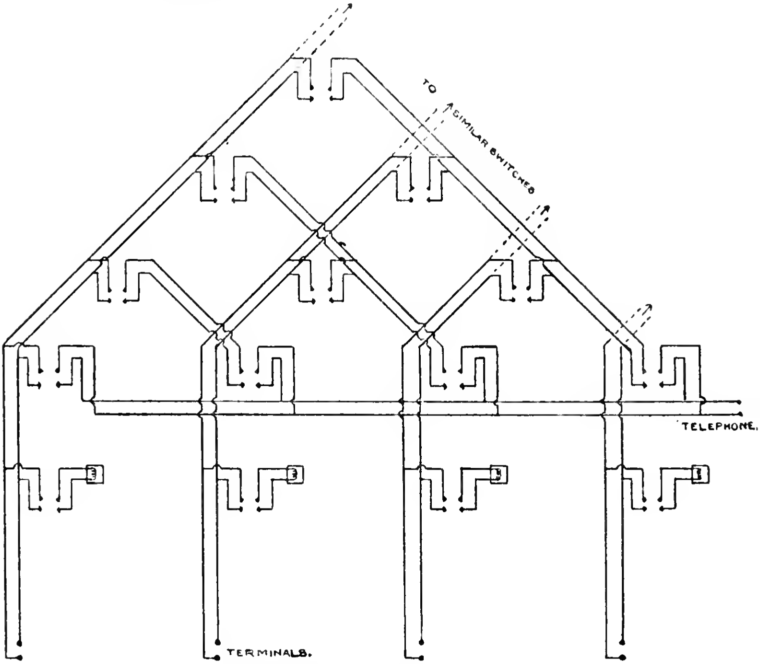


FIG. 4.—" Pyramid " Switchboard for Metallic Circuits.

It is probable that a new pattern will shortly be introduced, in which flexible cords will be used for making the connections. This method of construction enables the weight to be considerably reduced, though slightly at the expense of strength and simplicity.

" Pyramid " switchboard. 13. A simple form of switchboard suitable for small exchanges, of not more than 12 or 15 lines, is shown in Fig. 3.

The lines are connected to the terminals ①, ②, ③, &c., which are connected to the left contacts 1, 2, 3, &c., and to the other contacts as shown. The right contacts 1, 2, 3, &c., are connected through line indicators to earth. The contacts I, II, III, &c., are connected to the terminal for the operator's instrument, which instrument may be separate, or form part of the switchboard. The two contacts of each pair can be connected by a peg, or by a suitably arranged key. The method of operating is as follows:—

When a station calls, the ringing current flows through contacts 1, &c. (which are normally connected), and the line indicator to earth. The peg is then removed from 1 to I, this connects line 1 to the operator's instrument. If connection is then required to (say) station 3, the same peg is placed in the hole 1, 3. This connects lines 1 and 3. The peg in 3 remains, thus leaving the line indicator of line 3 in leak to earth, and ready to act as a ring-off indicator. This type of switchboard can also be made for metallic circuits as shown in Fig. 4. In this case the switches are slightly more complicated, as two pairs of contacts have to be closed by each peg or key. The disadvantage of this type of board is that the size of the board increases very rapidly as the number of lines for which it is constructed increases, and it soon becomes unwieldy.

Larger Switchboards.

Jacks and cords.

14. In all switchboards constructed for more than a few lines, the connections are made by "jack switches," plugs, and flexible cords.

The "jacks" are connected to the lines and indicators (one for each circuit), and the plugs to the cords. The usual form of jack for metallic circuits is illustrated in Fig. 5. A, B, 1 and 2, are springs; the two lines of a metallic circuit are permanently connected to the springs A and B, and the line indicators to the springs 1 and 2. Normally, A is in contact with 1, and B with 2, hence the line indicators are connected across the lines. When a plug is inserted, the springs A and B are forced away from 1 and 2 (Fig. 6) and A and B make contact with the two parts D and E of the plug. D and E are insulated from each other, and are permanently connected to the two conductors of

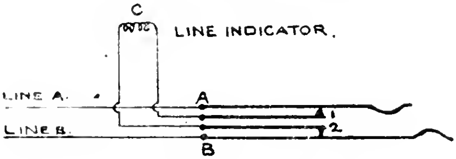


FIG. 5.—"Jack Switch" for Metallic Circuit.

the cord. When a plug is inserted in a jack, the line indicators are entirely disconnected, and the lines are joined to the cords. If there is a similar plug at the other end of the cord, any two lines can be connected together.

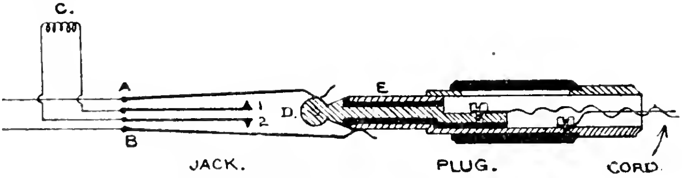


FIG. 6.—Jack with Plug inserted.

Operating keys.

15. In practice, the cords, each with one plug only, are arranged in pairs, and connected to keys by means of which they can be joined in one of the following ways :—

(1) Connected through, with ring-off arrangement in leak (for speaking through).
(2) Connected through, with exchange operator's instrument in leak (for speaking to the exchange).
(3) Connected to the switchboard generator (to enable the exchange to ring up an outside office).

The arrangements of these keys vary in different switchboards.

The cords in most cases pass through the board, and are kept taut, but free for use, by means of small weighted pulleys, running one on each cord.

Clearing signals.

16. There are two main methods of arranging the clearing signals on metallic circuit switchboards. In the first method the station both calls the exchange, and rings off, by sending a current along one line of the circuit and back by the other, the connections when one station is through to another being shown in Fig. 7. When the circuit is in this condition it will

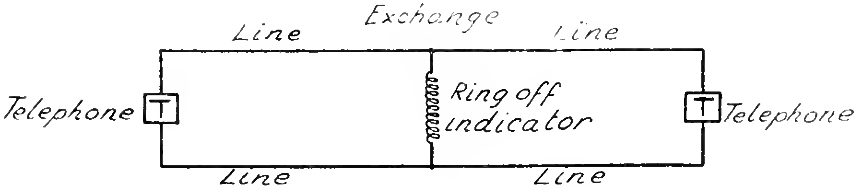


FIG. 7.

be seen that if either station rings, it will not only ring the bell at the other station but will also drop the ring-off indicator. This means in practice that the exchange operator calls the stations required, and clears as soon as either station rings. This arrangement is not very suitable for military work, where it is considered advisable to enable stations, when once connected, to ring each other independently of the exchange.

Ring-through system.

17. In the other method, which is adopted in all military metallic circuit exchanges, the exchange and the far station are both called as above described, but the clearing signal is sent along one line (or both lines in parallel) returning by earth. This latter current may be furnished either by the generator of the station instrument or by a battery at the exchange. The two lines are connected at the switchboard by "bridging coils," which are wound so as to have a high resistance and self-induction, so as not to interfere with the speaking; the centre point of these coils is connected through the ring-off indicator to earth. Fig. 8 shows the connections when two offices are connected at the switchboard; P shows the connections at a station when it is ringing the other station; and Q the arrangement when a station is ringing off. The necessary alterations in the connections at the stations are made by means of a press button or "Key, ring-off," described in para. 29. It will be seen that when P rings, a portion of the current will flow through the bridging coils and a portion through the instrument at the far end, but that none will flow through the ring-off indicator; a current from Q will flow through the ring-off indicator, but not through the instrument at the far end. We have thus an arrangement by which, when two stations are connected at the exchange, either station can ring the other independently of the exchange, or ring the exchange without affecting the other station.

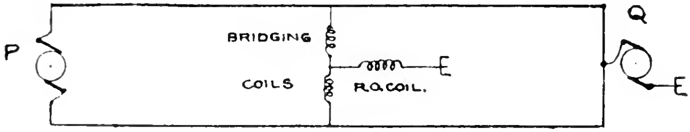


FIG. 8.

Fig. 9 shows the connections for a ring-off signal sent from a battery at the exchange, this method has the advantages that it is only necessary for a station to press a button to send the clearing signal, and that an earth fault on the line is at once made evident by the ring-off indicator refusing to stay up; it has the disadvantage that it makes the arrangements for junction working rather more complicated.

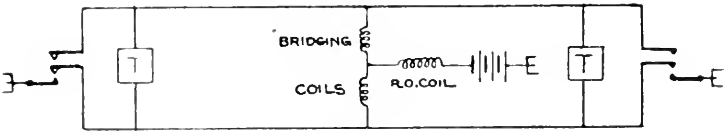


FIG. 9.

Fig. 10 shows the connections when only one line is earthed at the station sending the clearing signal.

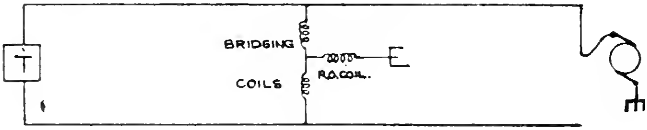


FIG. 10.

Switch-boards, telephone exchange, metallic circuit, Mark II.

18. There is now no sealed pattern of telephone switchboard in the service for garrison requirements, but a consider-

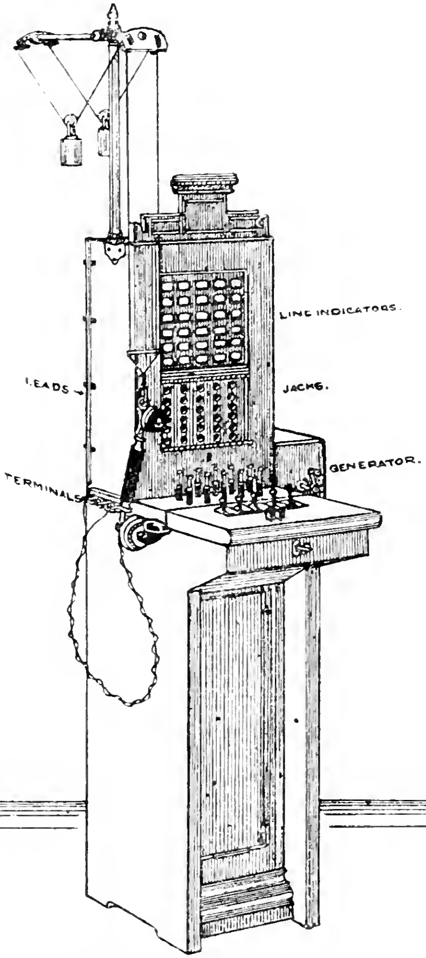


FIG. 11.—Switchboard, Telephone Exchange, Metallic Circuit, 25-line, Mark II. This has now been superseded by the Mark III which is a commercial pattern.

able number of "Switchboards, telephone exchange, metallic circuit," 50-line and 25-line are in use, and the Mark II pattern board will be a convenient one to describe in detail. The 25- and 50-line boards are generally similar. An illustration of the 25-line board is given in Fig. 11.

The switchboard is arranged in the form of a cabinet, to stand on the floor. The upper panel of the front carries the line indicators, arranged in five horizontal rows. Below this panel is one containing the jacks, also arranged in five rows, so placed that the jack of any line occupies the same position on the lower panel as the line indicator of the same line on the upper panel. Below these five rows of jacks is a sixth similar row, the use of which will be explained later; these jacks are only required in special cases.

Below the panels is a horizontal shelf projecting from the board, and placed at a convenient height for an operator seated in front of it. The cords pass through this shelf, and the plugs, when not in use, project vertically above the holes through which the cords pass. There are ten pairs of cords in the 50-line board and five pairs in the 25-line board, arranged in two rows, the two plugs of each pair being placed one in front of the other. Behind each pair of plugs, on the face of the board, is the corresponding ring-off indicator, and in front of each pair is the corresponding speaking or "Dewar" key; there are thus ten ring-off indicators and ten Dewar keys on the 50-line board. The ring-off indicators in the 25-line board are on the same panel as the line indicators, in the 50-line board they are below the jacks, and behind the plugs. There are also two "ringing" keys on each board, and one generator fixed on the side of the board. A "Telephone, hand A," is suspended from a bracket by a cord and counterweight, so that it hangs in a convenient position for the use of the operator.

The connections of the jacks and indicators are as shown in Fig. 12; the jack has three connections only, the indicator being disconnected from one line only when the plug is inserted, and left permanently connected to the other. This arrangement does not in all cases give such good speaking as the construction with four contacts, and no more switchboards with this pattern jack will be issued. The actual construction of

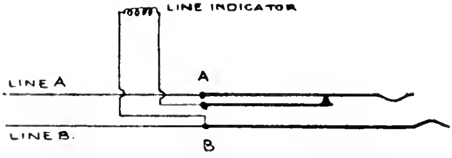


FIG. 12.—Connections of Jack Switch.

the jack and cord is shown in Fig. 13; there are actually five springs, but they are so connected that electrically there are only three.

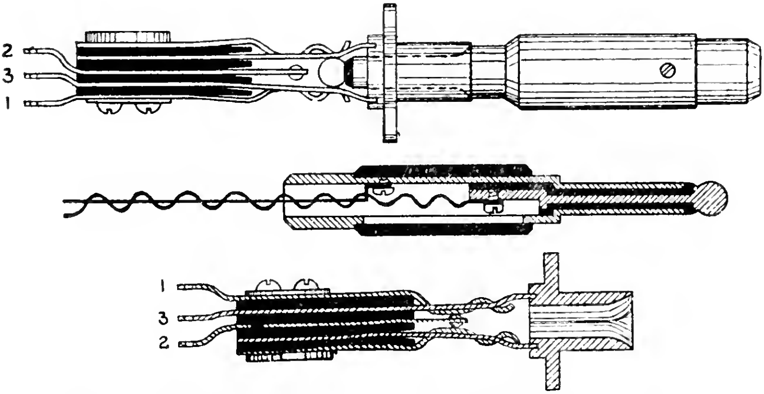


FIG. 13.—Construction of plug and Jack of Switchboards, Telephone Exchange, Metallic Circuit, Mark II.

Connections. 19. The connections of a portion of the board are shown in Fig. 14. The normal connections of the line and its indicator are as shown for line 1. The lines, after passing through a suitable test-board fitted with lightning dischargers, &c., are connected to the jack springs, and so to the line indicator. If No. 1 office calls, No. 1 indicator drops. The operator then inserts a plug (any plug not already in use will do), and pulls the corresponding Dewar key towards him. The connections are then as follows (as shown for No. 12 line). The A line of No. 12 circuit through cord, Dewar key, ringing key, to secondary of induction coil, receiver, Dewar key, cord, and to line B. There is no other circuit, as the second cord of the pair is not in use, and is disconnected. The operator can now speak to No. 12, and ascertain what connection he requires. Suppose he wants No. 23, the operator then inserts the second plug of the pair in No. 23 jack, and replaces the Dewar key. The lines are now connected together, with the bridging coils connected across in leak, and the connections are as shown in Fig. 8, as far as the exchange is concerned. Stations 12 and 23 are now connected together, and can ring each other and speak, without interfering with the exchange or being interfered with. When the conversation is finished, the stations ring off as described in para. 17, and the ring-off shutter falls; the operator then withdraws the plugs, and the connections are thus returned to their original condition. The shutters of the indicators should always be replaced by hand as soon as the connections or disconnections are made. If the operator pulls over the Dewar key when the plugs are both inserted, he can speak with both stations connected to the plugs, as his telephone is then connected across the lines, instead of the bridging coils, he can thus make certain if the stations are properly "through," or if the connection is finished with. If, when the Dewar key is pulled over, one of the ringing keys is pressed and the generator handle turned, a ringing current is sent out to the line connected to the one plug, and if the other ringing key is pressed, a ringing current is sent out along the line connected to the other plug, thus the operator can ring any station at will. One of the two ringing keys rings on the front row of cords and the other on the back row, the Dewar key connected to the cord on which it is required to ring must also be pulled over in each case.

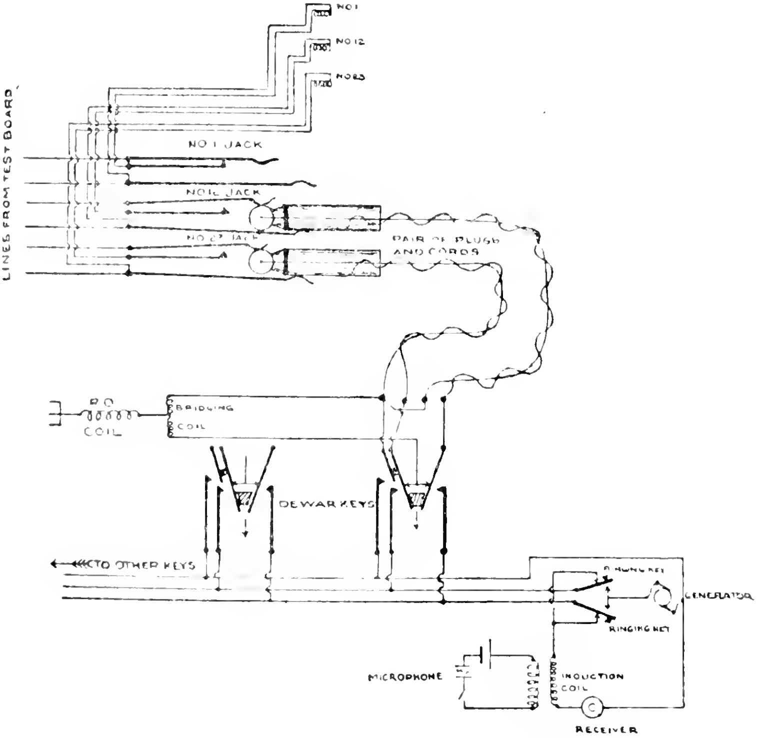


FIG. 14.—Connections of "Switchboard, Telephone Exchange; Metallic Circuit."

The circuits of the local bell are not shown in Fig. 14.

20. The lowest row of jacks, mentioned above, are not connected to any indicators, but are for use as "transfer jacks," or for junction circuits; in the latter case only for junction circuits on which all the work is in the outward direction. Transfer jacks.

Transfer jacks are required when several boards are used in one exchange room, and the cords are not long enough to reach across to the other board with which a connection may be required; in this case No. 1 transfer jack on one board is connected to No. 1 transfer jack on the other, and similarly with as many of the other jacks as may be required. The connections between stations connected to different boards are then made by a pair of cords on each board, the second plug of each pair being inserted in a transfer jack, the operators on the two boards communicating verbally as to the station required and which transfer jack is to be used. This method of transferring connections from one board to another is not suitable when much work of this description has to be dealt with, as it leads to too much talking on the part of the operators. If the number of connections to the exchange is too large for three operators sections to deal with, multiple working should be resorted to, see para. 37.

Details.

21. The line indicators are as shown in Fig. 1, and are wound to a resistance of 100 ohms with single silk-covered wire, 38 S.W.G. The ends are strengthened by using a length of 27 S.W.G. wire. The shutter should drop when a current of 20 milliamperes is passed through the coils. The bridging coils are wound in two parts, each to a resistance of 500 ohms, making a total of 1,000 ohms; they are sheathed in an iron cover to increase the self-induction and to prevent overhearing. The ring-off drops are illustrated in Fig. 15, and are generally similar to the line indicators, only wound with single silk-covered copper wire to a resistance of 1,000 ohms, and covered with a jacket of soft iron to increase the self-induction. The shutters should drop with a current of 7 milliamperes through the coils. The cords are 52 inches long. The primary and secondary coils of the induction coil are wound of single silk-covered wire, 31 S.W.G. and 38 S.W.G. respectively. The former to a resistance of 3 ohms and the latter to a resistance of 250 ohms. The coil ends are strengthened by a length of similar wire, 22 S.W.G. The core consists of a split iron tube. The generator armature is wound with single silk-covered copper wire, 39 S.W.G., to a resistance of 500 ohms, and should ring a 130 ohms resistance bell (Bells, electric magneto, "Q") through an external resistance of 12,000 ohms.

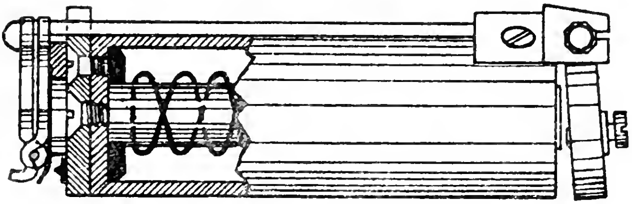


FIG. 15.—Ring-off Indicator.

Apparatus fitted by the Post Office at Home Stations.

Switch-boards, P.O. pattern.

22. The switchboards fitted at home stations by the Post Office are very similar to those just described. The chief

points of difference are as follows. The jacks are of the type with four springs, thus the line indicators are entirely disconnected from the lines when a plug is inserted. The line and ring-off indicators are of the same pattern, and are all

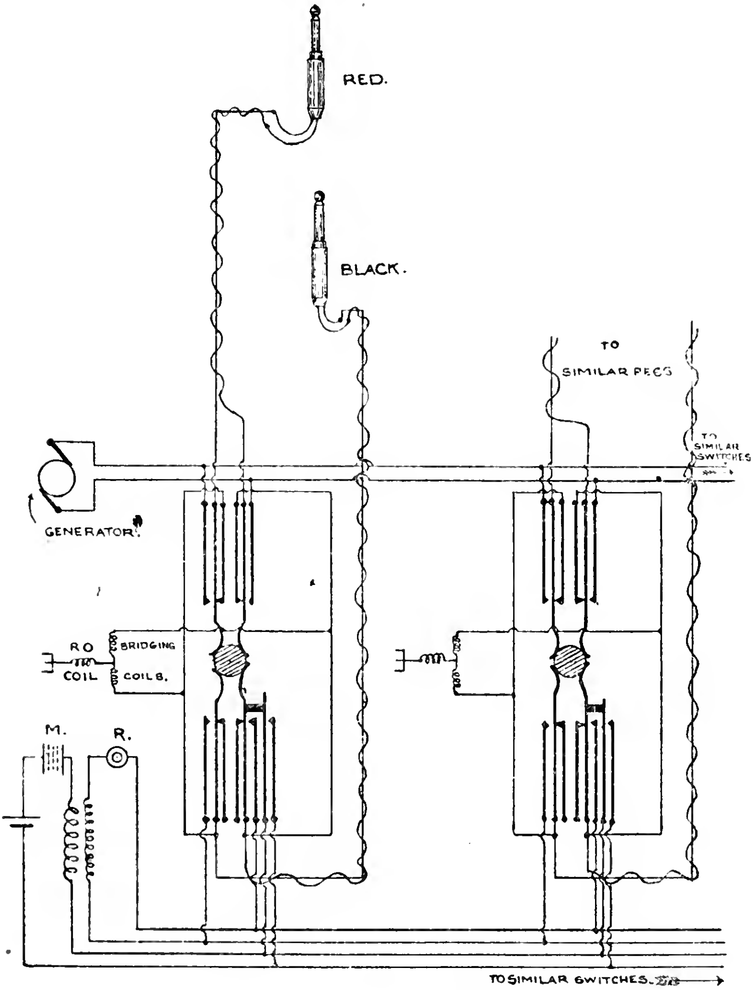


FIG. 16.—Cord Connections of P.O. Pattern Boards.

wound to a resistance of 1,000 ohms. Three position keys are provided instead of the two position Dewar keys, and the ringing keys are omitted. In the central or normal position of these keys the connections are the same as with the Dewar keys, *i.e.*, the lines are "through" with the bridging coils joined across in leak. When the key is pushed forward the lines connected to one of the plugs are disconnected from the bridging coils and the other line and are connected direct to the generator; it is only possible to ring with those plugs which are coloured red (to distinguish them from the other plugs, which are coloured black). When the key is pulled back the lines are connected "through" with the operator's telephone connected across the lines as well as the bridging coils, the operator can thus speak to either station when the key is in this position; placing the key in this position also closes the microphone circuit of the exchange telephone. A diagram of the connections is given in Fig. 16.

P.O. nomenclature of parts.

23. The Post Office nomenclature of the parts used in a switchboard of this pattern and the number of each part used in a 50/50 switch section are given below:—

Bell, trembler, 3-terminal, circular	1
Connector, switch, telephone	1
Coils, bridging, 1,000-ohm	20
Coil, induction, 150/1	1
Cords, red. No. 209	10
" white, No. 209	10
Generator, Bracket, 3-terminal	1
Indicators, N.P., "C," 10/12 (500ω+500ω)	6
Keys, ringing and speaking, Union pattern, 3-position, 14-pt.	10
Pegs, circular, red	10
" " black	10
Pulleys for cords, thin	20
Strips, cross-connection, 5/4	6
" cord-connection, 20-plate, 12½-inch	1
Suspender for microtelephone	1
Switch-springs, 5-pt., 10/10	5
Switch tumbler, 3-amp., bronzed	1
Auxiliary apparatus—	
Microtelephone, with hook	2
Pegs, circular, double	2
Batteries, 2-cell, 6-block, agglom.	2
Battery, Leclanché, 2-cell, No. 1, Cz.	1

"Batteries, Leclanché, G, 2-cell," are the same as the above mentioned. "Batteries, 2-cell 6-block, agglom." and "Telephone, hand, A," can be used instead of "Microtelephone with hook."

P.O. apparatus at telephone offices.

24. The Post Office apparatus fitted in offices connected to the above switchboards is as follows:—

Telephone, P.O., for granular transmitter "C"	1
Transmitter, Deckert	1
Bell, magneto, 1,000-ohm	1
Generator, Bracket, 3-terminal	1
Strip lugs with screws	2
Press-button "D"	1
Receiver, bell, "A"	1
Battery, 2-cell, 6-block, agglom.	1
or	
Telephone table with generator	1
Press-button "D"	
Battery, 2-cell, 6-block, agglom.	1

The equivalent service pattern instruments are :—

Telephone sets, office, Mark II	1
Keys, ring-off, telephone exchange	1
Battery, Leclanché, "G" 2-cell	1
or	
Telephone sets, office, Mark III	1
Battery, Leclanché, "G," 2-cell	1

Indicators combined with jacks.

25. The switchboards recently issued are fitted with combined indicators and jacks. This combination has the advantage that the jack is close to (usually immediately under) its own line indicator, thus making it easier for the operator to select the correct jack when answering a call. It has the further advantage that the action of inserting the plug can be made to restore the indicator mechanically, thus reducing the work of the operator when working the exchange. There are several types of these indicator jacks made.

Ericssen's indicator jack.

26. In the "Indicator jack" made by Ericssen, the signal is given by a metal tube being shot out by a spring when released by the attraction of the armature of the indicator coils. This tube then projects round the hole in which the peg is inserted, and is pushed back by the shoulder of the plug when the latter is inserted. The movement of the tube also serves to close a local circuit for the night bell, and if required, to put the engaged test on the line for multiple working. In boards made by Ericssen, and fitted with these indicator jacks, the ring-off indicators are of the ordinary drop-shutter type, and the shutters are replaced by being knocked up by a lever when the plug drops back into its normal position, the cord passing through a hole in one end of the lever.

"Switch-spring" indicator jack.

27. In the "Switch-spring" combined indicator and jack, made by the British Insulated and Helsby Cables, Limited, and used by the Post Office on their smaller trunk line switchboards, the signal is given by a metal flap falling forward by gravity through a slot in the board immediately above the corresponding indicator. The flap is replaced by the insertion of the plug in the jack. A sketch of this arrangement is given in Fig. 17.

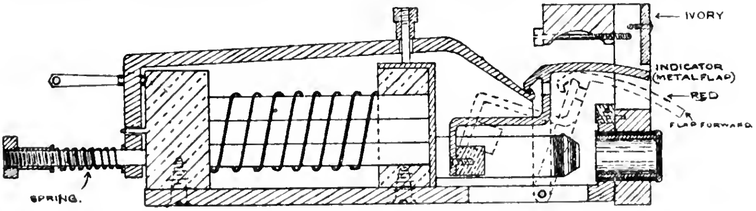


FIG. 17.—"Switch-spring" Indicator-jack.

"Drum jack."

28. The "drum jack" pattern made by the same firm, and used in some of the latest service boards, is illustrated in

Fig. 18. A drum of non-magnetic material is pivoted on its axis in front of the core of the indicator coil, and weighted so that it will rest in either of two positions, shown at A and B of Fig. 18. A portion of the drum is visible through a window in the front of the board, immediately above the jack. When the drum is in its normal position, a portion of the drum is visible, which is coloured black. A piece of iron is let into the drum at one side, and when a current passes through the coil,

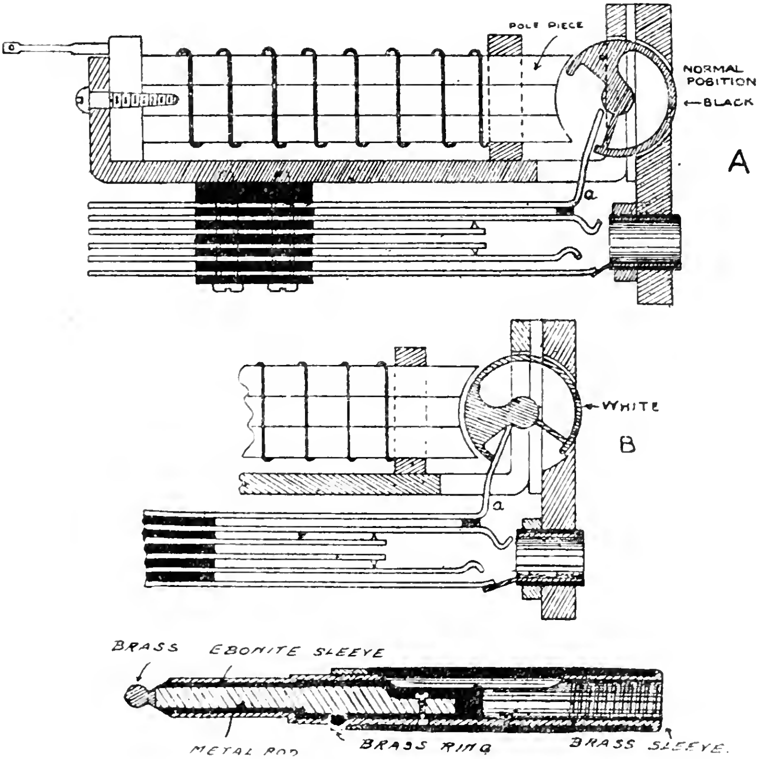


FIG. 18.—Drum Jack and Plug.

this iron is drawn round into the magnetic field, the drum rotating till a portion coloured white is visible; this gives the signal to the operator. When the drum is in this position it makes contact with the spring "a" and completes the circuit for the local bell. When a plug is inserted in the jack this spring is lifted by the plug and in its turn knocks up the drum till it is past the neutral position, when it falls into its normal position, is thus replaced, and the local circuit again broken. The ring-off indicators fitted on these boards are of a similar type, the drum being replaced by moving the speaking key into the speaking position.

Exchange Accessories.

29. The use of ring-off keys has been explained in para. 17. A ring-off key forms part of "Telephone sets, office, Mark III," Ring-off keys.

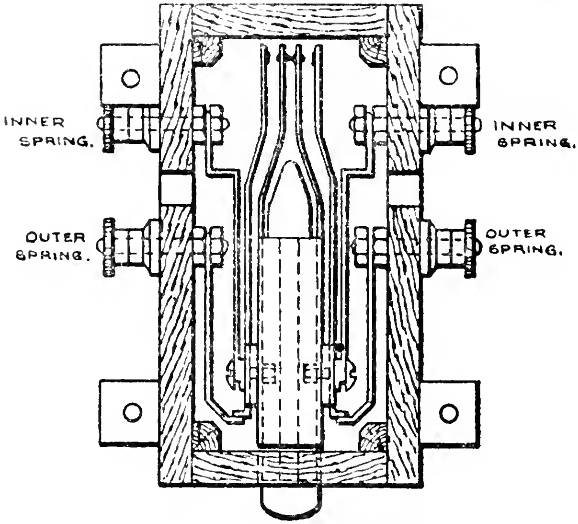


FIG. 19.—Key, Ring-off, Mark I.

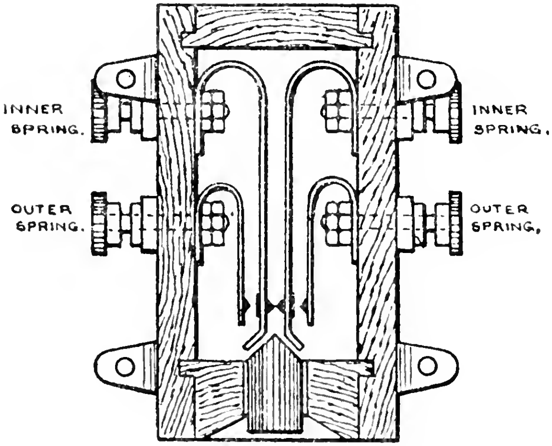


FIG. 20.—Key, Ring-off, Mark II.

but if other service pattern telephones are used with an exchange a separate key is required. The service pattern is known as "Keys, ring-off, telephone exchange," and Marks I and II are illustrated in Figs. 19 and 20; they are electrically similar, and the method of connecting them is shown in Figs. 21 and 22, for magneto and battery ring-off respectively.

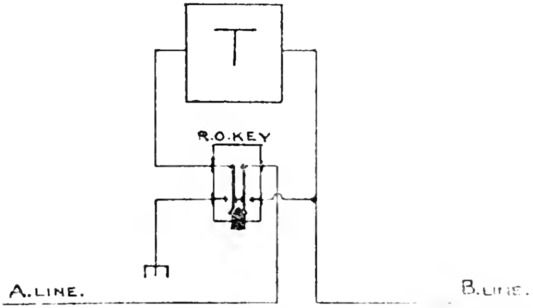


FIG. 21.—Connections of Ring-off Key. (Magneto Ring-off.)

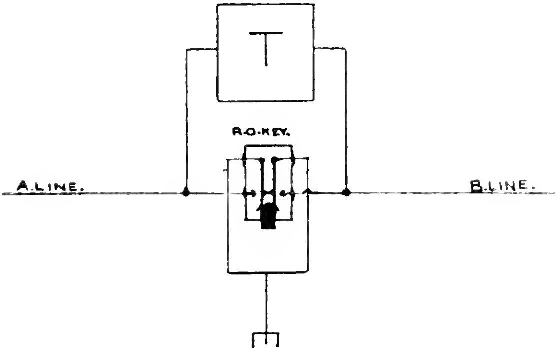


FIG. 22.—Connections of Ring-off Key. (Battery Ring-off.)

Translators. 30. Repeating coils, "translators," or "transformers" are specially wound induction coils constructed with a closed magnetic circuit, and having the two coils of the same resistance. The core is generally made of a bundle of soft iron wires, the wires being bent round the outside of the coils, as shown in Fig. 23. There is no service pattern of this instrument.* It is used in connection with exchanges when it is necessary to connect a single line circuit to a metallic line board. In this case it is not advisable simply to put one of the line terminals of the board to earth, as this is liable to cause overhearing and ring-off troubles. The connections of a translator used for this purpose

---

* Since the above was written it has been decided to introduce a pattern, *see* Chap. XVI, para. 8.

are shown in Fig. 24; the terminal marked C is not required in this case. The translator should be fixed between the test-board and the switchboard, and should be protected from lightning. If a metallic circuit is available for a portion of the line, the translator should be fixed at the end of the metallic portion, and should be protected from lightning if connected to aerial wires; it should be noticed that the translator completely disconnects the line as far as continuous currents are concerned, and consequently portions of a circuit containing a translator cannot be tested with a battery and galvanometer. It will also be seen that the station on the earthed circuit is unable to ring off.

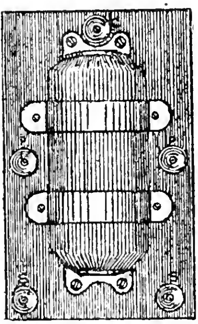


FIG. 23.—A Translator.

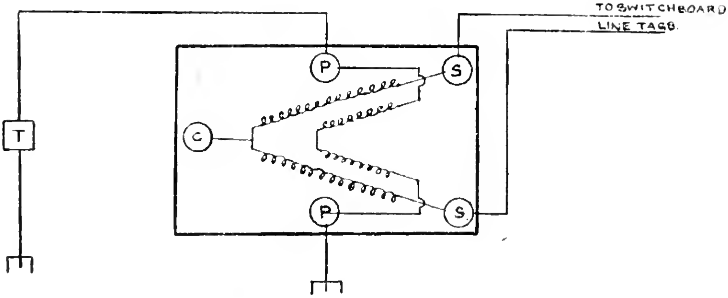


FIG. 24.—Connections of Translator.

Other uses of the translator are given in para. 35, and Chap. XVI, paras. 4 and 5.

Head receivers and breastplate transmitters.

31. In busy exchanges it is advisable for the operators to have both hands free for manipulating the plugs and keys, and this is not the case if a hand telephone is used by the operator. To meet these cases head receivers and breastplate transmitters are used on large switchboards; there is no service pattern for this purpose, but they have been issued in some

cases, and will in future be issued with the larger boards. The cords from the receiver and microphone are usually connected to a four-way plug, so that they can readily be disconnected when not required, and a hand telephone substituted for use at night, or during slack hours.

Pilot signals.

32. In the newer exchanges, "pilot signals" have been provided. These are indicators which are connected instead of the local bell, one for each operator's position, and which restore themselves when a current ceases to flow through their coils. They therefore indicate as long as any line or ring-off signal on the portion of the board to which they are connected has not been attended to. Where pilot indicators are provided, these indicators either act as relays to close the night bell circuit or are joined up in parallel with the night bell. Fig. 25 shows how this can be arranged, and shows the arrangement adopted on boards made by the British Insulated and Helsby Cables, Limited, fitted with their "drum jacks." Similar indicators are sometimes fitted in the generator circuit of each

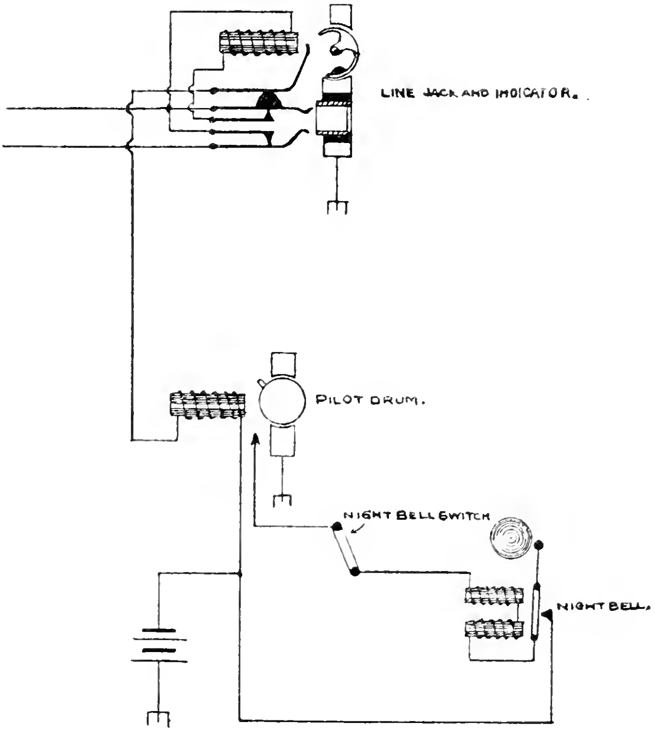


FIG. 25.—Pilot Indicators (Drum Jack Board).

board, to indicate that a ringing current is actually being sent along the line when the ringing key is depressed. Fig. 26, which is a diagram of the cord circuits of one of the "drum jack" exchanges, shows the connections.

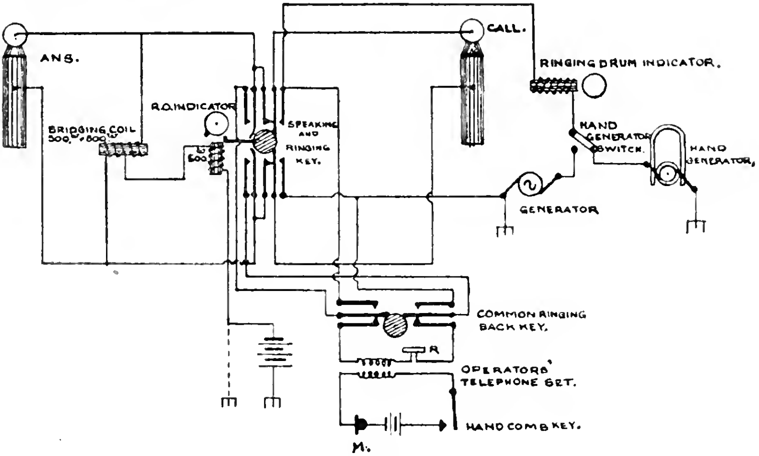
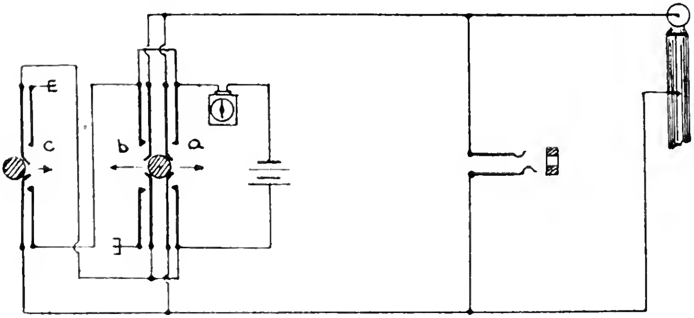


FIG. 26.—Cord Circuit of "Drum Jack" Board.



(*a*) Battery and galvanometer in loop. (*b*) Earthed battery and galvanometer to tip of plug and short spring of jack, ring wire insulated. (*c*) Earthed battery and galvanometer to ring of plug and long spring of jack, tip wire insulated.

FIG. 27.—Test Jack and Plug.

Power-driven generators.

33. In large or very busy exchanges, especially where the operator rings the station that is being called up, it is advisable to have a power-driven generator for ringing purposes. These generators are connected to the generator terminals of the boards. Where they are provided they should be in addition to, and not in substitution for, the hand-driven generators. A suitable switch should be provided for connecting the hand

or power-driven generator as required. The power-driven generator should only be used during the busy hours. The power is best furnished from the electric light circuit, if such be available, and in putting forward demands for the motors for this purpose it is necessary to state the voltage of the lighting circuit, and whether direct or alternating current ; if the latter, the frequency of the circuit must be given, or it will not be possible to ensure a suitable motor being sent. There is no service pattern motor or generator for this purpose.

Testing jacks and plugs.

34. In some switchboards a galvanometer is provided connected to a jack, plug and cord, and key, so that it can be used for testing the lines or the cords. Fig. 27 shows the arrangement adopted in the "drum-jack" exchange mentioned above. It will be seen that by inserting a plug in the test jack and pressing one of the test keys, the cord can be tested for continuity and insulation, and similarly by inserting the test plug in a line jack, the line can be tested in the same way.

Junction Working.

35. Junction circuits are circuits connecting two different exchanges, for use when a station connected to one exchange wishes to speak to a station on another exchange. The simplest, but not always the best, method of connecting the junction wires is to connect them at the two switchboards in the same way as ordinary circuits. If a station on "N" exchange wants a station on "M" exchange he rings up in the ordinary way and asks for "M" exchange, and is put through as in any other case ; he then rings "M" and asks for the station he requires, and is again put through by the operator at "M" ; he can now ring the station he wants. The circuits are now as shown in Fig. 28, and it will be seen that the ring-off indicators at both exchanges are connected across the lines, and will both indicate if either station rings off. It will be seen that if a battery is used for ringing off at one exchange and a magneto ring-off at the other a current will flow through the ring-off indicators at both exchanges as long as they are connected, whether a station is ringing off or not, hence in this case some special arrangement must be made. The difficulty can be overcome by inserting a translator

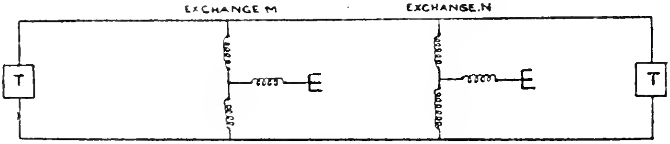


FIG. 28.

(para. 30) in the junction line as shown in Fig. 29. Another method is to insert a condenser in each wire of the junction. In these cases only one of the two ring-off shutters drops when one station rings off, and it is necessary for both stations to ring off before the signal to disconnect is given at both the exchanges. If it is necessary to be connected through three or more exchanges before the station required can be obtained, and translating coils are used as above described, clearing signals will only be received at the two terminal exchanges, and special arrangements must be made for warning the intermediate exchanges when the conversation is finished.

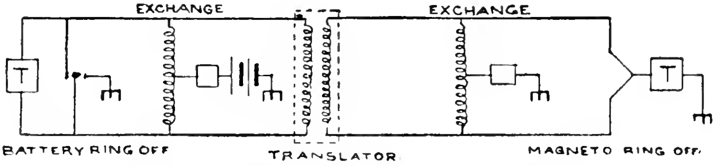


FIG. 29.—Use of Translator in Junction Working.

If batteries are used for ringing of all the exchanges on a system, translators need not be used if the lines are in good order, and if care is taken that the ring-off batteries at the different switchboards have the same E.M.F. and are joined up with the same pole to earth. The positive pole should always be the one connected to earth, for the reasons given in Chap. I, para. 41.

Where junction circuits are required between a magneto switchboard and a central battery board (*see* para. 39), special arrangements must be made, and would usually be provided by the authority in charge of the central battery board. The connections provided by the Post Office for a junction circuit of this nature are shown in Fig. 30; the lines are joined up as

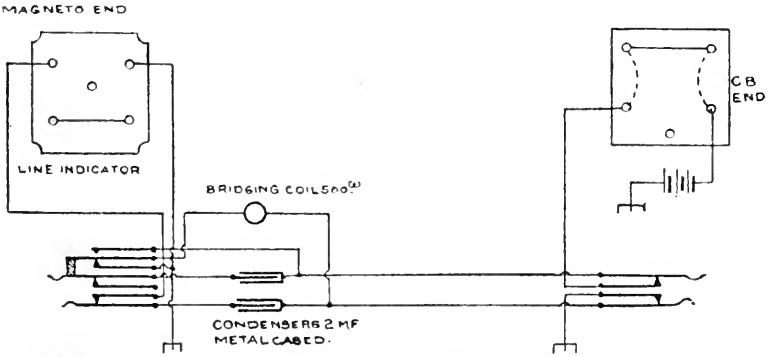


FIG. 30.—Junction Connection to Post Office C.B. Board.

an ordinary line at the central battery end, but special apparatus is necessary at the magneto end, as shown. The central battery end is called automatically by the insertion of a plug at the magneto end. The magneto exchange is called by a generator. The clearing signal at the magneto exchange is received from the station connected to it, and the withdrawal of the plug at the magneto exchange clears at the central battery exchange. Where these connections are necessary at a magneto exchange provided by the Post Office, a strip of switch-springs, 8-point, is fitted instead of the switch-springs, 5-point, mentioned in para. 23.

Arrangement when several junction circuits are available.

36. When there are several junction lines between two exchanges it is desirable to allot a proportion of the junction lines exclusively to the use of each of the exchanges, the proportion being regulated by the number of junction calls originating in offices connected to each exchange. In such cases line indicators are not required at the outgoing end, and the junction lines can be joined to the transfer jacks, when these are provided. In large multiple exchanges the incoming junction lines are all connected to sections separate from the subscribers' lines, and an operator at another exchange requiring a junction connection, depresses a special key which places her telephone in direct connection with a "call" wire which is permanently joined to the operator's telephone at the other end. She then gives the number of the subscriber wanted and the junction operator says which junction line is to be used; the connections are then completed at both exchanges. It is seldom that this method of working would be required in military systems, and the incoming junction lines should, as a rule, be connected in the same way as other lines. Where a power-worked generator is provided it will generally be best for the operator to ring the second exchange, and for the second exchange to ring the office wanted; this method ensures the operator knowing whether the required connection has been obtained, and thus prevents the line being occupied by an office on one exchange trying to get connected to an office already engaged, and the line thus lying idle, when it may be required by another office. Sufficient junction lines should be provided to carry the traffic between the exchanges without undue delay.

Multiple Working.

37. Where a larger number of offices than can be dealt with by three operators have to be connected to one exchange, multiple working should be resorted to. In this case the lines are connected to one answering jack and indicator, as in the exchanges already described, and also to a number of "multiple" jacks. The line springs of all these jacks are connected together, generally so that a plug inserted in any of these jacks is connected to the line (Fig. 31). The multiple jacks are arranged so that one jack connected to each line on the exchange is within reach of every operator on the exchange; a complete set of multiple jacks usually extends over three operators' positions, as each operator can reach the jacks opposite the

operators on either side. A panel containing one-third of a complete set of jacks is placed at the two ends of the switchboard, to enable the operators in the end positions to connect to any line. It is usual on large exchanges to use the jacks connected to the line indicators for answering calls only, and always to use the multiple jacks for calling a station; the answering jacks are often not marked with the number of the line connected to them, as this is not necessary in this case. This has the advantage that the lines can readily be distributed among the operators so as to equalise the work, irrespective of the numbers of the actual lines connected to each position.

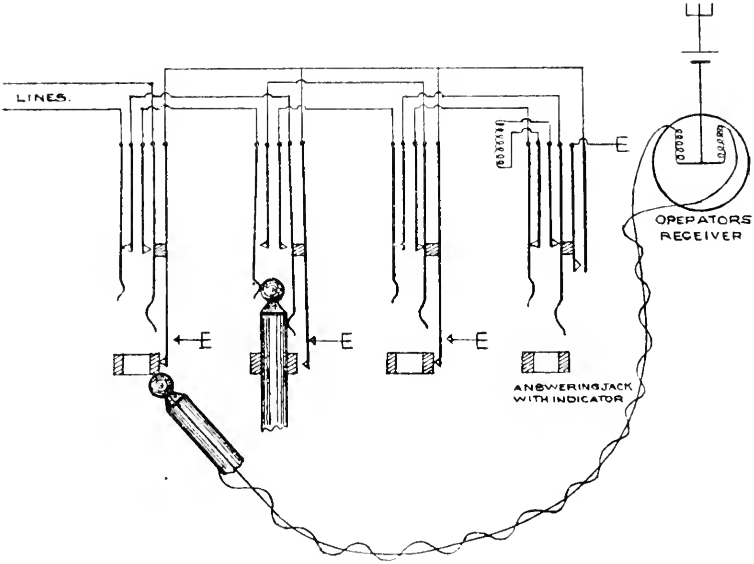


FIG. 31.—Multiple Jacks.

Engaged test.

39. It will be seen that with the above arrangement, connections might be made to the same line at different parts of the board, thus getting three or more lines connected together, and to prevent this some "engaged" test is necessary. The simplest method of connecting the multiple jacks and providing this engaged test is shown in Fig. 31, and is known as the "break" system. One extra contact spring is provided at each jack, permanently connected to a third wire. When no plug is inserted, this spring is in contact with the bush surrounding the jack, but when a plug is inserted, this contact is broken and the spring put to earth; thus, when a plug is inserted in any jack, the bushes surrounding all the other jacks connected to the same line are connected to earth. The centre point of the operator's receiver coil is connected through a battery to earth. This earth connection does not affect the speaking. The operator tests the line by touching the bush of the jack of the line wanted with the tip of a plug; if the line is engaged, a circuit is then completed, and a current flows from the battery through half the receiver coils, along the cord (the operating key being in the speaking position) to the third wire, and so to earth and back to the battery. This current produces a click in the receiver and tells the operator that the line is engaged; if there is no click, the line is disengaged, and the connection can be completed by inserting the plug. It will be noticed that the line indicator is disconnected when a plug is inserted in any jack. The disadvantage of this system is the large number of contact springs which are

in the speaking circuit, especially in a large exchange. In large modern exchanges the jacks are all connected in parallel (this system is called the "branching" system). This does away with the large number of contacts in the lines, but necessitates some special arrangement, such as a relay, for disconnecting the line indicator when the line is in use. A cord with three conductors is sometimes used instead of an extra contact in the jack switch.

Exchanges for any number of subscribers up to about 10,000 can be erected on this principle ; if still larger exchanges are required, they must be split up and treated as two or more separate exchanges with junction wires connecting them.

Central Battery Switchboards.

39. Central battery boards are used in all large modern exchanges in civil practice. They simplify the operating, but the boards themselves are very complicated, and will not work unless the lines are in good order. They are, therefore, not suitable for work in fortresses, where it may be necessary to connect temporary lines, which it may be impossible to maintain in as good condition as is desirable. Another disadvantage from a military point of view is that the telephone instruments used with them are not suitable for use on direct lines.

The broad principle on which they are constructed is that the lines at the out station are normally connected to each other through the bell and a condenser ; the condenser allows the alternating current from the generator used in calling from the exchange to pass through and ring the bell. When the receiver is removed from the hook, a metallic circuit is completed, which allows a current from a battery at the exchange to flow round the lines and through the line indicators at the exchange. Similarly, when the receiver is replaced, this circuit is broken, and breaking this circuit gives the clearing signal. The calling and clearing are thus done automatically by taking up and replacing the receiver. The indicators are small incandescent electric lamps, which are placed close to the corresponding jacks, and which take up very little space. The details of the boards are too complicated for inclusion here.

Instructions for Working an Exchange System.

40. In order to get the full benefit out of an exchange telephone system it is necessary for those using it, as well as the exchange operators, to comply strictly with the instructions as to calling, ringing off, and answering calls. Concise instructions should therefore be hung up at each telephone. These instructions will of course vary with the type of exchange, whether there are junction wires to sub-exchanges, &c. Some typical rules are given below.

(*a*) For an exchange on the ring-through system.

To call a station—

1. Give the handle one or two sharp turns, take up the hand telephone and listen for the reply from the exchange.
2. Give the *number* * of the office required, and, as soon as the operator says "through," replace the hand telephone,

---

* When the number consists of two or more figures, it is better to give each figure separately, thus, No. 123 should be asked for as "one two three" and not as "one hundred and twenty-three"

give the handle one or two sharp turns, take up the hand telephone and listen for the reply from the distant office.

N.B.—If the operator says "Number—engaged," replace the hand telephone and call again in a few minutes.

3. On termination of the conversation, replace the hand telephone and ring off by pressing the button (*or* by pressing the button and at the same time turning the handle.)

To answer a call—

4. Take up the hand telephone and speak.
5. On termination of the conversation, ring off as above.

General—

6. Speak distinctly, but do not shout.
7. Never leave the hand telephone off the hook, or rest, unless actually conversing.
8. Improper or abusive language over the telephone is strictly forbidden.
9. Reports of faults, or complaints as to the working of the system, should be sent by letter or telephone to .... and not to the exchange operators.
10. To call a station connected to a sub-exchange, call the exchange as in 1, above, ask for the sub-exchange required, replace hand telephone, and call the sub-exchange, then proceed as in 2, above.

(*b*) If the sub-exchanges are rung up by the operator.

For 10, above, substitute—

10. To call a station connected to a sub-exchange, call the exchange as in 1, above, give the name of the sub-exchange and the number of the office required, listen for the reply from the distant office.

(*c*) If the exchange rings all stations.

For 2, above, substitute—

2. Give the number (and if on a different exchange, the name of that exchange) of the station required, and listen for the reply from the distant office.

N.B.—If the operator.........&c.

Omit 10.

Rules for an exchange operator—

1. Immediately a number shows, insert a plug, depress ringing key, and say "exchange."
2. On receiving the number required, if that number is not engaged, insert the other plug of the pair, say "through," and restore the key to its normal position. If the required number is engaged, say "No. — engaged," and withdraw the plug.

3. On receiving a ring-off signal immediately withdraw the plugs.
4. If no ring-off signal is received after 5 minutes, come in on the line and ascertain if the conversation is finished. If so withdraw the plugs.
5. Switch on night bell at......p.m.
6. Improper or abusive language is strictly forbidden.
7. Speak distinctly, but do not shout. All unnecessary conversation and noise is strictly forbidden.

Rules *re* hours of duty, reporting faults, testing, &c., should be added according to circumstances.

It is not the duty of the exchange operator, especially in busy exchanges, to answer questions or to receive complaints, notices of faults, &c., but he should, of course, do all he can to facilitate the smooth working of the exchange. In busy exchanges it may be advisable to give the operator orders to switch anyone requiring information, &c., through to a separate instrument, where he can be attended to without delaying other work on the switchboard.

It is not as a rule satisfactory for the telephone system to be utilised as a telegraph system, *i.e.*, for messages to be written down and despatched, or received, by special telephone operators, though this cannot in all cases be avoided; except in the smallest exchanges the actual exchange operator should not transmit or receive messages. The system should, if possible, be so arranged that officers or clerks do their own telephoning, and speak direct to the person with whom they require to communicate.

If circumstances render it unavoidable that messages should be written out at the exchange, an independent instrument should be provided, and a special clerk detailed to attend to it.

CHAPTER XIV.

TELEPHONE ACCESSORIES AND SWITCHES.

Plug Boxes and Plug Jacks.

Box, plug, single.

1. The box, plug, single, is used for terminating a telephone or other line where it is not desired to leave the instrument permanently fixed. It is illustrated in Fig. 1, and consists of a socket, connected to the line wires, fixed in a suitable case. Connection is made to the instrument by means of a plug and cord ("Plug, jack, W.D.," *see* para. 3), which may be permanently attached to the instrument. When the plug is inserted in the socket, the two conductors of the cord are connected to the two line wires. The socket is formed of two split gunmetal rings, insulated from each other and from the case. A screw is provided on the base of each ring for attaching the conductors forming the line circuit. The split rings are mounted on a block of ebonite fixed to an iron bracket, and a gunmetal cover is provided. A hole in the cover, closed by a movable flap, allows the plug to be inserted in the socket. The box is strongly made, and can be fixed in the open without protection from the weather.

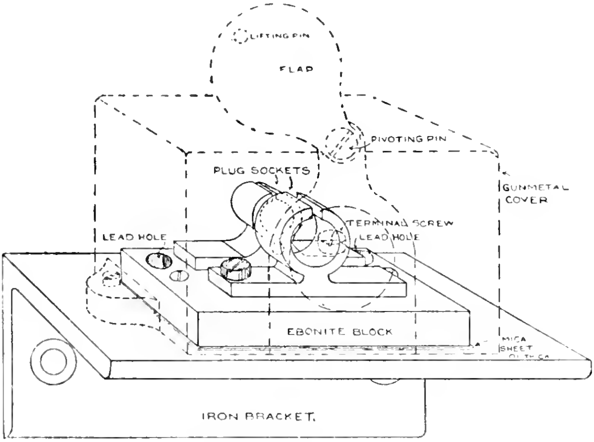


FIG. 1.—Box, plug, single.

Box, plug, double.

2. The "Box, plug, double," enables a telephone provided with a "Plug, jack, W.D.," to be connected at will to either of

two circuits. It is illustrated in Figs. 2 and 3. In the lower part of the box are two sockets, similar to that of the "Box,

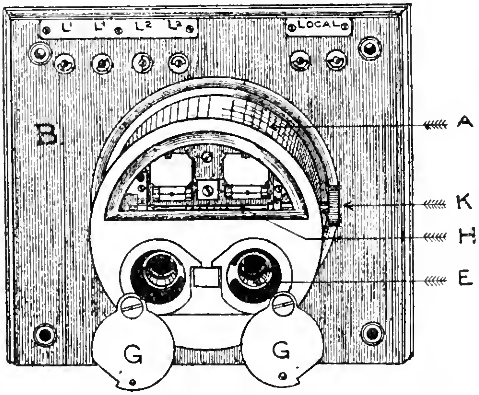


FIG. 2.—Box, plug, double.

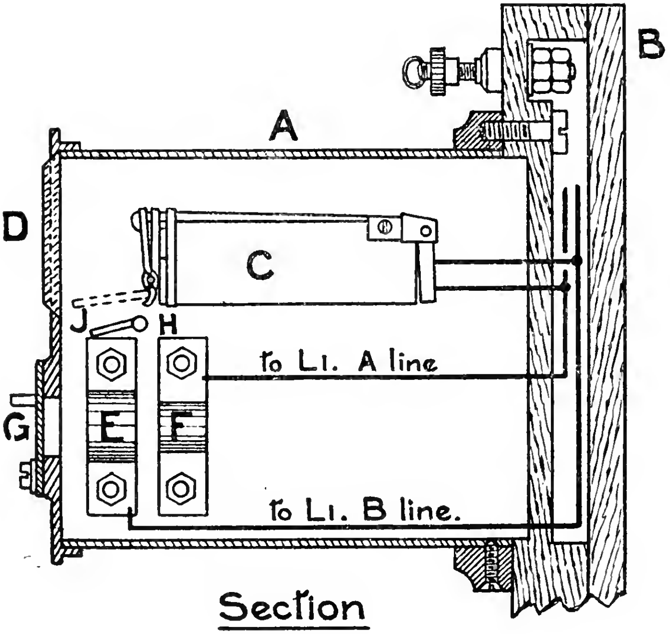


FIG. 3.—Box, plug, double.

plug, single." The left hand socket is connected to the terminals L_1. L_1, and the right hand socket to L_2, L_2.

Two indicators (C) are provided, fixed above the sockets EF and permanently connected to the respective terminals and sockets, so that they are permanently in bridge across the lines. This is to enable either line to attract the attention of the office, whether that line is connected to the telephone or not. The shutters of the indicators are replaced by turning the milled head K at the side of the case; this turns the spindle "H" against a spring, and raises the shutters by means of pins J attached to it.

The local contacts of the shutters are connected to the terminals marked "local," and if a battery and "Bell, electric, battery," be connected to these terminals, an audible warning will be given when the shutter drops. The indicators (resistance 1000 ohms) are the same as the ring-off indicators described in Chap. XIII, para. 21. The instrument is enclosed in a brass case A, with two holes for the insertion of the plug, and a glass window D, to enable the indicators to be seen. The holes are closed by movable flaps G. The instrument is mounted on a wooden back board B, and is not so well protected from the weather as the "Box, plug, single." It should not be fixed in the open, in exposed situations, without protection.

Plug, jack, W.D.

3. The "Plug, jack, W.D.," consists of a plug and a twin conductor cord. The plug is illustrated in Fig. 4, the handle and insulation are of ebonite. The cord (known as "Cord, telephone, plug, jack") is a twin flexible cord, 6 feet long, provided at the free end with hooks for attaching to the terminals of the instrument with which it is to be used.

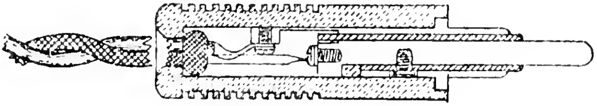


FIG. 4—Plug, jack, W.D.

This plug and cord form part of "Telephone sets, portable, 'A,'" but if required with other instruments they must be demanded separately. The "Plug, jack, W.D.," also fits the sockets of the "Box, connecting, buried cable" used on rifle ranges abroad, and in some cases at home.

Plug, jack, G.P.O.

4. The "Plug, jack, G.P.O.," is electrically similar to the "Plug, jack, W.D.," and the cord used is the same, but the end of the plug is flat. The plug is used for connecting telephones to the connecting boxes formerly fixed by the G.P.O. on rifle ranges at home; it is *not* suitable for use with the service plug boxes, &c. Any boxes fitted in future by the G.P.O. will be fitted to take the "Plug, jack, W.D."

Concentrators.

5. Where several telephone lines terminate in an office, but intercommunication is not required, some form of concentrator is desirable to avoid a large number of separate instruments, and to enable the central office to speak on two or more of the lines at the same time. This is especially the case in coast defence work. The "Box, plug, double," is a form of 2-line concentrator, but it does not enable both lines to be spoken on at the same time. The service instruments for this purpose are known as the "Switches, telephone, 5-line" and "Switches, telephone, 10-line," for five and ten lines respectively. The nomenclature is somewhat confusing, and the existing patterns are not very satisfactory. A new pattern has been designed and will probably be shortly introduced under the nomenclature "Concentrator, 5-line" and "Concentrator, 10-line."

Switch, telephone, 5-line, Mark I*, and 10-line, Mark I*.

6. The general appearance of the switch, telephone, 10-line, Mark I*, is shown in Fig. 5, the 5-line is similar in all respects, except that it has only five indicators and five jacks.

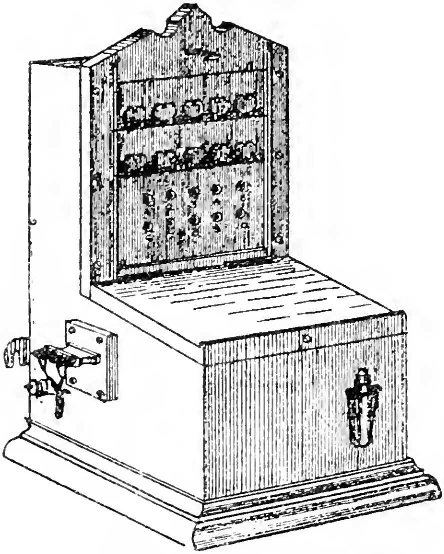
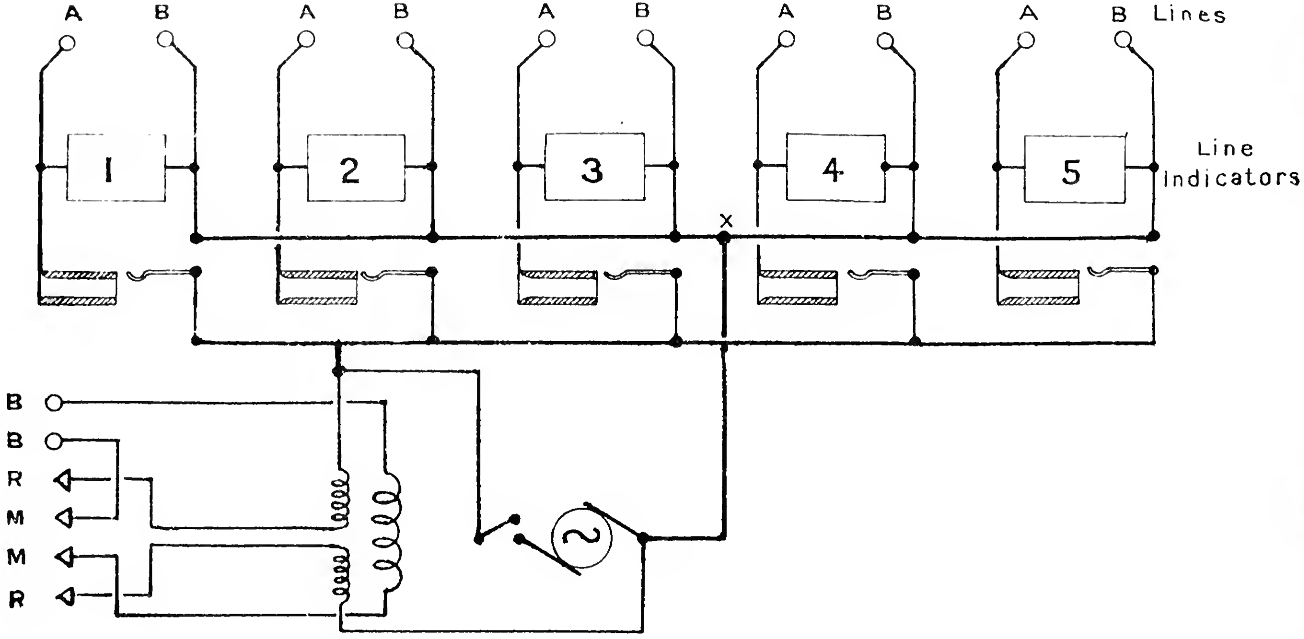


FIG. 5.—Switch, telephone, 10-line, Mk. I*.

Each switch (Mark I*) consists of five (or ten) indicators and jacks, a generator, induction coil, microphone on a stand, and a head receiver. The microphone and receiver are connected to the instrument by a flexible cord and 4-way plug fitting into a socket. This plug must be inserted in the socket only when actually speaking or listening. If it be inserted

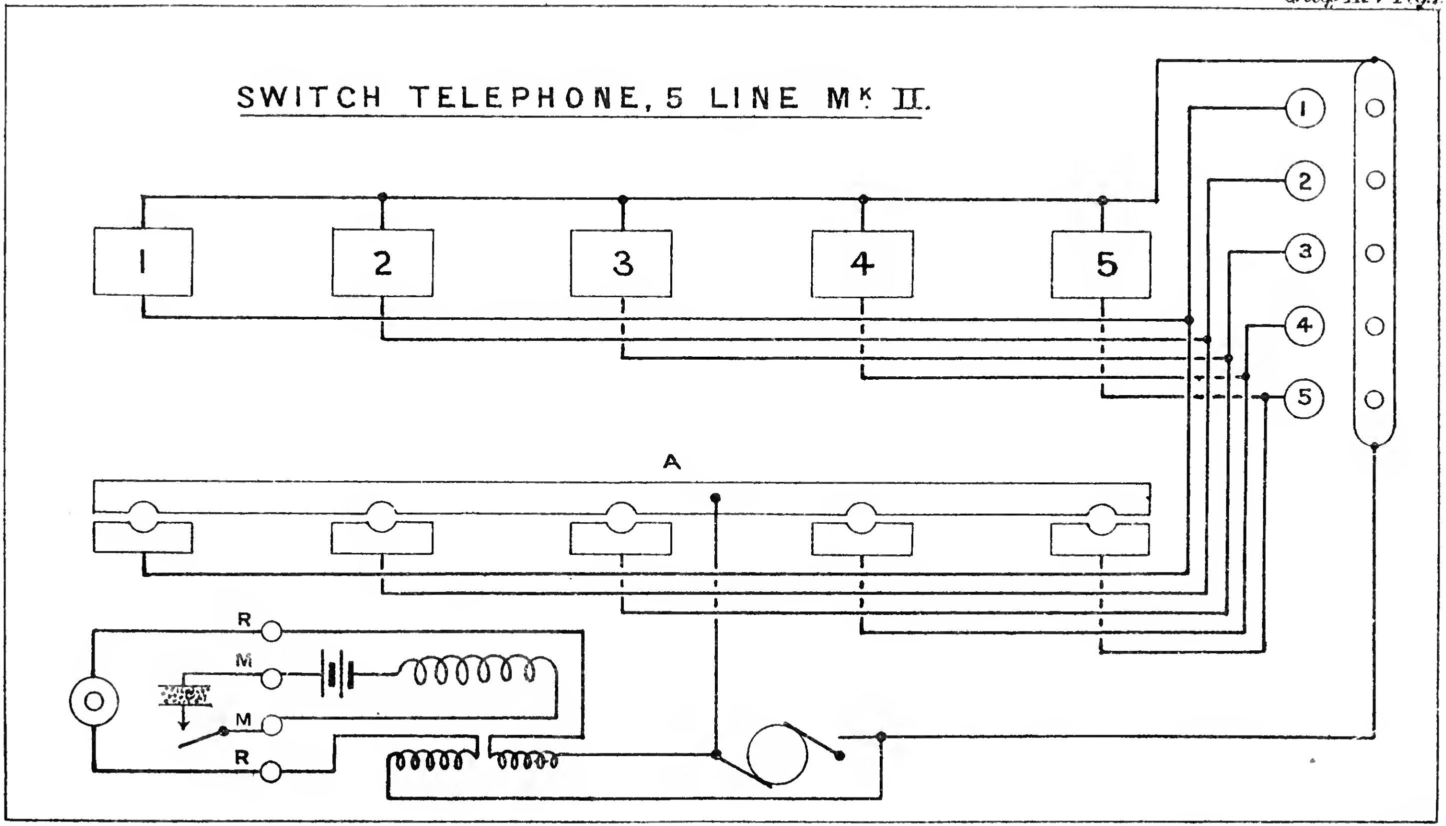
SWITCH TELEPHONE, 5 LINE Mk I*



H & C GRAHAM LTD, LITHRS LONDON, S.E

To face p. 207

Chap XIV Fig 7.



SWITCH TELEPHONE, 5 LINE M^K II.

H. & C. GRAHAM L^{TD}, LITH^{RS}, LONDON, S.E.

To face p. 207.

when the instrument is not in use, the speaking battery will be exhausted, and if inserted when ringing, the secondary and receiver are in parallel with the generator. The necessary connections are made by means of a plug, which is the same as that described in Chap. XIII, para. 18, and Fig. 13, except that there is no cord, and the tip and sleeve of the plug are electrically connected.

The connections are shown in Fig. 6. The lines are soldered to tags inside the case. The indicators are permanently connected to the lines. The "B" lines are all connected to one pole of the generator and to the secondary of the induction coil. The other side of the generator and induction coil are joined to one point of the jacks, while the "A" lines are joined to the other point of the jacks. There is an automatic switch in the generator which disconnects it when the handle is not being turned. When a plug is inserted in a jack, the circuit from the corresponding line is completed through the secondary. Terminals are provided at the side of the case for the microphone battery, and at the top for a local bell and battery, if such be required, the bell circuit being closed by the local contacts of the indicators. The indicators are the same as those used with the "Boxes, plug, double." The fact that all the "B" lines are permanently connected together leads to overhearing and cross talk, &c.

Switches, telephone, 5- and 10-line, Mark II.

7. The Mark II pattern of 5- and 10-line switches are electrically the same as the Mark I*, and suffer from the same disadvantages. The general appearance is also the same. The differences are as follows :—

Terminals are provided for the line wires.

The plugs are of solid brass, and make contact between a brass "bus" bar on the face of the switch (connected to the generator and secondary) and a brass block connected to the line.

A "telephone, hand, 'A,'" is used instead of the head receiver and separate transmitter.

A space for two "cells, electric, dry, 'A,'" is provided in the case, so that a separate battery is not required.

The connections are shown in Fig. 7.

Concentrator, 5-and 10-line.

8. Switches, telephone, 5- and 10-line, have now been converted to Concentrators, 5- and 10-line embodying the following alterations :—

I.—The line connections are altered, preventing overhearing.

II.—For "calling up" lever, switches are substituted for plugs.

III.—Supporting hooks are provided for the "Hand telephone," also a holder and clip for the generator handle when detached.

IV.—Two terminals are provided for connecting a pilot bell, which would be required if a concentrator be authorised to be used as a small exchange, when it is not necessary that the operator should remain actually sitting in front of the concentrator.

The bell to be issued for this purpose is "Bell, electric, magneto, 'R.'"

With the bell in circuit and five "Telephone sets, office, *Mark II*" connected through the bars of the concentrator, all the stations can be called simultaneously, but they cannot ring the pilot bell and clear reliably with more than three of these instruments connected ; the clearing signal can, however, be given by each instrument when "Telephone sets, portable, 'C,' Marks I or II," are used.

V.—The "Hand telephone, 'C,' Mark II" is substituted for "Hand telephone, 'A,'" thereby cutting out the resistances of the secondary and receiver coils when calling up.

The "Hand telephone, 'C,' Mark II," should be separately demanded.

Telephone Switches.

9. There are several simple 2- and 3-way switches in the service for throwing in and out of circuit extension bells and telephones, &c., and also for use in offices where two telephone lines are terminated, and it is desired to speak on either or both lines, or to switch the lines through at will.

Switch, single line, 2-way.

10. The "Switch, single line, 2-way," is a simple switch for connecting a single line to either of two other lines or instruments, or it can be used as a simple make and break switch. It is chiefly useful for throwing in and out of circuit extension bells, or the bells used to give audible warning when the indicator at an exchange switchboard, &c., drops.

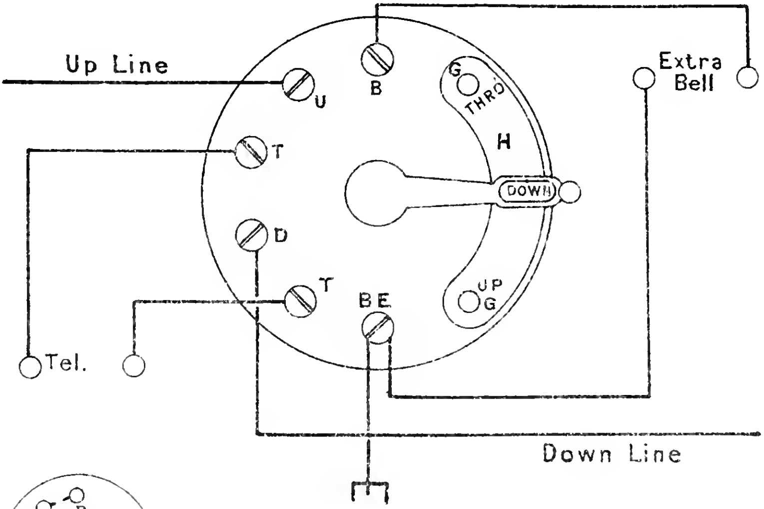
When the extension bell is rung by an indicator, or sounder, acting as a relay, or when the extension bell is arranged in parallel with the main bell of a telephone set, the switch must be arranged so as to *break* the bell circuit when it *is not* required. When the extension bell is connected in series with the main bell, or sounder, the switch must be arranged so as to short-circuit the extension bell when it is not required.

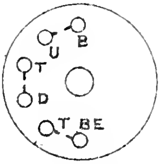
Switch, single and duplex.

11. The "Switch, single and duplex," described in Chap. VI, para. 5, is really a double-line 2-way switch, and can therefore be used when it is required to connect a metallic circuit to either of two instruments. For example, it would be used if it was required to connect the telephone line from the exchange to the orderly room during office hours, and to the guard room at other times, so as to ensure the telephone always being available in case of emergency. If it is required to enable either position to call up at any time, a "Switch, telephone, intermediate," must be used.

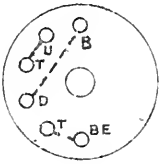
Chap XIV. Fig. 8.

SWITCH TELEPHONE INTERMEDIATE A.

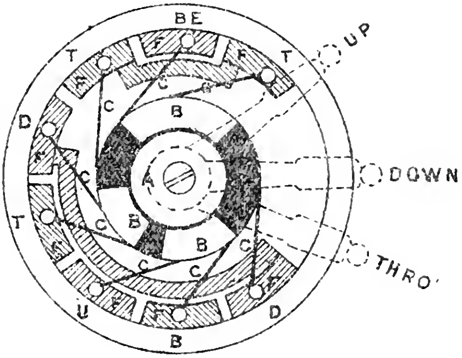




DOWN

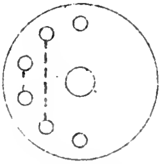


UP



INVERTED PLAN

Showing "Down" Position.



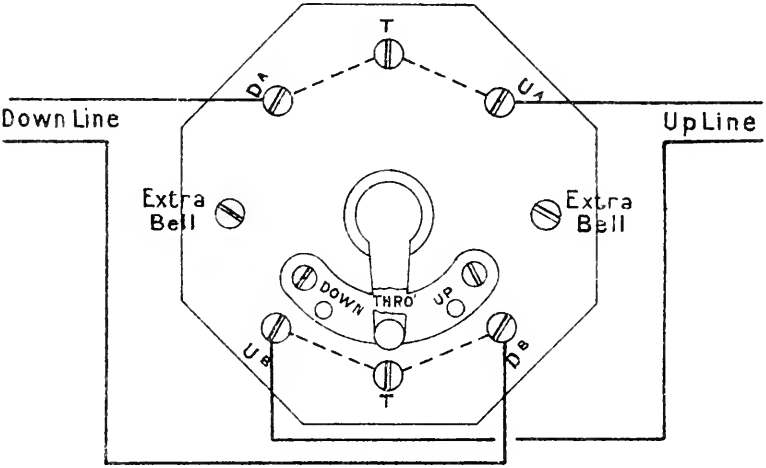
THROUGH

H & C GRAHAM LTD. LITHRS. LONDON S.E.

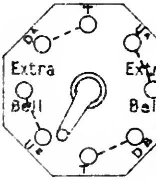
To face p. 209.

SWITCH TELEPHONE INTERMEDIATE B.

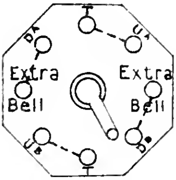
MARK I



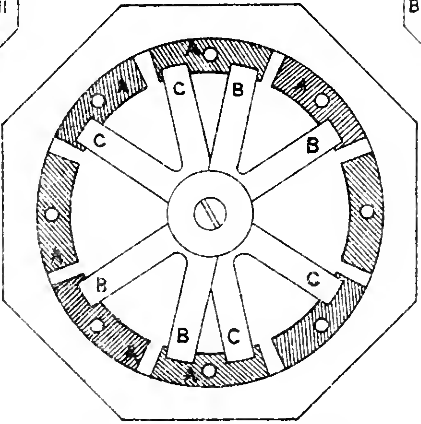
THROUGH



DOWN



UP



INVERTED PLAN.

H & C GRAHAM LTD, LITHRS, LONDON S.E

To face p. 209

Switch, telephone, intermediate, "A."

12. The "Switch, telephone, intermediate, 'A,'" is a three-position switch intended for use where two telephones on single wire (earth return) circuits enter the same office, and communication is required in either direction, and it is also required to put the lines through, or to speak to both at once. This frequently occurs when two telephones are connected to an exchange by the same wire, *e.g.*, one instrument in the clerk's room and one in the officer's. In such a case the switch is placed in the "intermediate office."

The switch is illustrated and the connections shown in Fig. 8. "A" is a drum, carrying three brass plates "B," and can be revolved through an angle of about 70° by means of the handle. The plates "F" are connected to the terminals as shown, and the connections are made between the plates by the springs "C"; the black portions of the drum "A" are insulating material.

With the switch at "through" the local telephone is connected in series in the line, and the extra bell is disconnected. With the switch at "up" the up line is connected to the local telephone, and the down line to the extra bell. With the switch at "down" the down line is connected to the local telephone, and the up line to the bell. Either out station can, therefore, call the intermediate station irrespective of the position of the switch.

When one of the out stations is an exchange this is usually considered the "up" station.

The "Switch, telephone, intermediate, 'A'" is *not* suitable for metallic circuits.

Switch, telephone, intermediate, "B."

13. The "Switch, telephone, intermediate, 'B'" is intended for the same purposes as the "A" switch, but is suitable for metallic circuits. It is illustrated, and the normal connections are shown in Fig. 9. The bell is normally connected to the terminals marked "extra bell," and the local telephone to those marked "T."

If it is desired that the intermediate office shall not be in circuit (and so in a position to overhear) when the lines are put "through," the bell may be joined to terminals TT and the telephone to those marked "extra bell." In this case the up lines should be joined to the down terminals, and *vice versa*. When the lines are "through" the bell is connected across them so that the intermediate office can still be called, but cannot listen in or speak; the intermediate office can still speak to either of the other offices by moving the switch.

The terminals are connected to the brass plates "A," and the connections are made by the bars BBBB and CCCC, which form two sets rigidly connected, and turned together by the handle, but the "B" bars are insulated from the "A" bars.

CHAPTER XV.

THE VIBRATOR SYSTEM.

1. In most systems of Morse telegraphy, the time intervals composing the various letters are intervals of silence between sharp and distinct sounds, caused by the armature of an electro-magnet being moved against a stop when the signal starts, remaining there during the signal, and returning to its original position against another stop, when the signal is completed. In the vibrating system an ordinary telephone receiver is used as the receiving instrument, and the signals are given by long or short durations of "buzzes" in the receiver, separated by periods of silence.

To produce these signals in the receiver, a rapidly vibrating or intermittent current is required, the "period"* of the vibrations being about 150 to 500 a second, viz., that of sound-waves. If this period is kept steady, a more or less musical note, having a definite pitch, is produced in the receiver.

Advantages.

2. The advantages of this system are :—

(i) The telephone receiver is extremely sensitive, and consequently a very small current is required.

(ii) Vibratory currents (as explained in Chap. I, para. 62) will pass through condensers, and consequently a circuit can be divided into two parts, so that ordinary Morse currents will pass through one path only, and the vibrating currents through the other. This enables one line to be used for two independent telegraph circuits at the same time.

(iii) It is easy to produce very high momentary E.M.Fs by means of induction coils, or similar devices, and this, combined with (i), enables this system to be used on lines of very high resistance, and comparatively poor insulation, without the very large battery power that would otherwise be required.

(iv) The telephone receiver requires no adjustment, and is always ready to receive either strong or weak signals.

(v) The instruments required are light, and the battery power small, consequently the apparatus is very portable.

---

* The "period" of the vibration is the time taken for one complete vibration to and fro, *e.g.*, from b to b, Fig. 3.

3. The disadvantages of the system are due to the same peculiarities of vibrating currents, and are :— Disadvantages.

(i) The vibrating currents induce similar currents in all neighbouring wires, and these produce buzzes in any telephone receiver connected to them. Thus several vibrator circuits cannot be run side by side for any distance, or even be connected to the same earth, unless the latter be of extremely low resistance. Similarly, vibrator circuits in the neighbourhood of telephone circuits interfere very seriously with the latter, unless these are very carefully constructed metallic circuits, properly revolved.

(ii) Every line has a certain capacity between itself and earth, and this capacity increases with the length of the line. Vibrating currents will pass through such a capacity, and leak to earth on a long line, even if it is well insulated. The vibrating system is therefore not suited to working on long lines.*

(iii) It is more tiring to the operators than ordinary sounder circuits, and the speed of operating is slower.

4. It will be seen from the above that this system is very suitable for use on advanced military lines, as these are generally not of great length, and seldom of as low resistance and high insulation as is desirable. It is also of use for work at small intermediate offices, when a separate line for local work is not available, the through line being worked at the same time with a sounder. A small addition to the apparatus enables it to be used as a telephone; this is very useful for what may be called "tactical" lines, and also enables it to be used for communication with a lineman equipped with a telephone, portable, D, without interrupting the Morse working on the line. Uses of vibrator system.

The system is also used for "calling" in telephone work, where it is desirable to avoid the weight due to a generator and bell.

5. The method of producing the intermittent currents is illustrated in Fig. 1. The principle is the same as that of the trembling battery ringing bell described in Chap. X, para. 13. On depressing the key a current flows through the magnet coils "A," and attracts the armature "B"; this breaks the circuit, and the armature flies back and again completes the circuit. This process is repeated as long as the key is kept depressed. The armature is made of a stiff spring, and weighted at the free end, so that it has a natural period of vibration of 300 to 400 a second. The period can be slightly altered by advancing or withdrawing the contact screw "C." Transmitter.

---

* About 40 miles is found to be the limit for field cable lines.

Connections of transmitter used with telephone, portable, "D."

6. If this arrangement were connected up in the line, the maximum E.M.F. produced would be that of the battery, and the effect produced in a high resistance circuit would be small. The circuit is therefore completed through the primary "*p*" of an induction coil, and the secondary of this coil is connected to the external circuit, as shown in the figure. By this means the E.M.F. can be largely increased, and considerable current variations produced in a high resistance external circuit. The action of the induction coil is the same as when used in telephone sets (*see* Chap. X, para. 8). The currents induced in the secondary coil will be alternating, even if those in the primary are only intermittent.

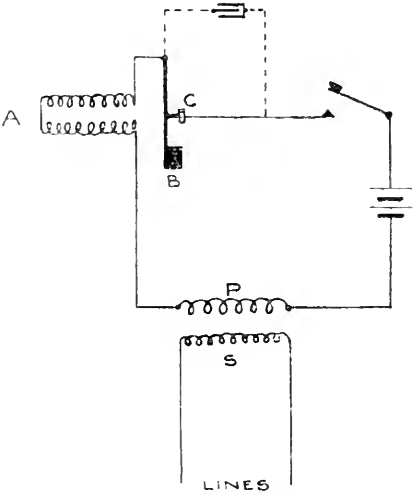


FIG. 1.—Buzzer Circuit of Telephone Sets, portable, D, Mark II.

Use of condenser across break.

7. When the circuit is broken the current does not stop suddenly, but dies out more or less gradually, and a spark occurs at the break (*see* also Chap. I, para. 54); this spark is caused by the current jumping the small air gap when the circuit is first broken. It must be remembered that we are now considering currents that stop, reverse and restart several hundred times a second, and that a current that takes, say, $\frac{1}{200}$ of a second to die out must be spoken of as dying out gradually; in ordinary Morse working a current that had ceased in, say, $\frac{1}{50}$ of a second would still have stopped instantaneously for all practical purposes. The E.M.F. induced in the secondary coil depends on the rate at which the lines of force, produced by the current in the primary, cut the coil; consequently, the quicker these lines collapse, *i.e.*, the quicker the current in the primary coil dies down, the greater the

momentary E.M.F. induced in the secondary. A condenser connected across the break, as shown by the dotted lines in Fig. 1, has the effect of making the current die out quicker, and also reducing the sparking. For these reasons a condenser is usually connected in this manner. These are the connections of the calling circuit of the "Telephone sets, portable, 'D,' Mark II" (Chap. XII, para. 49).

Theory of telegraph vibrator.

8. In the "Transmitter, vibrating" and "Vibrator, telegraph," which are designed on the same principle, the vibrating currents are produced in a slightly different manner. The connections are simpler, and are as shown in Fig. 2. There is no regular induction coil, and the lines are connected direct to the ends of the magnet coil: a receiver is inserted in one line.

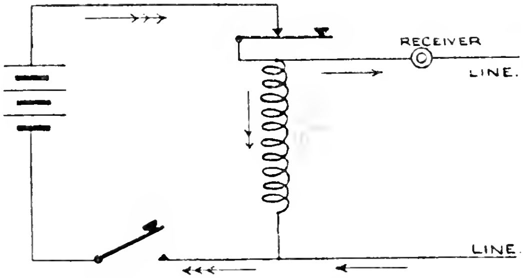


FIG. 2.—Connections of Telegraph Buzzer.

It will be seen that when the key is depressed there are two paths for the current, viz. (*a*) through the coils—resistance about 10 ohms, (*b*) out to line—resistance may be very great, but will seldom be less than 300 ohms. A small portion only of the current will, therefore, flow out to line, the greater part flowing round the coils as indicated by the arrows in Fig. 2.

When the circuit is broken at the contact spring the lines of force collapse and cut the wires of the coil, producing a high E.M.F. This E.M.F. tends to—

(*a*) Keep the current flowing in the same direction in the coils.
(*b*) Send a current out to line in the reverse direction to that previously flowing.
(*c*) Spark across the gap, and continue the current through the battery.

The result is:—

(*a*) The existing current in the line is reversed, and a powerful spurt of current is sent along the line.
(*b*) A spark is produced at the break, and the battery current dies out, but does not stop suddenly.

The armature then swings back to the contact screw, and again completes the circuit. This happens while the reverse current is still flowing to line, but is dying out, and takes place about $\frac{1}{600}$ of a second after the current is first started. The result is :—

(*a*) The current flowing in the line is again reversed, and flows in its original direction.

(*b*) The current in the coils grows, until it pulls the armature away from the contact screw. This takes place about $\frac{1}{300}$ of a second after the current is first started.

The same procedure is now repeated.

The actual currents in the line and battery circuits at any moment are shown in Fig. 3, "A" represents the current in the line and "B" that in the battery. In these curves "b" is the point where the circuit is broken "c" where the induced current in the line begins to die out, "d" the point where the circuit is again made. The curves are those actually observed when the transmitter was connected up with its receiver to an external resistance of 200 ohms, the battery used had an E.M.F. of 8 volts, and a resistance of about 1 ohm. With other resistances in circuit, curve "A" would remain the same in general character, but the amplitude would vary, curve "B" would remain practically unaltered.

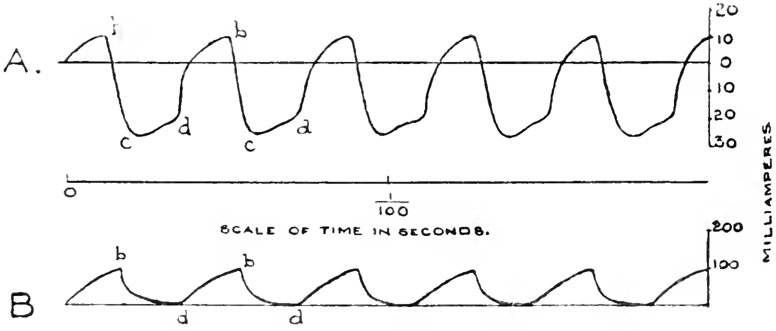


FIG. 3.

Water analogy.

9. The action of this transmitter is almost exactly equivalent to that of the water ram, sometimes used for raising water. In this contrivance water from a stream is allowed to flow through a pipe "P," Fig. 4; as soon as the

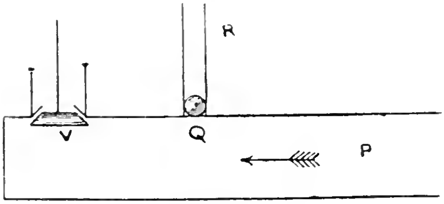


FIG. 4.—Water Ram.

flow of water is established, a valve "V" is automatically closed, and the current stopped. The inertia of the moving water creates a considerable pressure (compare Chap. I, para. 55) against "V" and "Q," and this pressure opens a valve at "Q" and forces a portion of the water from "P" up a pipe "R," and will raise it to a considerable height. As soon as the water in "P" has definitely stopped flowing, the pressure is only that due to the fall along the pipe "P," which may be small and insufficient to raise water in "R" to the required height. As soon as the pressure falls, "V" opens, and the cycle is repeated. The flow in "R" is intermittent, and water spurts up it each time "V" is closed. This corresponds to the spurts of current in the line when the circuit is broken in the vibrator. It should be noted that in both cases the current produced when the valve is closed, or the circuit broken, is always less than that flowing in the original circuit, but that the pressure produced is much greater.

Apparatus for a vibrating telegraph set.

10. The complete apparatus for a vibrating telegraph set consists of a transmitter, a hand telephone, and a battery (a "Battery, dry, 6-cell," is generally used). The transmitters in the service are the "Transmitter, vibrating, Mark IV," and the "Vibrator, telegraph." The first mentioned was that formerly used by the Telegraph Companies, and is still used by the R.A. The latter will in future be supplied to the telegraph units.

When used in the field, a "Receiver head" is generally provided as well, and connected in parallel with the receiver of the hand telephone.

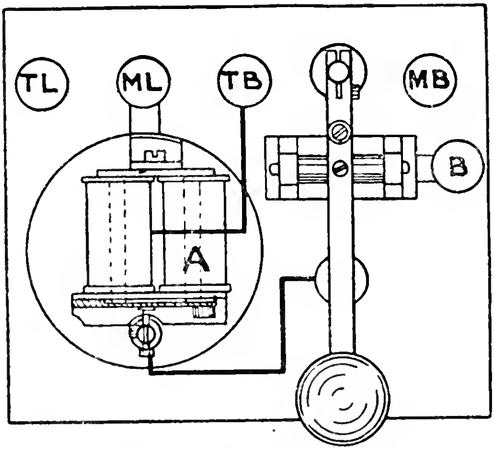


FIG. 5.—Transmitter, Vibrating.

Transmitter, vibrating.

11. The "Transmitter, vibrating," is illustrated in Fig. 5, and the connections, joined up with a "Telephone, hand, 'A,'" in Fig. 6. When the switch of the hand telephone is pressed, a circuit is completed round the coil, through the microphone and two cells. Speaking into the microphone then produces variations in the current in the usual way, these variations are

communicated to the current in the line, and speech is reproduced in a receiver introduced elsewhere in the line, though not quite so efficiently as with an ordinary telephone. It is immaterial which of the terminals marked "L" is connected to line and which to earth.

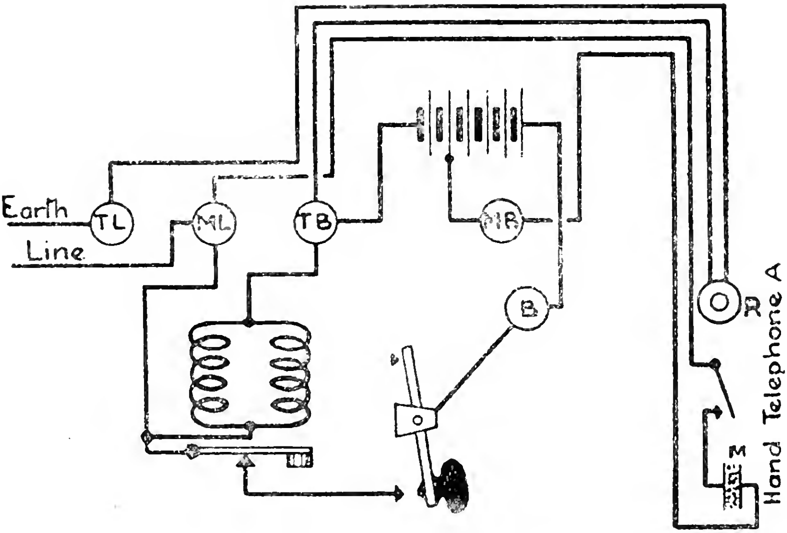


FIG. 6.—Connections of Transmitter, Vibrating.

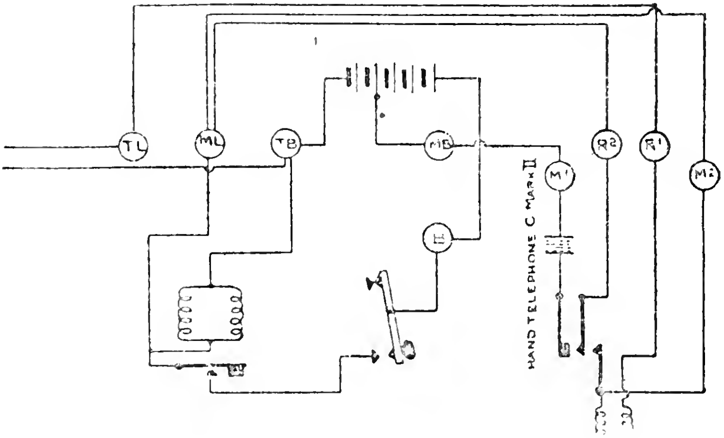


FIG. 7.—Transmitter, Vibrating, Mark IV, connected up with Telephone, Hand, C, Mark II.

It will be noticed that if a "Telephone, hand, 'C,' Mark II," be used with this instrument, it must be connected up as shown in Fig. 7, and not according to the labels on the baseboard of the transmitter, otherwise either the coil or the lines will be short circuited.

Details.

12. The magnet cores are composed of split tubes of soft iron, packed with charcoal iron wire. The yoke is of soft iron, secured to the cores by two No. 4 B.A. iron screws. The bobbins are formed by fixing ebonite cheeks to the ends of the cores, the latter being insulated with paper and shellac varnish. The coils are wound with double silk covered copper wire, ·0108 inch in diameter (No. 32 S.W.G.), soaked in paraffin before winding. The coils are wound so as to produce opposite poles at the free ends of the magnet limbs. Each bobbin is wound to a resistance of 20 ohms; the inner ends are soldered to the cores, and the outer ends are led to the terminal marked "T.B."; the two coils are thus connected in parallel and have a combined resistance of 10 ohms. The coils are jacketed with sheet ebonite. The armature is of spring steel with a brass block fixed at the free end. The contacts are platinum. Two adjusting pins are provided, which, when not in use, are screwed into holes provided in the base. The knob of the key can be removed and screwed into the base, for convenience of packing. The instrument, when properly adjusted, should produce a sharp and distinct sound when a current from one Leclanché cell (resistance 2 ohms) is passed through the coils, and should work without change of adjustment with a current from 10 such cells.

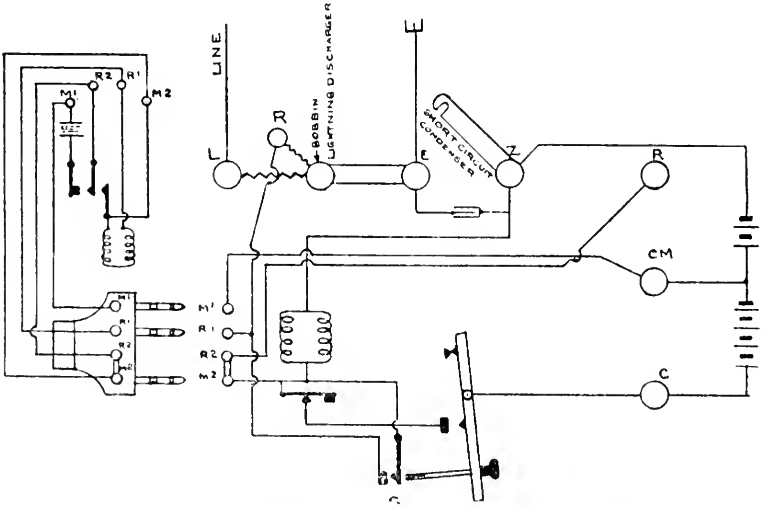


FIG. 8.—Vibrator, Telegraph, with Telephone, Hand, "C," Mark II.

Vibrator, telegraph.

13. The "Vibrator, telegraph," is very similar to the above and is illustrated in Fig. 8. The differences from the "Transmitter, vibrating," are :—

(*a*) A condenser of $\frac{1}{20}$th microfarad capacity is inserted between the instrument and the earth terminal, and a brass strap is provided to short circuit the condenser when not required. The use of the condenser is explained later.

(*b*) A "Discharger, lightning, bobbin," is provided, and a spare bobbin is supplied, mounted on the same fixing screw as the one in use. In consequence the terminal marked "E" should always be connected to earth.

(*c*) The receiver is short circuited when the key is depressed, by means of the contact "S." This is to avoid unnecessary self-induction and resistance in the line.

(*d*) A three-way plug is provided for connecting the "Telephone, hand, 'C,' Mark II," which is intended to be used with this instrument. Four terminal screws are provided on the plug, and should be connected to the hand telephone as marked. The lead R_2 is not required when the hand telephone is used with the vibrator, the terminal screw is only provided to avoid loose leads. If a "telephone, hand, 'A,'" is used with the vibrator, the microphone leads are connected to M_1 and M_2, and the receiver leads to R_1 and R_2; M_2 and R_2 are connected by a strap.

(*e*) If a head receiver is used it is connected to the terminals marked "R"—not to the plug.

Details.

14. The ends of the cores are provided with small non-magnetic projections, to prevent the armature from touching the cores. The steel plunger on the underside of the key lever is provided with an ivory tip. The condenser is of $\frac{1}{20}$ microfarad capacity, within 25 per cent., and is jacketed with ebonite. The connections on the underside of the base are of No. **22** tinned copper wire, cotton covered and braided. The details of the coils, &c., are the same as for the "Transmitter, vibrating."

Superimposing, Vibrator and Sounder.

15. It has already been stated that Morse* and vibrator instruments can be simultaneously used on the same line. The currents used in vibrator working alternate so rapidly, and are, as a rule, so small that they do not in any way interfere with the Morse working. It is usual to connect a vibrator to a line by "tee-ing" in, *i.e.*, connecting the line through the vibrator to earth, whether at a terminal or intermediate office. This method of connecting up reduces the resistance and the self-induction of the line, and also in many cases avoids cutting the line wire. If an instrument were connected up in this manner to a sounder circuit it would, however, provide a path for the Morse current to leak to earth, and be equivalent to putting an earth fault on the line. To avoid this a condenser is inserted between the line and earth, and it is for this purpose that the condenser in the base of the "Vibrator, telegraph," has been provided. This connection to earth through a condenser does

---

* In this chapter the term "Morse" applies to ordinary sounder or recorder circuits, whether S.C. or D.C., simplex or duplex, &c.

not provide a path to earth for the continuous current used, and the only result on the Morse circuit is to slightly increase the capacity of the line. The effect in D.C. simplex working is negligible, but in duplex or "quad" working it may necessitate a slight adjustment of the compensation circuit (*see* Chap. VII, para. 10).

Action of receiver.

16. To understand the effect of the condenser, and of the Morse signals, on the receiver of the vibrator circuit, it is necessary to consider more fully the action of the telephone receiver. When a current passes round the receiver coils, the magnetic field of the receiver magnet is either strengthened or weakened by the current (*see* Chap. X, para. 5). As long as the current remains steady the receiver diaphragm remains steady, but as soon as the current varies the field will vary, and the diaphragm will move. If the diaphragm moves sufficiently sharply a sound will be produced. If the current suddenly rises and then remains steady, as is the case with the currents used in ordinary sounder working, the diaphragm will suddenly move, and then remain steady. The result is a "click" in the receiver. When the current ceases suddenly the diaphragm moves suddenly back, producing another click. If the current grows or dies down slowly, the diaphragm will move slowly, and consequently produce little or no sound. In other words, the noise produced in the receiver depends not on the strength of the current flowing through it, but on the *rate of change* of the current.

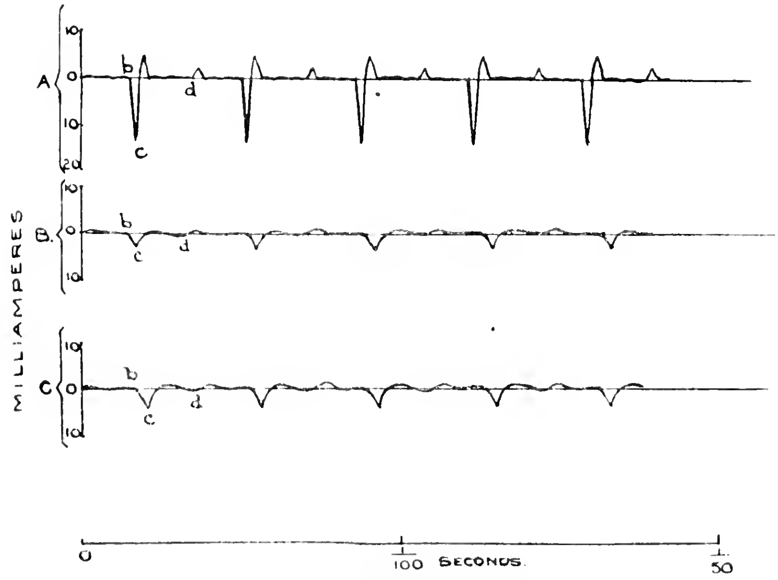


FIG. 9.

Effect of condenser in series with receiver.

17. If a condenser be inserted in series with a receiver, no steady current will flow through the latter, but anything tending to alter the current that would pass through the receiver, in the absence of the condenser, will cause a momentary current to flow into (or out of) the condenser. Thus, anything that would produce a varying current in the receiver when no

condenser is inserted will still produce a varying current when a condenser is inserted. The shape of the current curve, and therefore the quality of the sound produced, may be slightly altered, but the frequency and the general characteristics remain the same. The insertion of the condenser does not. therefore, materially affect the vibrator signals.

Fig. 9 shows the current curves in three different cases when the condenser in the base of the vibrator is in the circuit. Curve A is when the vibrator is connected through its own receiver, but no other resistance. Curve B shows the current at the end of a line of 200 ohms resistance as well as the receiver, and a capacity to earth of 1 microfarad. Curve C with 300 ohms resistance and $\frac{1}{3}$rd microfarad between line and earth. The curves are all drawn to the same scale (compare Fig. 3).

Effect of Morse on vibrator signals.

18. The above shows that a circuit connected up as shown in Fig. 10 will enable the sounder to work irrespective of the vibrator, but the effect of the sounder signals on the receiver has not yet been considered. When the key at "A" is depressed there will be a rush of current into the condensers, and therefore through the receivers. The loudness of the resulting noise depends on the suddenness of the rush of current, and this depends on the rate at which the current in the line at the point to which the condenser is connected rises or falls. This depends, again, on the capacity and self-induction of the circuit between this point and the battery. If there be neither capacity nor self-induction in the line, the current will rise and fall suddenly, as shown by the curve "a," Fig. 11. If there is any considerable capacity in the line between A and B (Fig. 10), a portion of the current will at first flow into this condenser, and the rate of growth of the current in the line at B will at first be slow, as shown in curve "b" (Fig. 11). If there is self-induction between A and B, and no capacity, the current will rise rapidly at first and then slower, the curve being as shown at "c." When both self-induction and capacity are present, the current will rise and fall as shown by curve "d." In each case the ultimate value of the current will be the same, provided that the E.M.F. and resistance are not altered.

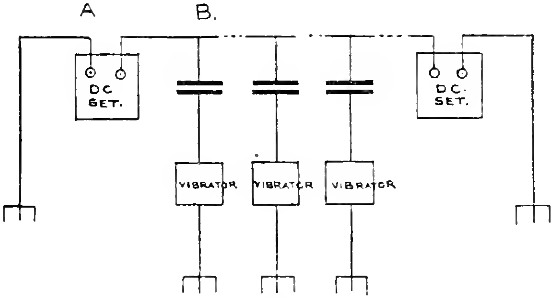


FIG. 10.

It will be seen that curve "d" is the one that shows the most gradual rise and fall in the current, and therefore is the arrangement that will least affect the receiver of the vibrator ; if the capacity and self-induction are of the proper value, the effect of the Morse working will be insufficient to interfere with the vibrator working. As every line has a certain amount of capacity and self-induction, it may be found that, if the Morse set is at a distance, it will not interfere with the vibrator, and in any case the interference will be less the farther the Morse set is from the receiving vibrator office.

If the Morse and vibrator sets are in the same office, or close together, the necessary capacity and self-induction must be inserted as shown in Fig. 14. As vibrator currents do not pass readily through a circuit possessing much self-induction, special self-induction *must not* be inserted between two vibrator offices, but *must* be inserted between the vibrator and the Morse.

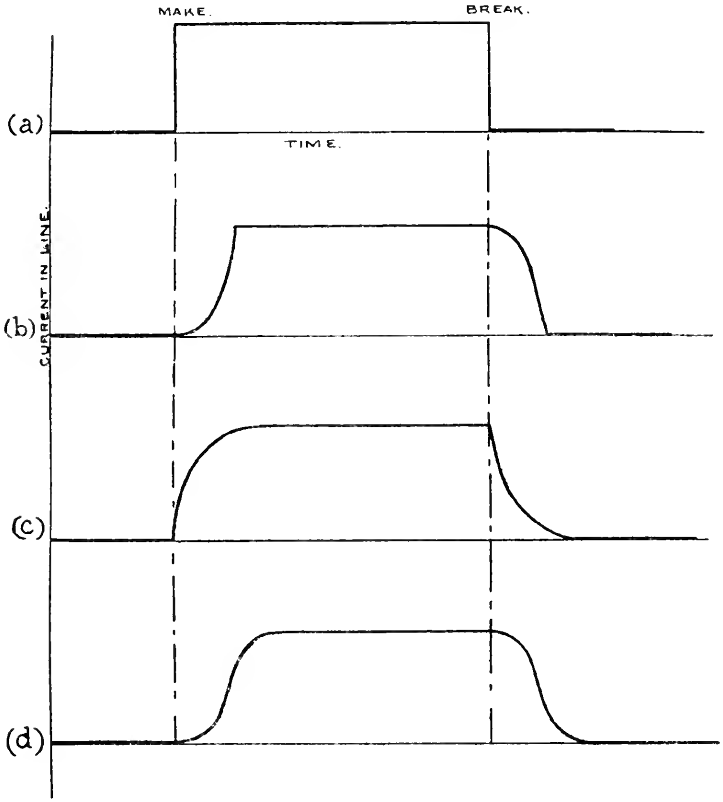


FIG. 11.

If there is an intermediate Morse office between two vibrator offices, the self-induction of the Morse relay, &c., will weaken the vibrator signals when that office is not sending, but not when it is sending ; the intermediate Morse sets should therefore be shunted with a condenser (*see* para. 23) : this allows a free path for the vibrator currents, irrespective of whether the Morse office is sending or not.

The above applies whether the Morse sets in use are D.C. or S.C., simplex, duplex, or quadruplex. It is, however, practically impossible to work a vibrator on the same line as a high speed Wheatstone automatic. The currents in this case alternate so rapidly that they cannot be modified so as not to affect the telephone receiver without at the same time reducing the speed of working to almost key speed. It may even be found impossible to work vibrator over any considerable distance on a line running on the same poles as one forming part of a Wheatstone circuit.

Conditions for simultaneous working.

19. We see from the above that the following conditions are necessary for simultaneous sounder and vibrator working on the same line :—

(*a*) There must be a condenser in series with each vibrator, to avoid putting an earth fault on the line.

(*b*) There must be a certain amount of capacity and self-induction in the line between the Morse and vibrator sets, and it is usually necessary to insert this specially.

(*c*) There should be as little self-induction as possible in the vibrator circuit.

Separator, field service, Mark II.

20. The necessary self-induction is provided in practice by an electro-magnet of 200 ohms resistance. This electro-magnet and two condensers are contained in the "Separator, field service." The pattern now in use is Mark II. This consists of a wooden box with an ebonite top, on which are two rows of four terminals each (Fig. 12). The four terminals in the front row are marked "V," "L," "M," and "E" respectively. These terminals are connected to the corresponding back terminals by four "lightning choking coils," each consisting of 6 feet of "S 11" wire, coiled into a spiral, and enclosed in a rubber tube. These coils possess a small amount of self-induction which, while too small to affect the vibrator signals, is sufficient to offer a considerable "impedence" to a lightning flash. Between the back (unmarked) terminals "V" and "L" is connected a condenser of $\frac{1}{10}$ microfarad capacity, and between the back terminals "M" and "E" one of $\frac{1}{3}$ microfarad. Between the back terminals "L" and "M" is connected the electro-magnet of 200 ohms resistance, jacketed with iron to increase its self-induction. The connections are shown in Fig. 13. The $\frac{1}{10}$-mf. condenser is intended for inserting between the line and the vibrator, and the $\frac{1}{3}$-mf. condenser for modifying the Morse currents.

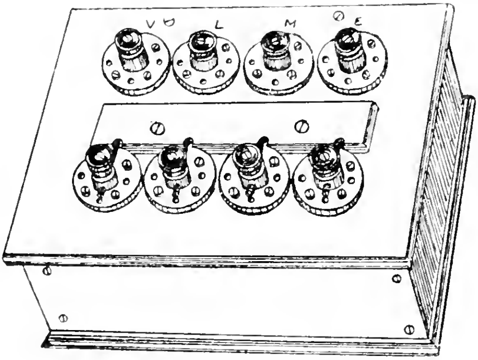


FIG. 12.—Separator, F.S., Mark II.

The eight terminals are mounted on circular metal plates, undercut, the plates in each row being spaced $\frac{1}{32}$ inch apart. The object of these is to act as a lightning discharger, the discharge jumping from plate to plate, and so to earth (either direct, or through the discharger of one of the sets) in preference to going through the "lightning choking coils" and the condensers. The plates can be revolved so as to present a fresh portion of the edge to the adjoining plates in the event of their being damaged by a discharge. The plates on the back terminals can be substituted for the front plates if the latter are damaged.

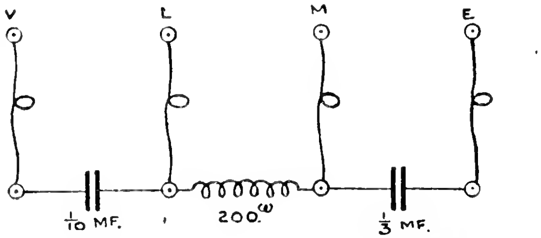


FIG. 13.—Internal Connections of "Separator, F.S., Mark II."

Care should be taken that dust, dirt, &c., do not short circuit the plates. The connections should be made on the marked terminals.

Details.

21. The electro-magnet is wound to a resistance of 200 ohms (within 2 per cent. at 60° Fah.) with double silk covered wire, No. 35 S.W.G., the coil ends being of No. 26 S.W.G. The core and jacket are of Swedish soft iron. The condensers are made of tin foil, insulated with mica, and are coated with paraffin wax after being fitted in the box. The capacities should be correct to within 5 per cent. The lightning choking coils are led into a hole in the pillars of the terminals, and fixed by a small screw. The leads from the condensers are brought through the top of the box and connected to the unmarked terminals. The electro-magnet is connected to the plates of the two centre unmarked terminals.

Connections of separator, vibrator, and Morse sets.

22. Fig. 14 (a) shows the theoretical and (b) the actual connections of two Morse offices, with vibrators and separators for simultaneous working with one or more intermediate vibrator offices (Fig. 14 should be compared with Diagram A, Chap. XVIII, p. 242). If one or both of the Morse offices were intermediate, the connections would be altered as indicated in the figure, provided it was not required to work the vibrator on the farther portions of the line. It should be noticed that a separator is required at each Morse office, and at these offices the condenser in the base of the vibrator is not required. At intermediate vibrator offices no separator is required when the "Vibrator, telegraph" is used,*

---

* If the condenser is damaged the instrument can still be used, but the connections must be as given below for the "Transmitter, vibrating."

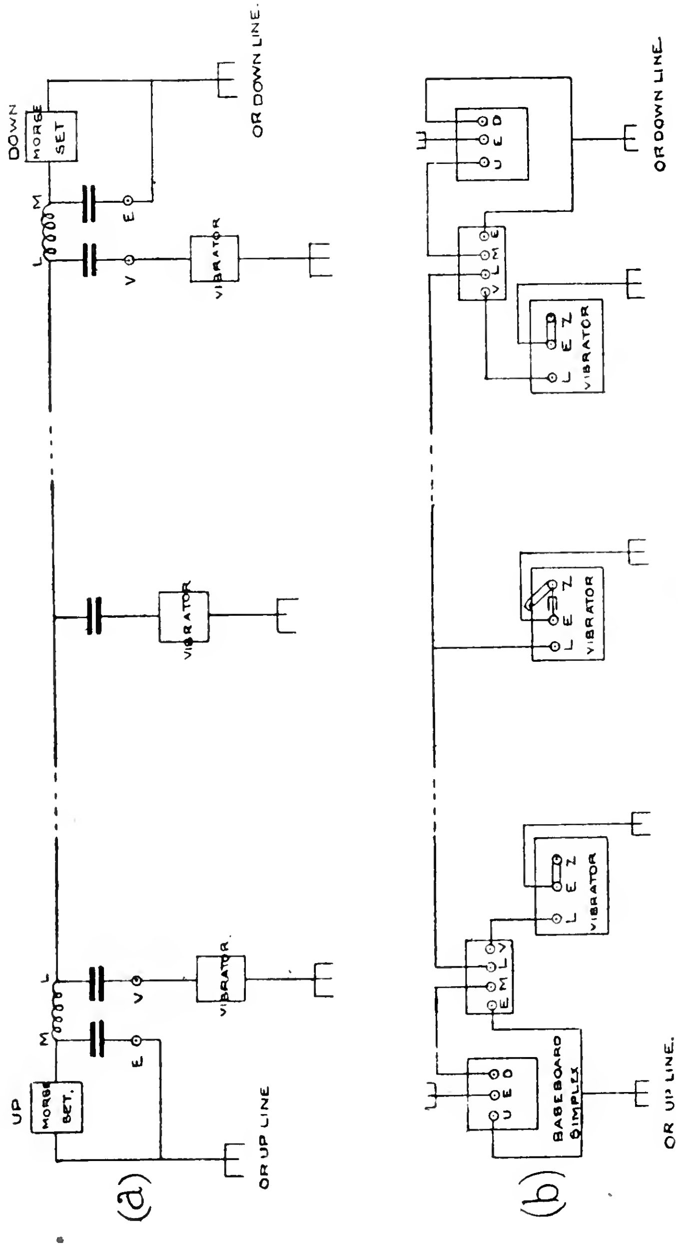

DOWN
MORSE SET
OR DOWN LINE
M
L
E
V
VIBRATOR
VIBRATOR
VIBRATOR
L
M
V
E
UP
MORSE SET.
OR UP LINE
(a)
OR DOWN LINE
U E D
V L M E
L E Z
VIBRATOR
L E Z
VIBRATOR
L E Z
VIBRATOR
V L M E
U E D
BASEBOARD SIMPLEX
OR UP LINE.
(b)

FIG. 14

but terminals "E" and "Z" must be disconnected by moving the copper strap. It is not necessary to cut the line at these offices.

If a "Transmitter, vibrating," is used at the intermediate office, a separator (or separate condenser) is required, terminal "L" of the separator being connected to line and "V" to the transmitter. Terminals "M" and "E" are not required, though it may be desirable to connect terminal "E" to earth as a protection against lightning.

Connections of separator at intermediate Morse office.

23. Diagram B, Chap. XVIII (p. 245) shows the normal connections at an intermediate Morse office when it is required to work vibrator through it. This provides a path round the Morse set, free from self-induction, and at the same time modifies the Morse currents. It will be noticed that these connections are not possible with the "Transmitter, vibrating," unless two separators are available. If only one separator is available it is generally best to connect up as shown in Fig. 15

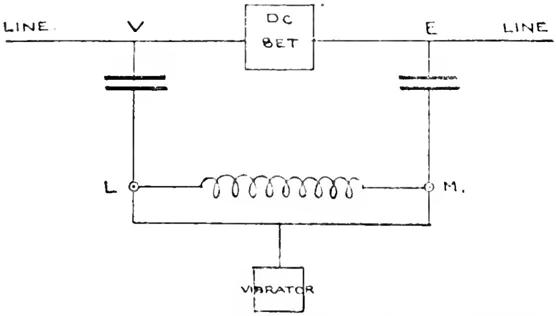


FIG. 15.—Separator and Transmitter, Vibrating, at intermediate Morse Office.

In this case the terminals "L" and "M" of the separator should be joined by a piece of wire. This arrangement provides a free path for the vibrator currents round the Morse set, and prevents an earth fault, but the Morse currents may interfere with the vibrator when the intermediate Morse is sending and the vibrator at the same office receiving. As a rule, however, this will not matter, as the vibrator will generally only be required when the line is being used for through Morse working.

If it is required to establish local communication by means of vibrator offices on a main line, the vibrators should be "tee-ed" in through a condenser, as shown for the intermediate vibrator office in Fig. 14. If the Morse offices on either side are not provided with separators, the Morse signals may be found to seriously interfere with the vibrator working. In this case it will be necessary to cut the line at the two terminal vibrator offices, and insert a separator, as shown in

Fig. 16; the earth connections shown dotted will usually not be required, care being taken that the coil of the separator is inserted in the main line *outside* the portion in use for the vibrator circuit. The intermediate vibrator offices should be connected with a condenser only.

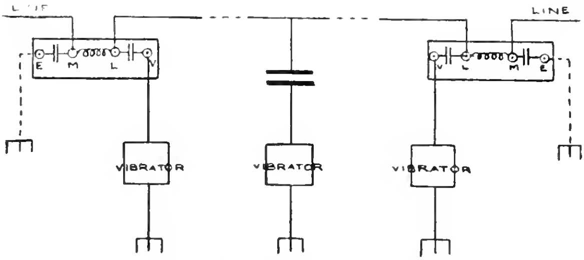


FIG. 16.—Local Vibrators on through Morse Line.

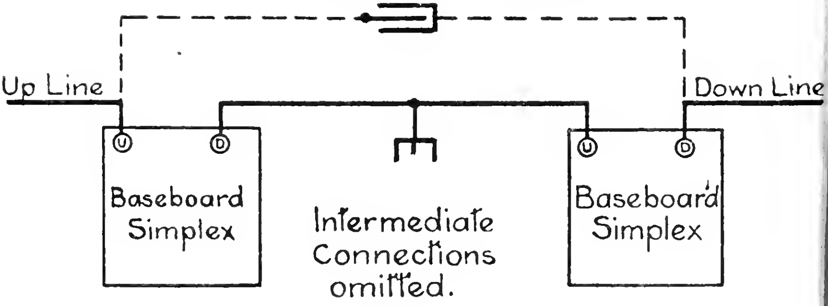


FIG. 17.

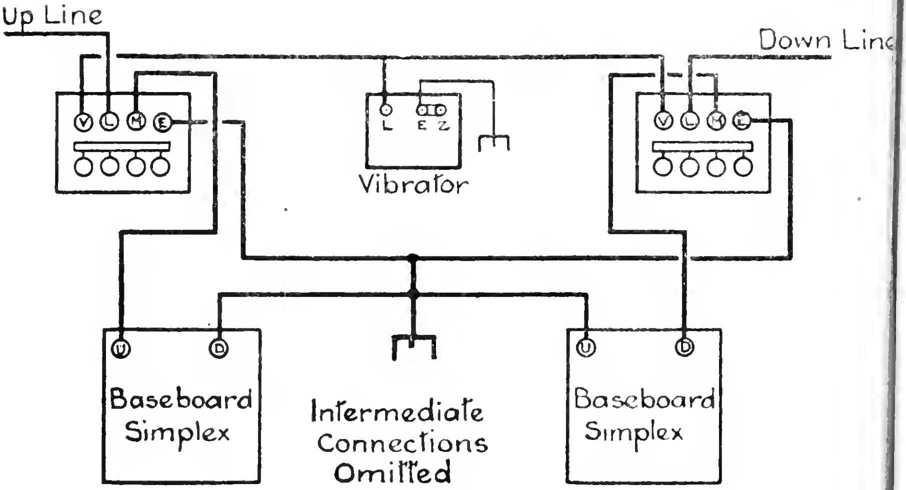


FIG. 18.

If it is required to work vibrator through a translating station, the up and down lines must be connected through a condenser (Fig. 17). If a vibrator is required in circuit at the translating station, the connections are as shown in Fig. 18. and two separators are required.

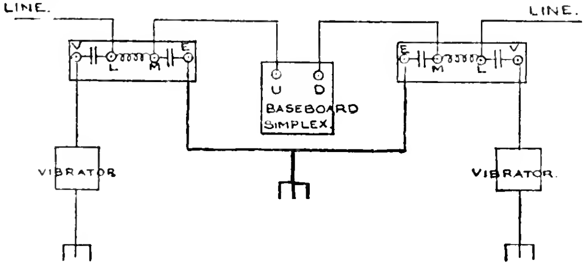


FIG. 19.

If it is desired to work vibrators at an intermediate office in both directions on the same line, independently, the connections shown in Fig. 19 will often enable this to be done. Three separate earths should be used, and kept as far apart as possible.

CHAPTER XVI.

SUPERIMPOSING.

1. Superimposing means the utilization of an electrical circuit for the simultaneous transmission of signals by two or more methods. The examples of this most used in military work, viz., simultaneous sounder and vibrator, or sounder and telephone (phonopore), working on a single line, have been dealt with in Chaps. XV and XII respectively.

It was explained in Chap. I, para. 52, that it is generally necessary, in order to ensure good speaking, to use a metallic circuit for telephone working where the lines run on the same poles as telegraph wires, and that it may be quite impossible even to work vibrator in such a case, if one of the wires forms part of a Wheatstone circuit. The methods described in this chapter enable a metallic circuit being used for telephone working, thus getting rid of 'inductive disturbances, while at the same time one or both of the lines is used for telegraph working. It is, however, impossible to use one of these wires for high-speed automatic working, owing to the fact that it is necessary to include inductive resistances in the telegraph part of the circuit, and to the great difficulty in the prevention of interference with the telephone.

There are two main methods of simultaneous telegraph and telephone working :—

(*a*) By modifying the telegraph signals so that they will not interfere with the telephone.

(*b*) By means of bridging coils or transformers, acting on the principle of the Wheatstone's bridge (Chap. XX).

The methods already explained are examples of (*a*).

Van Rysselberghe's system.

2. A system known as Van Rysselberghe's, largely used in Belgium, enables a telephone circuit to be superimposed on two telegraph lines, each of these lines being still employed for telegraph work. This method is shown in Fig. 1, the telegraph sets at C and D being exactly similar to those at A and B. It will be seen that the principle is exactly the same as that of the service separator when used with the vibrator, and that the telegraph circuits cannot interfere with each other, owing to the condensers inserted in the lines. The condensers inserted in the line have a capacity of $\frac{1}{2}$ microfarad, those in the telegraph set 2 microfarads. Two impedence coils, each of 500 ohms resistance, are used at each telegraph set, as shown. If para. 18, Chap. XV, be referred to, it will be seen that the effect of the Morse signals on the telephone will be even less in this case

than in that shown in Fig. 14, Chap. XV, partly owing to the inductances and capacities used being larger and partly because the telephone receiver is not connected direct to earth.

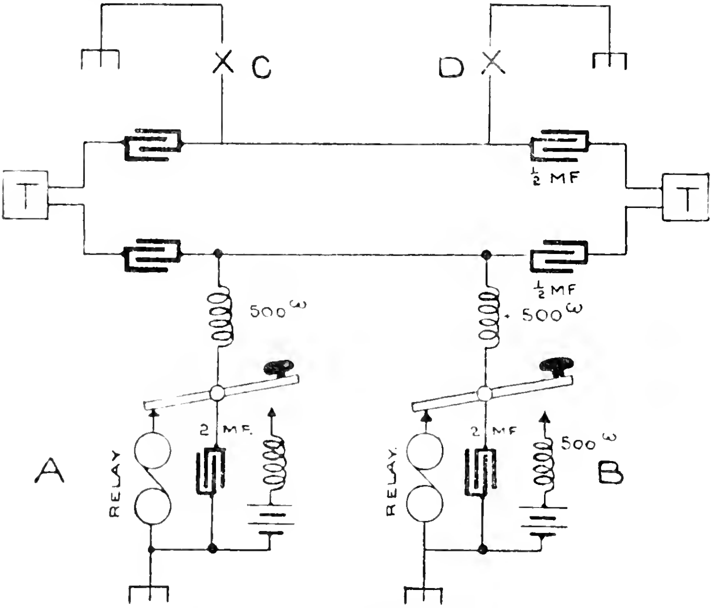


FIG. 1.—Van Rysselberghe's System.

The calling on the telephone circuit cannot be done with the ordinary generator, as this would interfere with the telegraph working, and either a buzzing call must be used or a low frequency current from an induction coil actuating a special and extremely sensitive form of relay.

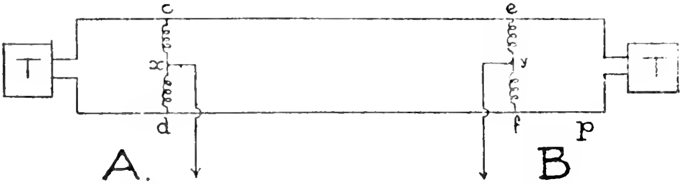


FIG. 2.—Use of Bridging Coils for Superimposing.

Use of bridging coils.

4. The use of bridging coils for superimposing is shown in Fig. 2. The insertion of the bridging coils does not affect the speaking, owing to their high self-induction. The current from the telegraph instrument at A divides at x into two parts, which reunite at y and return through the telegraph instrument

at B and earth. If the two portions of the circuit are alike in all respects, the current will divide into two equal parts, and the points c and d will always be at the same potential as far as the telegraph instruments are concerned. Similarly the points e and f are always at the same potential. Consequently the telephone instruments will not be affected by the telegraph currents. It is not sufficient that the two paths $x\,c\,e\,y$ and $x\,d\,f\,y$ should merely have the same resistance; they must also have the same capacity, self-induction, and insulation, or the currents due to the telegraph working will not rise and fall at the same speed in the two branches, and the points c and d will not *always* be at the same potential. It is seldom possible in practice to make the portions $c\,e$ and $d\,f$ absolutely similar, but the portions $x\,c$, $x\,d$, $e\,y$, and $f\,y$ can be made so, and as a large proportion of the total resistance and self-induction in the circuit is in these portions, a small difference between $c\,e$ and $d\,f$ is not of such great importance.

It will be seen, however, that a small earth fault between the bridging coil and the telephone (say at p) will at once cause a portion of the telegraph current to pass through the telephone, and will thus prevent good speaking. This method, therefore, is not suitable for use when the telephones are at any distance from the bridging coils, as would be the case, for example, if the wires were used as a junction circuit and extended to other lines through an exchange.

The translator described in Chap. XIII, para. 30,* can be used as bridging coils for this purpose, and in this case the terminals marked S, S, and C, in Fig. 24, Chap. XIII, are used. A common value for the resistance of the bridging coils is 150 ohms each, *i.e.*, resistance $c\,x$ (Fig. 2) is 150 ohms, and resistance $c\,d$ is 300 ohms.

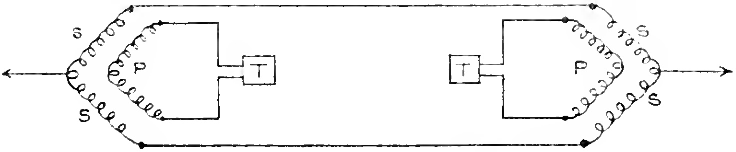


FIG. 3.—Use of Translator.

Use of translator.

5. The method of using translators, or transformers, is shown in Fig. 3. The telegraph currents divide as before, but as the two halves of the secondary winding *s* of the translator oppose each other there is no magnetic effect, and therefore no current is induced in the primary, *i.e.*, in the telephone portion of the circuit. As far as the telephone is concerned, the translator acts as an ordinary induction coil. The calling must be done by a generator, or by a buzzing call.

---

* See also para. 8 of this Chapter.

This method has the advantage that an earth fault in the line between the translator and the telephone does not cause the telegraph currents to interfere with the speaking; it is therefore the preferable method when the telephone circuit is liable to be extended over other lines. On the other hand, the insertion of a translator in the telephone circuit reduces the loudness of the speaking.

The translator may also be usefully employed when an earthed telephone circuit runs a portion of the way on a main route and then branches off. The inductive disturbances will be mostly produced on the main route, and they can be eliminated as shown in Fig. 4.

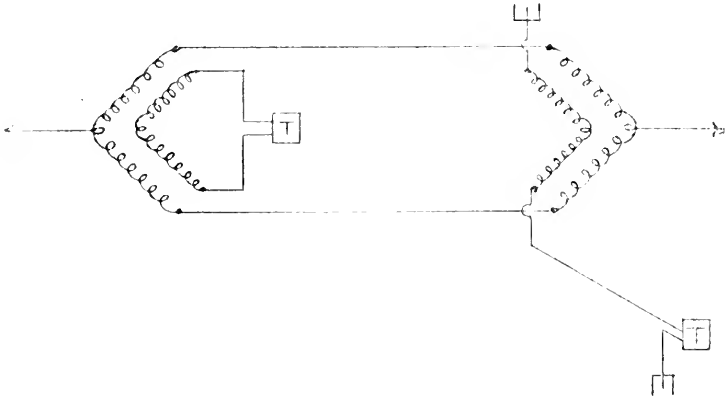


FIG. 4.

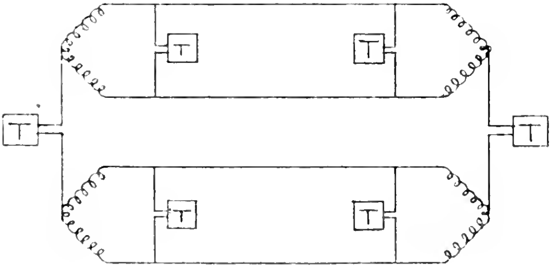


FIG. 5.

Elimination of induction.

6. It should be noticed that to obtain the full benefit of the metallic circuit for the telephone in the above described methods of superimposing, this circuit should be constructed as described for telephone circuits in Vol. II, *i.e.*, the wires must be of the same material and gauge, have equal insulation, and they should preferably be "revolved," or at any rate "crossed." If this is not attended to the speaking will not be good.

Multiplex telephony.

7. Translators, or bridging coils, can also be used to superimpose a third metallic telephone circuit on two existing circuits, *i.e.*, to enable four wires to furnish three good metallic telephone circuits. Fig. 5 shows the arrangement which is adopted on some of the Post Office trunk lines. All the four wires used must be of the same material, gauge, &c., to ensure satisfactory working.

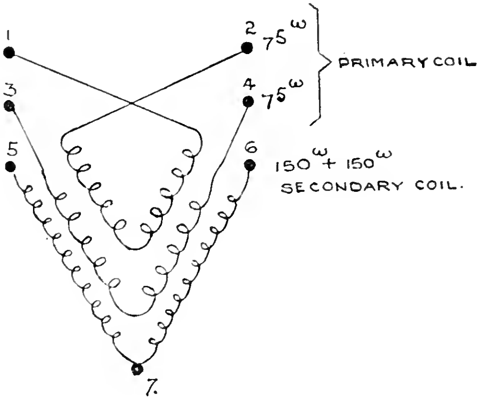
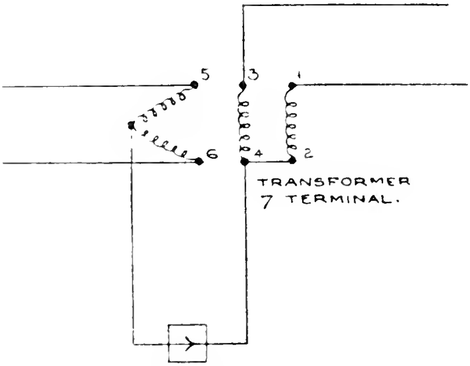


FIG 6.

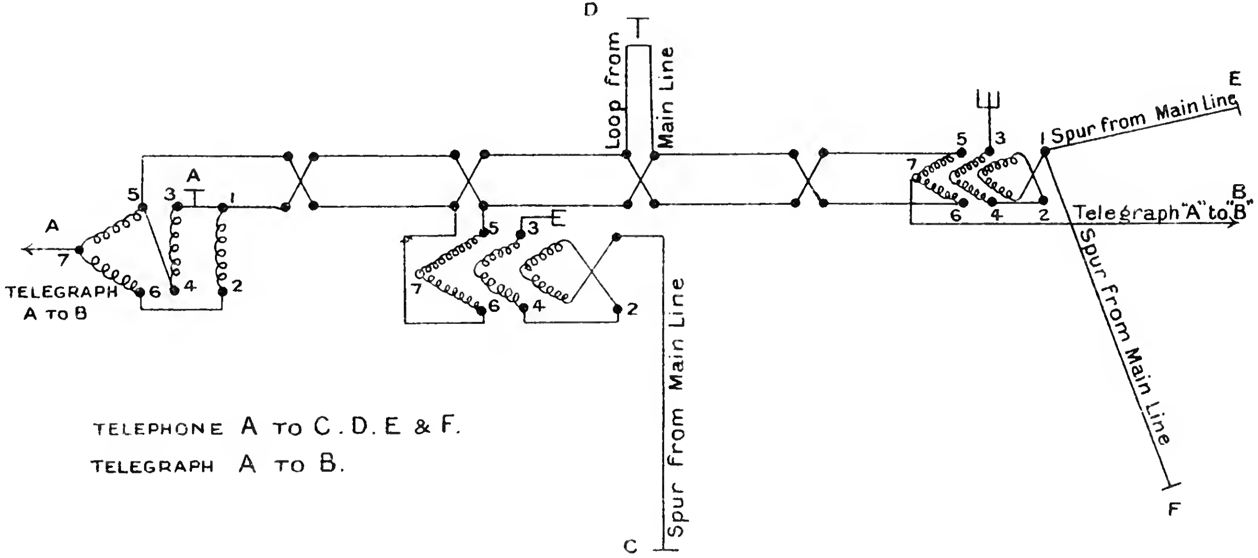


TELEGRAPH SET.

FIG. 7.

8. Since the above was written it has been decided to introduce a transformer as a service store, under the nomenclature "Transformer, telephone." This transformer is provided with seven terminals, which enables it to be used for a variety of purposes. The terminals are connected as shown in Fig. 6. The coils between terminals 5—7 and 7—6 have a resistance of 150 ohms each, those between 3—4 and 1—2 of 75 ohms each.

Figure 8 Chapter XII



TELEPHONE A TO C. D. E & F.
TELEGRAPH A TO B.

H & C GRAHAM LTD, LITHRS, LONDON, S.E

To face p. 233.

When used as a 4-terminal transformer (*see* para. 30, Chapter XIII, and para. 5 of this chapter), terminals 2 and 4 are joined by a piece of wire, terminals 1 and 3 are used as the primary coil, and terminals 5 and 6 as the secondary; terminal 7 is not used.

When used as bridging coils (para. 4), terminals 1 and 3 are used as the ends of the bridging coils, and 7 as the centre point: 4 is joined to 5, and 2 to 6, thus forming a bridging coil of $225^{\omega} + 225^{\omega}$.

When used as a 5-terminal transformer (para. 5), terminals 2 and 4 are connected together, 1 and 3 to the telephone, 5 and 6 to the lines, and 7 to the telegraph set.

Fig. 7 shows how this transformer can be used to insert an intermediate telegraph office where the telegraph circuit is superimposed on a telephone circuit.

Fig. 8 shows another use of this transformer.

Other applications.

9. Other applications of the methods described above are sometimes employed, but as they are not likely to be of much military use they are not described here.

CHAPTER XVII.

PROTECTION FROM LIGHTNING, AND POWER CIRCUITS.

Lightning Dischargers.

Lightning discharge.

1. A lightning discharge consists of an oscillating current with a high frequency, and with an enormously high E.M.F. or potential, and occurs when the difference of potential between a cloud and earth, or between two clouds, is sufficient to break down the insulation of the air between them. The spark or lightning flash thus produced may actually strike a telegraph pole, or wire, or may induce a similar current in the wire.

A lightning discharge has thus all the properties of the vibrating current used in the vibration system (Chap. XV), only to a far greater extent. Owing to its enormous potential, the energy in a lightning flash is very large, and it is capable of doing a large amount of damage to telegraph instruments, and even to the office. The high potential will force the flash through very high resistances, if such occur in its path, but owing to the rapid oscillations it will not pass through a circuit having self-induction; if a flash passing along a wire comes to a coil having any appreciable self-induction, it will not pass round the coil, but will break through the insulation and take the shortest and straightest path to earth.

Principles of lightning dischargers.

2. We see from the above that if we provide a path to earth which has a small self-induction, the lightning will pass through it in preference to passing through the instruments, even if the path has a very high resistance. The simplest way of doing this is to provide a path to earth containing a small air gap, either between points or plates of metal or carbon, or the plates may be separated by a slight insulation such as cotton, silk, mica, or paper, sufficient to prevent the ordinary telegraphic currents from passing.

If a small coil be added on the instrument side of the gap the protection is increased.

All "protectors" or "dischargers" are made on the above principles, and in fitting them up it should be remembered that small self-induction is far more important than low resistance in the path the discharge is intended to take; in other words, the earth leads from the discharger should be as straight as possible, and should contain no turns or coils.

A type of discharger that is fitted to many commercial telephones, &c., consists of two metal plates, with serrated edges placed side by side with the serrations just not touching, one plate being connected to the line, and the other to earth.

The service types will be described in detail: all commercial patterns are more or less similar.

Discharger, lightning, circular, Mark I.

3. The "discharger, lightning, circular, Mark I" is supplied either mounted on a wood base or unmounted, and is illustrated in Fig. 1. It consists of two circular brass plates about $2\frac{1}{4}$ inches diameter, separated by a thin perforated mica disc.

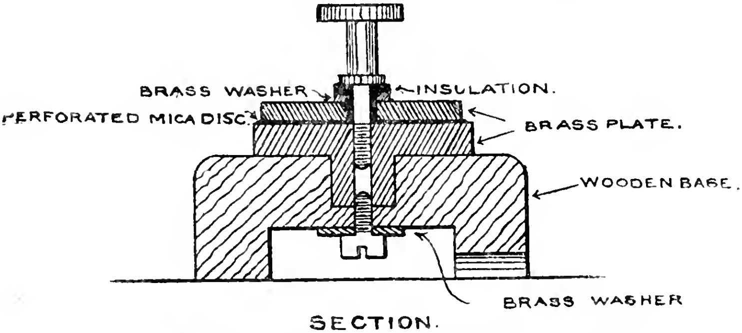


FIG. 1.—Discharger, Lightning, Circular, Mark I (Mounted).

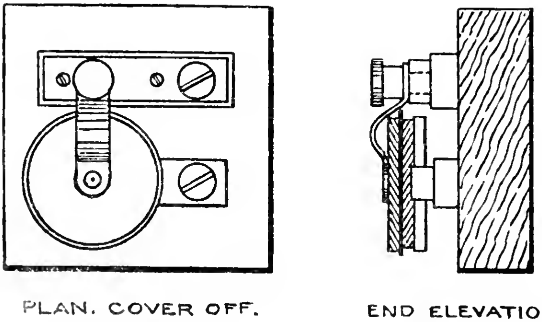


FIG. 2. -Discharger, Lightning, Circular, Mark II (Mounted, Single).

The plates are held together by a screw, which is insulated from the upper plate by an ebonite bush, and screws into the lower plate. The line wire is placed under this bush in contact with the upper plate, and the earth wire is attached either above the bush to make contact with the screw, or to the lower screw, which attaches the lower plate to the base.

Discharger, lightning, circular, Mark II.

4. The "discharger, lightning, circular, Mark II" has two circular carbon discs about $1\frac{1}{3}$ inches diameter, separated by a similar mica disc, and held together by a spring (see Fig. 2); the line and earth wires are connected to the screws shown.

The dischargers are supplied unmounted and mounted single, or mounted double, the mounted dischargers being provided with a wood cover. This pattern is also used by the Post Office.

In both the above forms of protector, the plates are liable to make contact after a discharge, owing to the metal fusing, or the carbon dust falling between the plates. Consequently an earth fault may occur after a discharge, and must be removed by separating the plates and wiping them.

Care should be taken that only one mica disc is used with each discharger.

Discharger, lightning, bobbin, Mark I.

5. The "discharger, lightning, bobbin, Mark I" is used with most of the service field pattern instruments, and consists of a metal reel—(*see* Fig. 3)—on which are wound a few turns of silk-covered wire. This wire forms a portion of the line circuit. The bobbin is connected to earth by being screwed on to an earthed plate, forming part of the set with which it is used. A lightning discharge will break through the insulation to earth, and may even fuze the wire and thus put the line to earth and disconnect the instrument. This discharger is very efficient, and also very compact, but has the disadvantage of usually putting a fault on the line when it acts. It is, however, very easily replaced; a spare bobbin is always supplied, and also a reel of wire for rewinding. The wire used is known as "Wire, electric, W3"; 52 inches are wound on each bobbin.

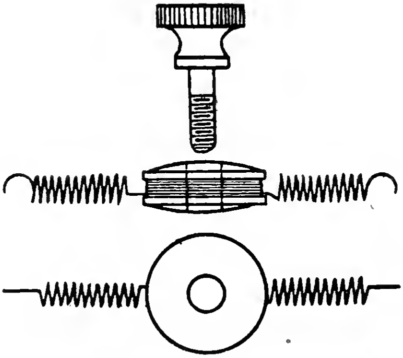


FIG. 3.—Discharger, Lightning, Bobbin, Mark I.

Dischargers, lightning, vacuum, Mark I.

6. The "discharger, lightning, vacuum, Mark I" consists of two wires sealed into an exhausted glass bulb, with their ends about $\frac{1}{32}$ inch apart. One wire is connected to line and one to earth. These dischargers are very efficient, but expensive both in first cost and in maintenance. They are usually destroyed when a discharge takes place. They are used with "Boxes, Test, Pole, E" (Vol. II), where dust or moisture

would be liable to cause faults on plate dischargers. They can also be used with "Boxes, ebonite, batten."

Great care must be exercised when fixing them not to strain the glass tube.

These protectors should be tested at regular intervals of about a month, and also after heavy storms. It is most convenient at these tests to remove the whole of the protectors to the headquarters of the person testing, and replace them by protectors previously tested.

Testing vacuum dischargers.

7. "Coils induction, for testing vacuum lightning dischargers," are provided for testing. The coil is worked by one large Leclanché cell (*e.g.*, A, Mark III, or Dry A) of low resistance. The adjustment of the contact-breaker should be such that when the contact point is withdrawn the face of the armature may be practically parallel with the end of the coil, and at a distance from it of about $\frac{1}{32}$ inch.

The contact point being replaced, a piece of stiff bare copper wire, about 3½ inches long, and pointed by the end being nipped off at an angle, should be clamped by the left-hand secondary terminal so that its point may be $\frac{1}{8}$ inch from the centre of the face of the block of the right-hand terminal. A continuous series of sparks should then pass between the point and the block when the key is depressed. This will insure the coil being in good order. The length of the spark should not much exceed $\frac{1}{8}$ inch. The length of the spark can readily be adjusted by varying the length of the conductors used to connect the cell.

To test a protector, it is fitted across the secondary terminals of the coil and the key depressed, when a steady blue glow in the tube shows that it is in good order. The test should be carried out in a dull light in order that the glow may not be obscured.

If there is no glow, or if sparking appears in the protector, the tube must be treated as faulty. If the coil is in use for some time, the sparking distance should be verified at intervals, as the cell polarizes rapidly.

Protection against Power Circuits.

8. Where telegraph or telephone wires run close to or crossing electric power circuits, *e.g.*, electric tram trolley wires, there is the possibility of current from such circuits getting on to the wires, either by leakage, or by direct contact owing to broken wires. These currents may damage instruments, or even in some cases start a fire.

Lightning discharges afford no protection against such currents, and "fuzes" and "heat coils" are used.

Fuzes, tube, 2-inch.

9. The fuze, tube, 2-inch (Fig. 4), consists of a thin platinum wire, about 5 mils thick and 2 inches long, contained in an insulated tube of glass or fibre. When a current

of 2¼ amperes, or over, passes, the wire melts and disconnects the instrument. The tube has a metal cap at each end to which the wire is soldered, and these make contact with the spring clips of the "cut-out." If the fuze cannot be otherwise readily removed from the clips, slide it sideways till the ends are clear of the clips, when it can easily be lifted. The fuze is replaced by being pressed straight into position.


Elevation. Section.

FIG. 4.—Fuze, Tube, 2-inch. Full size.

This fuze is used with "dischargers, lightning, D," "links cut out," "insulators, porcelain, fuze, Mark II."

"Fuzes, tubes, 2-inch, with wire extension," are used with insulators, porcelain, fuze, Mark I (*see* Vol. II). They are similar to the fuzes, tube, 2-inch, but have 15 inches of tinned copper wire attached to each terminal cap.

Heat coils.

10. The fuze, tube, 2-inch, protects the instruments from a strong current, but a current that would be strong enough to damage the instruments if long continued might still not fuze the wire. Protection is provided to meet this case by "Heat coils, A," which consists of a metal cylinder, A (Fig. 5), on which is wound a coil of fine insulated wire, B, to a resistance of 25 ohms. One end of the coil is soldered to A, while the other is led through to the grooved piece, C, which is insulated from the bobbin. A ⊤-shaped piece, E, is soldered to the inside of the cylinder with a special soft solder, D. The heat coil is placed in circuit between two German silver springs, which tend to pull the pin, E, away from the coil. The coil is surrounded by fibre. When a current passes through the coil (which is in the line circuit), the solder is heated, and it is so

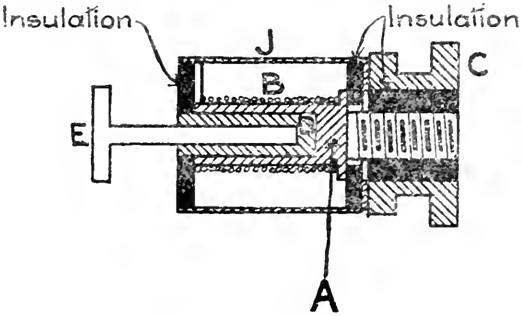


FIG. 5.—Heat Coil. About three times full size.

arranged that a current of about 250 milliamperes will release the pin in about 30 seconds, while a continuous current of 150—160 milliamperes will not release the pin, even after several hours.

"Heat coils, A," are used with "Dischargers, lightning, D."

Dischargers, lightning, D.

11. "Dischargers, lightning, D" combine "Heat coils A" "tubes, fuze, 2-inch," and a small carbon plate discharger, and are illustrated in Fig. 6. They are mounted in pairs on a porcelain base. The carbon discharger consists of two small rectangular carbon plates held by a spring clip, and separated by a U-shaped mica sheet. One of the carbon plates has a small plug of easily fuzible alloy in its face, which on a heavy discharge taking place, or an arc starting, melts, and by connecting the plates puts the line straight to earth.

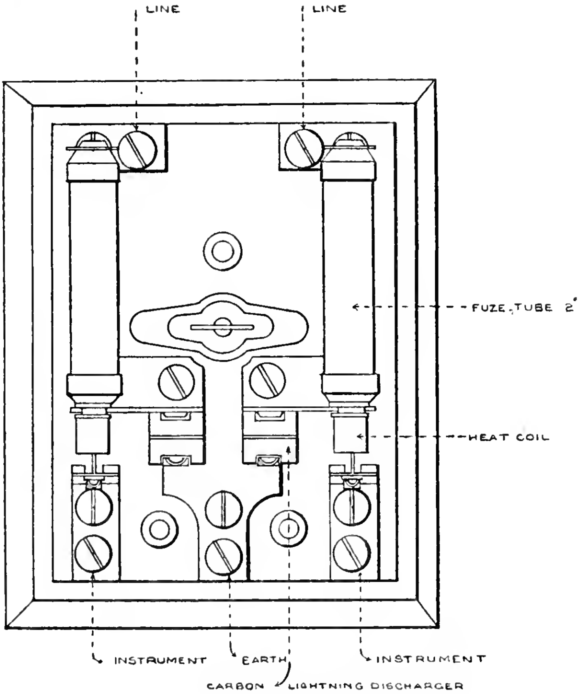


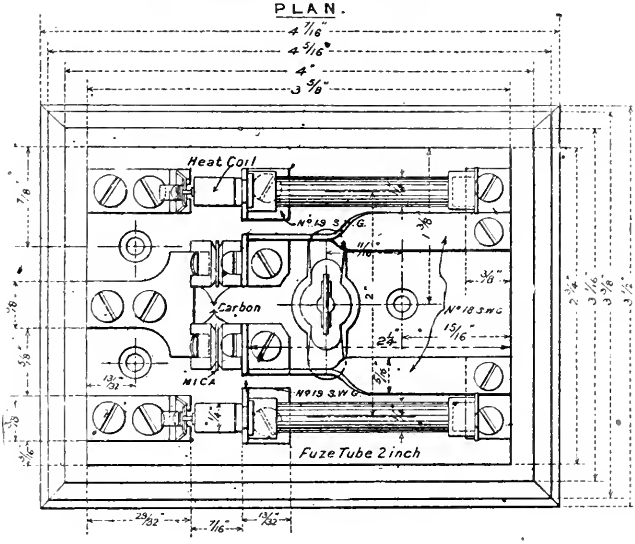
FIG. 6.—Discharger, Lightning, D.

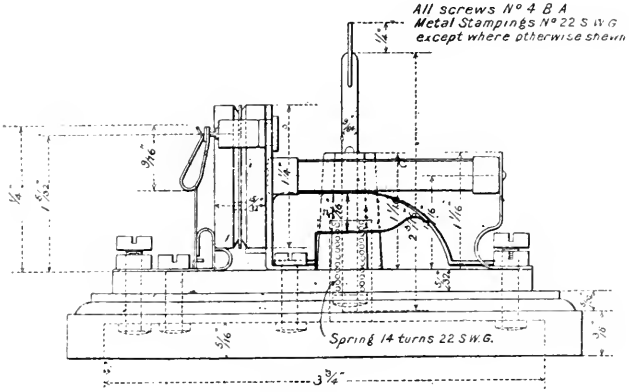
12. "Dischargers, lightning, D," have now been superseded by a pattern called "Protectors, Lightning and Power." The alteration provides a route for the lightning discharge to the carbon discharger without passing through the fuze, and this has been effected by cutting the metal clip which holds one end of the fuze, and one carbon block, into two parts, and by taking an additional

connection from the line terminal to the carbon holder as shown below :—

—DISCHARGER LIGHTNING D MARK I—

PLAN.





ELEVATION, (COVER OFF)

The plain and plugged carbon plates and mica have been re-nomenclated "Dischargers, Lightning—Rectangular," so as to avoid comparison between the complete "Protector, Lightning and Power" and the dischargers contained in it.

The complete article is composed as follows :—

Protectors, Lightning and Power.	Porcelain base with metal fittings and sheet-iron cover, with 2 fuzes (tube 2 inches) and 2 dischargers, lightning, rectangular.

13. Where the circuits are entirely underground, dischargers are unnecessary. Where circuits are partly overhead and partly underground, protection should be given at the junction between overhead and underground work, see Vol. II. Underground circuits.

14. *In all cases the lightning dischargers, and fuzes (if these are required) should be placed as near the leading in point of the wires as possible.* Position of lightning dischargers.

15. When a fuze is found to have acted, no attempt must be made to renew it until it has been ascertained that no source of dangerous current remains in contact with the line wire. Renewal of fuzes.

The readiest means of doing this in the case of a fuze is to connect a piece of stout *insulated* wire to earth, and apply the free end to the line wire on the power circuit side of the fuze. A fuze must be inserted in the test wire as a precaution.

CHAPTER XVIII.

ARRANGEMENT OF TELEGRAPH OFFICES AND TESTING ACCESSORIES.

FIELD TELEGRAPH OFFICES.

1. Telegraph offices established in the field will usually be required to deal with more vitally important work than an ordinary telegraph office working under peace conditions. The work will have to be done often under most trying circumstances. It is, therefore, essential that the training and efficiency of the personnel shall reach a high standard.

It is impossible to insist too emphatically on the necessity for perfect neatness and order in all the arrangements for the office. These will, as far as possible, be made on one system, so that every member of the Army Telegraph Staff can understand at once the arrangements of any office of which he has to take charge.

All instruments in the office, whether in use or not, will be kept in perfect working order.

In temporary offices all leads will be run clear of each other, be stapled down, clearly marked and visible, so that every circuit may be easily traced.

Diagrams of circuits will be kept and corrected to date.

Common faults.

2. Field telegraph offices are specially liable to the following faults and causes of inefficient working:—

(1) *Bad Earths.*—No trouble should be spared in endeavouring to make the office earth as nearly perfect as possible. In most places the Service pattern earth pipe, if inserted in a jumper-hole deep enough to take it up to its head, and kept thoroughly watered, provides a good earth; but sometimes it will be necessary to dig a large hole and bury a larger mass of metal of any sort that is procurable. Particular attention should be paid to the earth at large offices which contain several circuits, and it is a good plan in such cases to run a bare wire to the source of water supply.

(2) *Faulty Lightning Protectors.*—The Service pattern of bobbin lightning protector is very efficient but somewhat sensitive, and is liable to cause an earth fault owing to the silk insulation of the wire burning through on a slight discharge of lightning or cutting through from want of care in handling the instruments. Faults on the lightning protectors are easily detected by testing them, and easily removed as the bobbins can be rewound.

(3) *Loose connections* are a frequent source of intermittent faults and give much trouble. They are easily guarded against.

(4) *Dirty contacts* give much trouble and result from indifferent protection of instruments from dust and weather. Constant care is necessary to keep the instruments clean and to protect them as far as possible.

(5) *Local batteries* exhaust quickly if the relay is not kept correctly adjusted, *i.e.*, with the tongue, when at rest, in contact with the spacing stop and not against the marking stop. Slight incorrect adjustment of the relay in this direction does not, in double current working, affect the signals until the local battery becomes exhausted. The reason of this is, that the current put on the line by a distant office, when it puts its key switch to "send," will bring the tongue of the relay over to the spacing stop. The faulty adjustment is, therefore, frequently overlooked until permanent damage has been done to the battery.

(6) *Batteries* become exhausted through being allowed to rest on damp ground or the battery boxes being allowed to remain wet in damp weather.

Test box.

3. Every telegraph office which has more than one set of instruments in circuit, or more than one line leading into it, requires a telegraph test box. The above term applies to any suitable apparatus to which are attached—

(*a*) The lines entering an office; so that they may be easily identified for testing or other purposes.

(*b*) The office earth lead.

(*c*) The sets of instruments in the office, so that they may be connected to the lines and earth as required.

In permanent offices, all lightning dischargers and battery leads also are often fixed on the test box.

If terminals are available, a test box can easily be extemporized.

Commutator telegraph, 6-line.

4. The form of test box adopted in the Service for field use is the commutator telegraph, 6-line, Mark II, shown in Fig. 1.

Six metal bars, marked 1, 2, 3, 4, 5, 6, cross, at right angles, six other bars lettered A, B, C, D, E, F. Each bar is separated from the bars next to it by an air space, and the upper set of bars is also separated from the lower set of bars by an air space. There are holes in the upper bars above corresponding holes in the lower bars.

Six metal plugs are provided, and by inserting these in the holes, any one of the upper bars may be connected to any one of the lower bars as desired.

Each of the upper (numbered) bars is provided with a binding screw, by means of which a wire can be secured to it. The lower (lettered) bars are provided with binding screws at each end and are bored with two additional holes to take the plugs.

The smaller holes are simply holes in which plugs rest when not in use. The larger holes are bored through the wood base into an additional metal bar, shown dotted, which runs parallel to the numbered bars but underneath the wood base. This bar is permanently connected to another metal bar, "The Earth Bar," which runs along the ends of the upper (numbered) bars. Therefore, by inserting plugs in the larger holes in the lower (lettered) bars, those bars are connected to the earth bar.

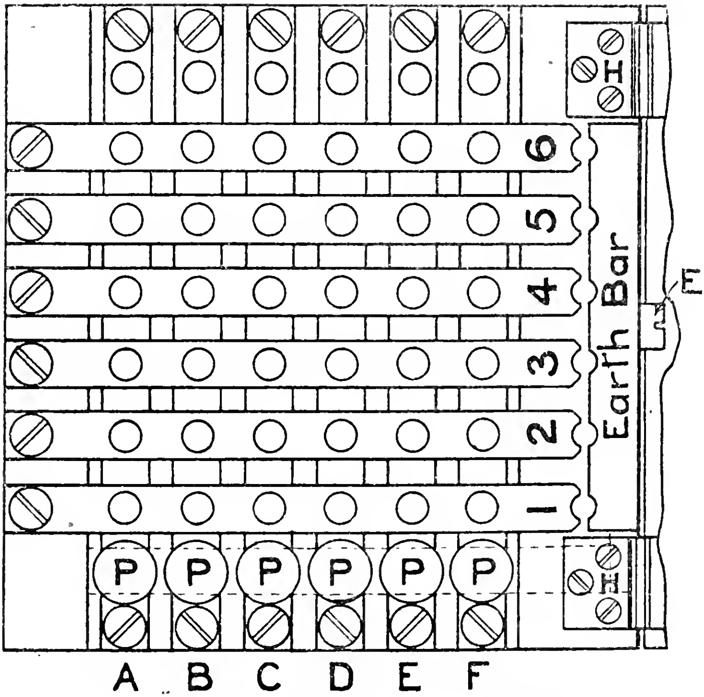


FIG. 1.—Commutator Telegraph, 6-Line, Mark II.

By inserting plugs in spaces provided, the upper (numbered) bars can also be connected direct to the earth bar. The earth bar is provided with a binding screw to take the earth lead.

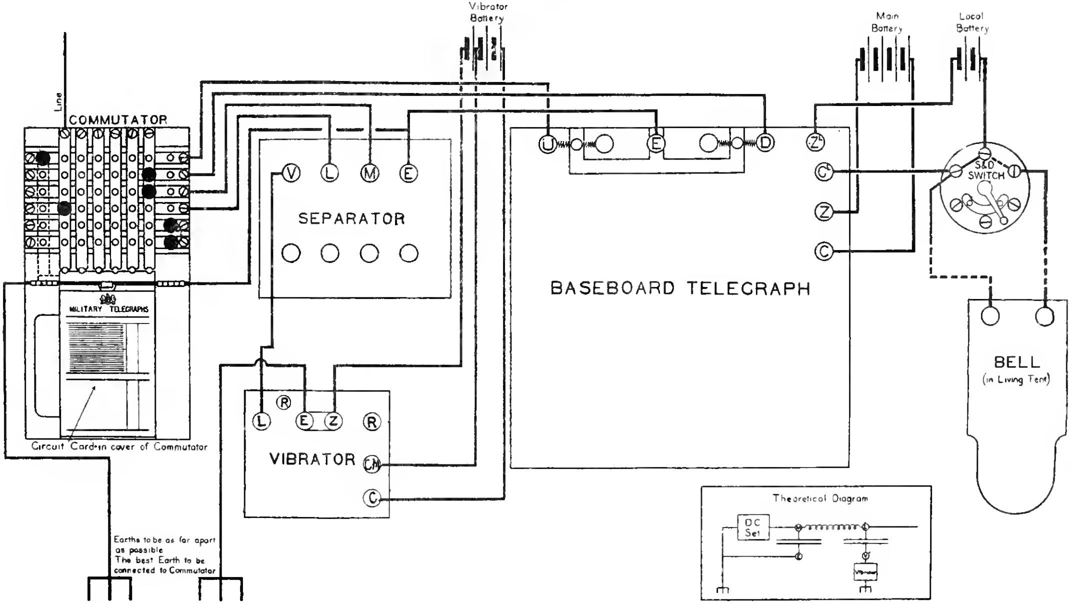
The commutator is intended primarily for use in small telegraph offices, *i.e.*, offices which have not more than three sets of instruments in circuit or six lines coming into them. When more than this number of instruments or lines have to be dealt with, a larger commutator or some other form of test box is required, or two commutators can be joined together.

Arrangement of circuits.

5. The following diagrams are intended both as a guide as to the normal arrangement of circuits and as illustrations of the use of the commutator.

DIAGRAM "A"

2ND CLASS OFFICE SET – DIAGRAM OF NORMAL CONNECTIONS – TERMINAL UP STATION

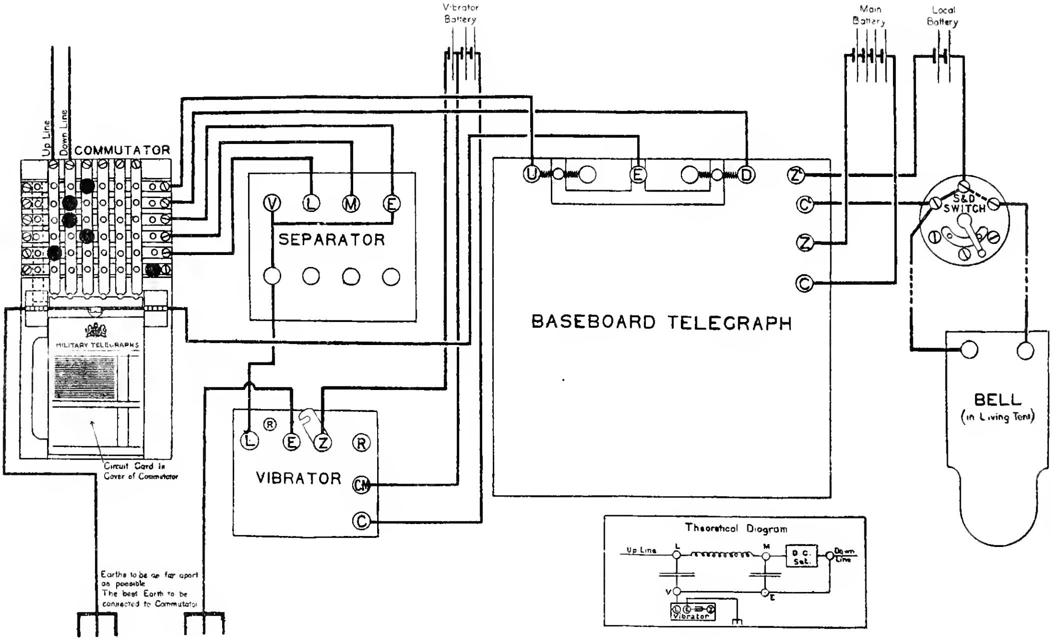


To face p 242.

H & C GRAHAM LTD LITHRS LONDON S.E.

DIAGRAM "B"

2ND CLASS OFFICE SET. DIAGRAM OF NORMAL CONNECTIONS. INTERMEDIATE STATION



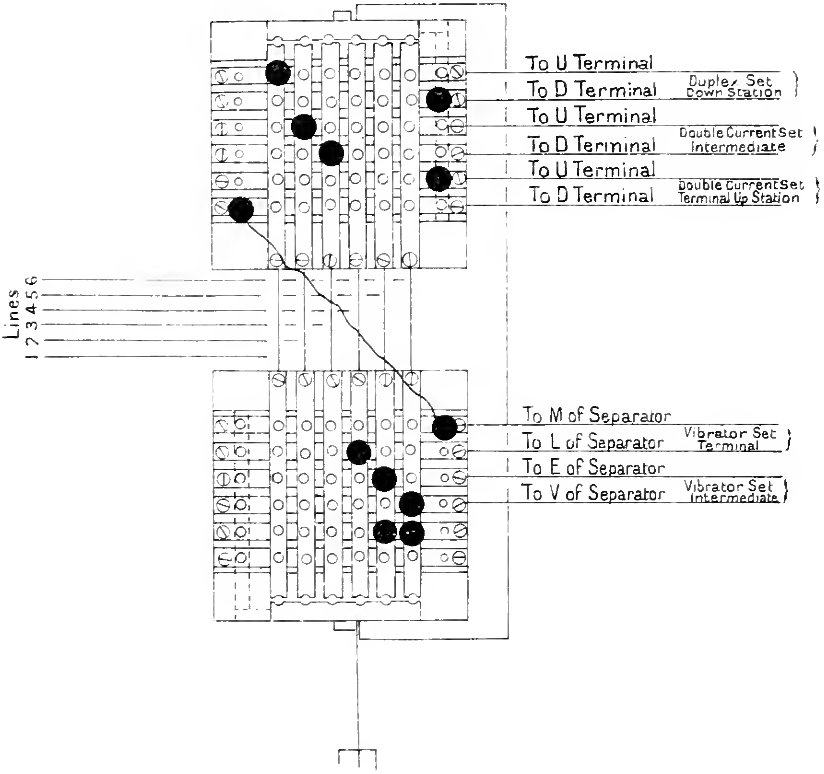
Earths to be as far apart as possible
The best Earth to be connected to Commutator

To face p. 242.

H & C GRAHAM LTD LITHRS, LONDON S E

DIAGRAM C.

TWO 6-LINE COMMUTATORS JOINED UP IN AN OFFICE WITH 2 SECOND CLASS OFFICE SETS AND 1 FIRST CLASS SET OF INSTRUMENTS.

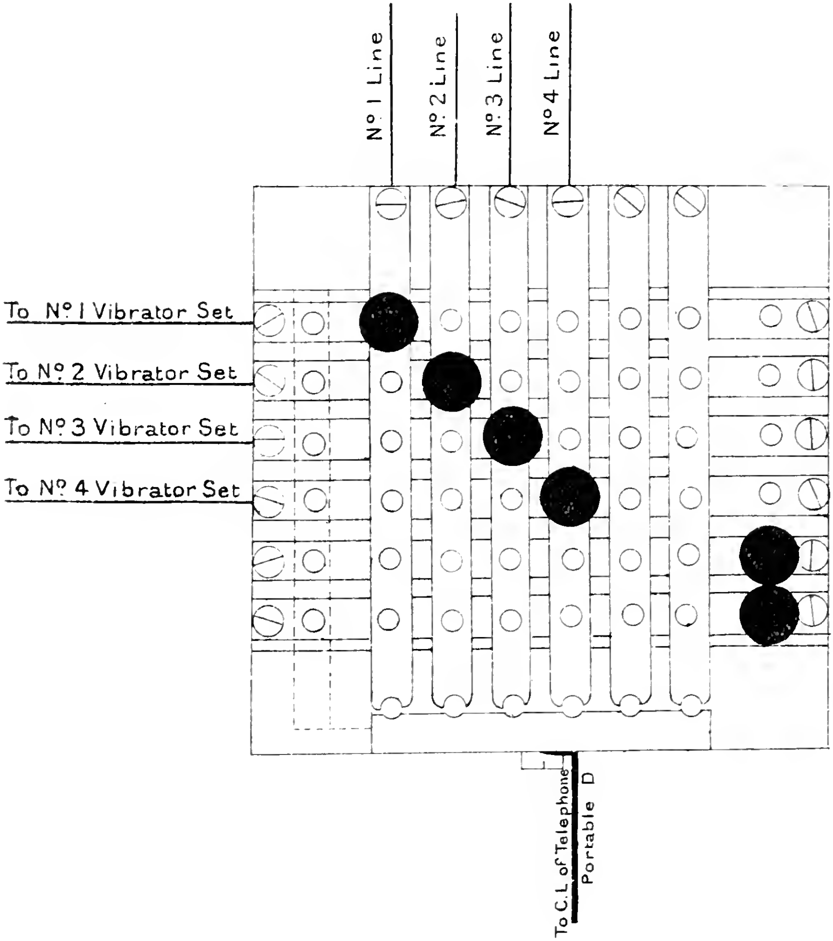


To face p. 245.

H & C. GRAHAM LTD. LITHRS. LONDON S.E.

DIAGRAM D.

FIELD CABLE TELFGRAPH SYSTEM BASE OFFICE — NORMAL CONNECTIONS.



To face p 245.

H & C GRAHAM LTD. LITHRS. LONDON. S. E.

2nd class office.

6. Diagram "A" shows the "2nd Class Office" set of instruments connected up for a terminal office. When connected as here shown, the office is ready to work with both the double-current set and the vibrator set simultaneously, thus diplexing the line. The bell can be brought in circuit so that it will be rung by the local battery whenever the relay is closed by the current from another office on the line. By alterations of the plugs on the commutator, and without disconnecting any leads, the line can be disconnected or earthed, the double-current set can be disconnected, short-circuited, or reversed, and all ordinary tests can be carried out.

Diagram "B" shows the "2nd Class Office" set of instruments connected up in the normal method for an intermediate office.

The separator, connected as shown in the diagram, provided a path, free from any choking coils, for vibrator signals passing through the office (see also Chap. XV, para. 23).

Any alteration in the circuits can, as at the terminal office, be made by altering the position of the plugs of the commutator.

Larger office

7. Diagram "C" shows the arrangement of two commutators in use at an office with six lines and five sets of instruments in circuit:—

On No. 1 line	Duplex set, terminal.
On Nos. 2 and 3 lines...	Double-current set, intermediate.
On No. 4 line	Double-current set, terminal. Vibrator set, terminal.
On Nos. 5 and 6 lines which are put through	Vibrator set, intermediate.

Cable office.

8. Diagram "D" shows the arrangement usually made at the base office on a field cable telegraph system where each line has its own vibrator set.

Where there is not much traffic on the lines, two or more can be bunched, by means of the commutator, on to one vibrator, so that some of the clerks may rest. Distant offices can, when required, be put through to each other direct. If this is done, care should be taken to keep a telephone or a vibrator set in leak, on the through line, to ascertain that the through communication has been established, and when it is no longer required. Frequently it will not be possible, owing to the combined length of cable, to establish direct communication between distant offices, although these offices can both communicate satisfactorily with the base office.

In the arrangements of all telegraph offices it is most important to remember that *each vibrator set must have its own earth* (as is shown in diagrams). *This earth should be as far as possible from every other earth, or there will be interference from other circuits.*

Permanent Telegraph Offices.

9. In permanent telegraph offices the wires are led in to a test box and from there to the instruments. The lightning dischargers, &c., are fixed either at the back of the test board, or else where the lines enter the building. The latter is preferable in a large office. The wires should be run neatly in casing, or if there are only a few they may be stapled down. They should always be accessible.

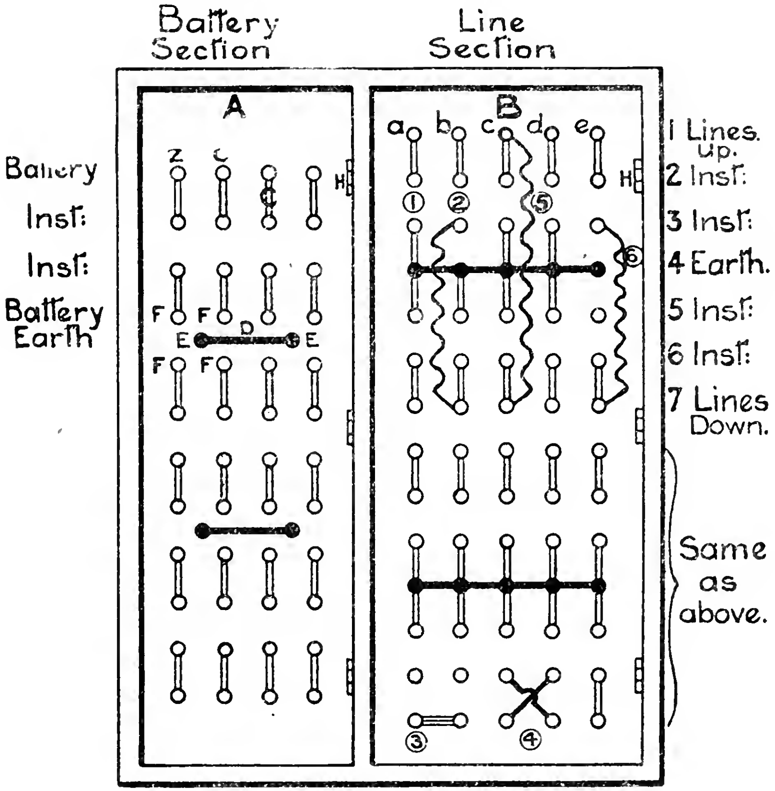


FIG. 2.—Box, Test, Telegraph.

Box, test, telegraph.

10. There are many forms of test box in use, the service "Box, test, telegraph" is convenient for medium-sized offices, and is simple. It can be supplied in different sizes, and with or without "dischargers, lightning, circular, Mark II," fixed on the back. It is illustrated in Figs. 2 and 3 and consists of a framework, 2 feet 8 inches high by 2 feet wide by 5 inches deep, divided by a vertical partition into two panels, each of which is closed by a hinged door.

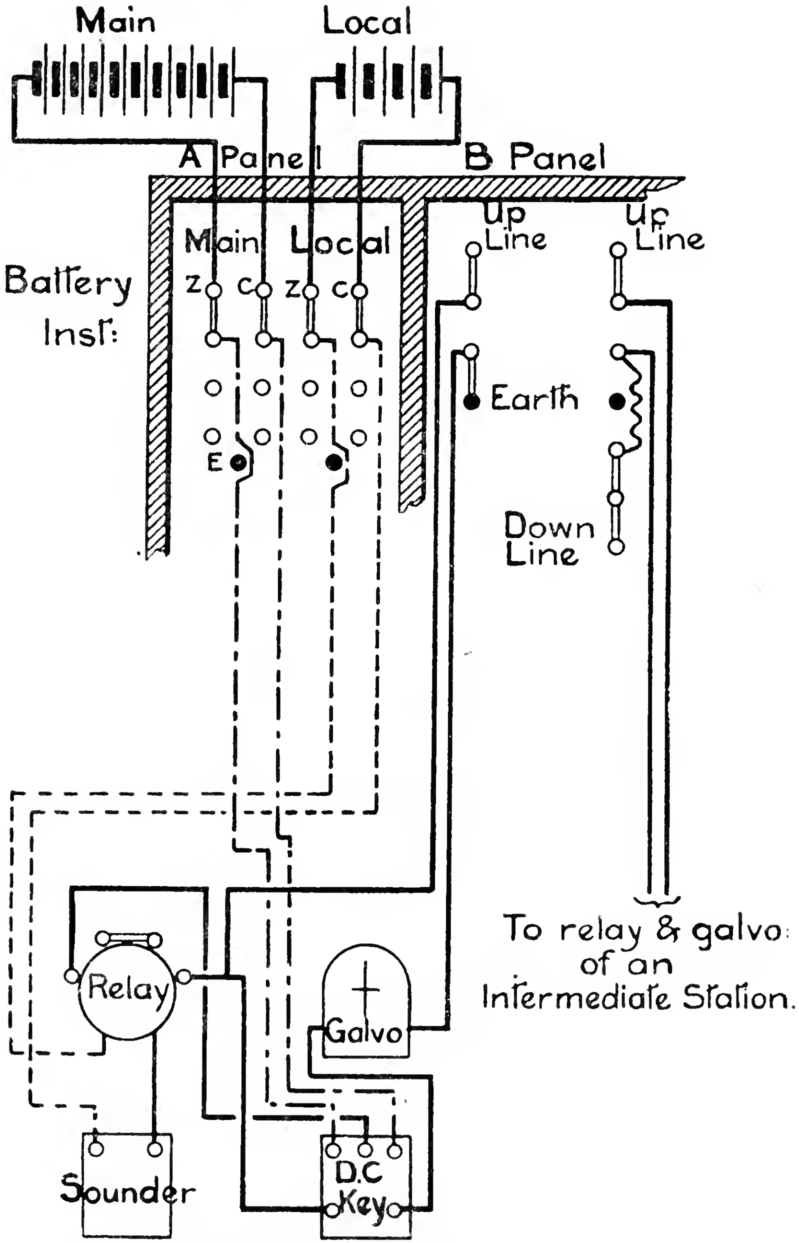


FIG. 3.—Box, Test, Telegraph, Terminal Station (Down).

To these doors are fixed terminals, fitted with pins $\frac{13}{16}$ inch by $\frac{1}{4}$ inch, which project through to the back of the doors. All leads from lines, batteries, and instruments, are soldered to these pins at the back, and should also be fixed by one staple to prevent any chance of a sudden jar pulling them off the pins. The fronts of the doors are left clear for connections between the terminals. It is important that *rosin* and *not* soldering solution should be used in making these connections.

The left panel, "A," is used for connecting the various sets of instruments to their batteries: the right panel, "B," for connecting instruments to lines.

In panel A the terminals are arranged in four vertical, and 12 horizontal rows, all at 2-inch interval, with the addition of two extra terminals between the fourth and fifth, and eighth and ninth rows. These extra terminals are also at 2-inch interval from the adjacent rows, diagonally, they are marked "E" in the diagram, and are connected together at the back by horizontal straps.

Panel A is provided with 24 brass links, which fit under the milled heads of the terminals, for making cross connections. In a make-shift box pieces of stout copper wire may be substituted for these.

The two vertical lines of terminals on the left are for joining instruments to their main batteries, the two on the right to their local batteries (see Fig. 3). Thus the panel as shown will take six sets of instruments.

Panel B carries five vertical and 14 horizontal rows of terminals set at 2-inch intervals throughout. The fourth and eleventh rows are joined together by straps at the back for earths. Brass links similar to those before described are provided.

Each vertical row is used in two separate groups of seven terminals, the seven being allotted thus:—

1. Up Line; 2. Instrument; 3. Instrument; 4. Earth; 5. Instrument: 6. Instrument: 7. Down Line. Thus the panel can carry 10 up lines and 10 down lines.

(1) The top half of column "a" shows the normal arrangement for a terminal office (see also Fig. 3). The line comes in at back of top terminal, which is joined by link to second, whose back goes to instrument. The other lead from instrument comes to back of third terminal, and is joined by brass link to fourth terminal, which is earth. Fifth, sixth, and seventh terminals are not used.

(2) In the top half of column "b" is an intermediate office. Here the third terminal is joined by a lead to the seventh, or down line terminal, instead of by strap to them.

(3) In the bottom half of columns "a" and "b" two down lines are looped, for testing at another office.

(4) In the bottom half of columns "c" and "d" two sets of instruments are "crossed" on their respective lines.

(5) In the top half of column "c" the up line is put straight through to down line by a piece of lead.

(6) In the top half of column "e" a spare set is shown intermediate in a through line.

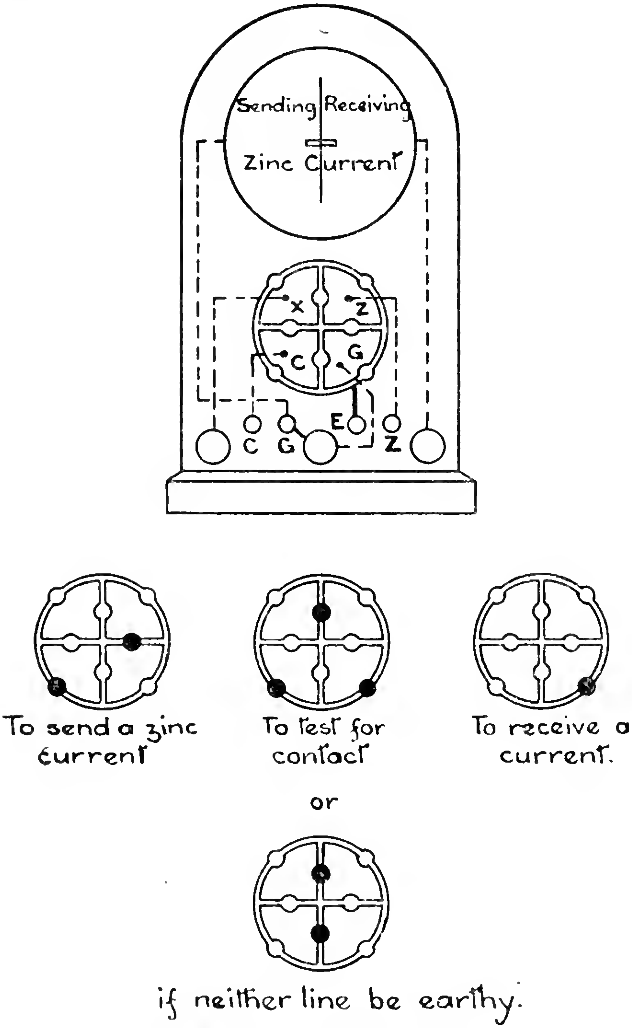


FIG. 4.—Text-Box Galvanometer.

Test-box galvanometer

11. A special galvanometer is used by the Post Office for testing at test boxes; this is known as the test box galvanometer, but is not a service instrument. The upper part (see

Fig. 4) consists of a galvanometer with a vertical needle. The resistance is 200 ohms, and a current of 3 milliamperes will give a deflection of 20 to 30 degrees. Below the galvanometer is a switch, consisting of four brass quadrants and a brass ring, all insulated from each other, and connected as shown in the figure. The four terminals C, G, E, and Z, are at the back of the galvanometer, C and Z are connected to copper and zinc of a testing battery, and E to earth. The three large terminals are for connecting the lines to be tested.

The galvanometer is used as follows :—

(*a*) To send a zinc (or − ve) current to line, join line to right hand terminal and plug Z to G, and C to earth.
(*b*) To send a copper (or + ve) current to line, join line to right hand terminal and plug C to G, and Z to earth.
(*c*) To receive a current from an earthed line, join line to right hand terminal and G to earth.
(*d*) To observe a current on a through wire, connect lines to right hand and centre terminals, and remove all plugs.
(*e*) To test for contact, join lines to outer terminals and plug X to Z, and C to G, or if lines are also earthy, plug X to Z, and C and G to earth.

See also Chap. XIX, paras. 4—6.

Telephone Test Boxes, &c.

Box, test, telephone.

12. There is now no sealed pattern of telephone test-box, but boxes will in future be supplied to meet the requirements of each case. The types described below may be taken as typical of those likely to be met with.

13. The pattern formally sealed as "box test telephone" was supplied for multiples of 20 wires (10 metallic circuits), with a maximum of 120 wires. This box is suitable for use with small exchanges where special protection from lightning, or from power circuits, is not required.

Part of a test-box strip is shown in elevation and section in Fig. 5. (A 120 wire box is 34″ × 22″ × 4¼″ in size.)

Each strip consists of a base plate of sheet brass, B, upon each edge of which is fixed a batten of ebonite, C and S. (Each strip consists of one, two, or three sections.)

Upon ebonite batten, C, are fitted 10 pairs of springs, L_1, L_2, which normally rest upon points projecting from the brass plates, l_1, l_2, fitted upon the channelled ebonite strip, S. To the springs, L_1, L_2, are connected the switchboard wires, and to the contacts, l_1, l_2, are connected the line wires. The test strips slide in racks in the cabinet in which they are enclosed, so that they are easily removable, and are made up in sections of 10 metallic lines (20 wires); each pair of lines occupies a vertical height of 1 inch.

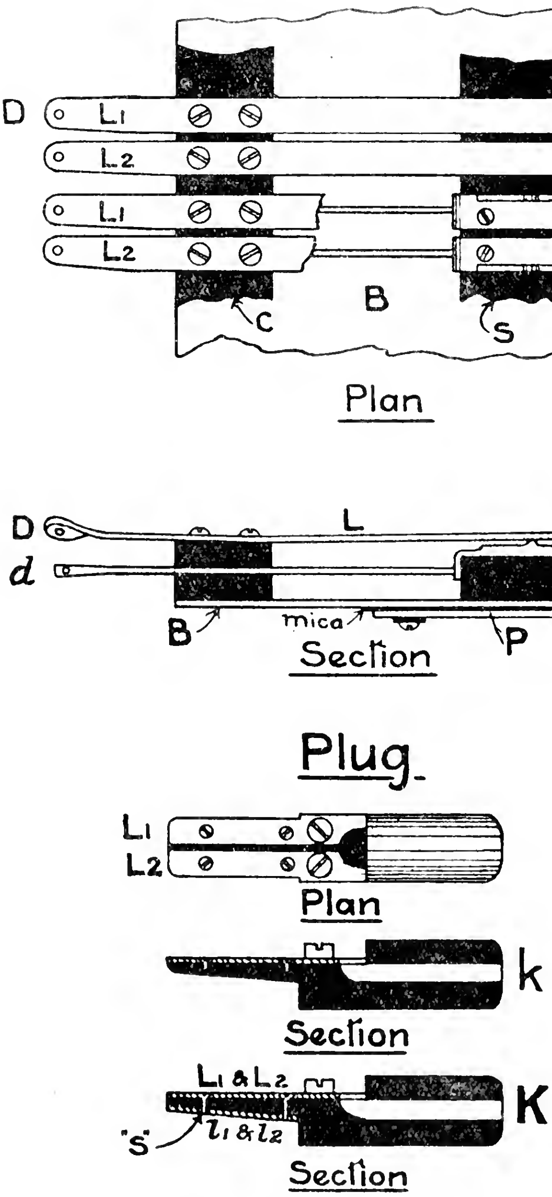


FIG. 5 —Box, Test, Telephone.

The wires are soldered on to the tags, D, *d*. Actually the tag is led back so that its end lies near D on the same side of the strip. At the top and bottom ends of the cabinet are two holes each, through which the line leads and switchboard leads are brought. Connected to a testing telephone set by a twin flexible conductor is a plug, K. On the ebonite body of the plug are four brass strips, L_1, L_2, and l_1, l_2. L_1 and l_1 are electrically connected, and so are L_2 and l_2 by means of the small screws, "S."

The insertion of the peg K between L and *l* of a metallic circuit between the projections on l_1, l_2, places the testing telephone in bridge across the line without affecting the normal connections at all. A second test peg, *k*, with two brass strips on one side only is also provided. The two strips are connected by a flexible twin conductor to the right and left terminals of a test-box galvanometer, or testing telephone. By means of this peg, either the external or the switchboard circuits can be tested.

Protection against lightning is afforded by earthing the brass sheet, B, and joining the contacts, *l*, to metal strips, P, these strips being insulated from B by perforated mica strips. Q is a brass ribbon soldered to P and to *l*.

"U" link test boards.

14. The U-link test boards are now very generally used by the G.P.O. They are more compact and convenient than the old description of board, which becomes somewhat unmanageable when a large number of wires have to be dealt with.

The following description applies to a test board fitted in some Garrison Exchanges by the G.P.O. at home stations. See Fig. 6.

In the upper half of the board are two panels of ebonite, in each of which are 25 pairs of U-shaped metal links. Each pair of links is associated with four sockets, which are sunk in the ebonite panel; the extremities of the tubular sockets project from $1\frac{1}{8}$ inches to $1\frac{1}{2}$ inches from the back face of the panel. The U links are placed in the sockets so that the plane of the link is vertical. Each area, including four sockets and their two links, is numbered, and as there are 50 such areas, and each serves one pair of leads (A and B), the board accommodates 50 metallic circuits.

In the lower half of the board are six long ebonite battens and eight short ones. These are arranged in pairs, so that there are three pairs of long and four of short battens. Each long pair contains 10 sets of tags, and each short pair five sets. Each set numbers 16 tags. The connections of one set only are shown.

The line wires (A and B) are soldered on to the two tags, W, and the two exchange wires (A and B) are similarly soldered to the two tags, Z. The two tags, X, and the two tags, Y, are connected by permanent leads to the lower and upper pair of sockets respectively, of the set corresponding.

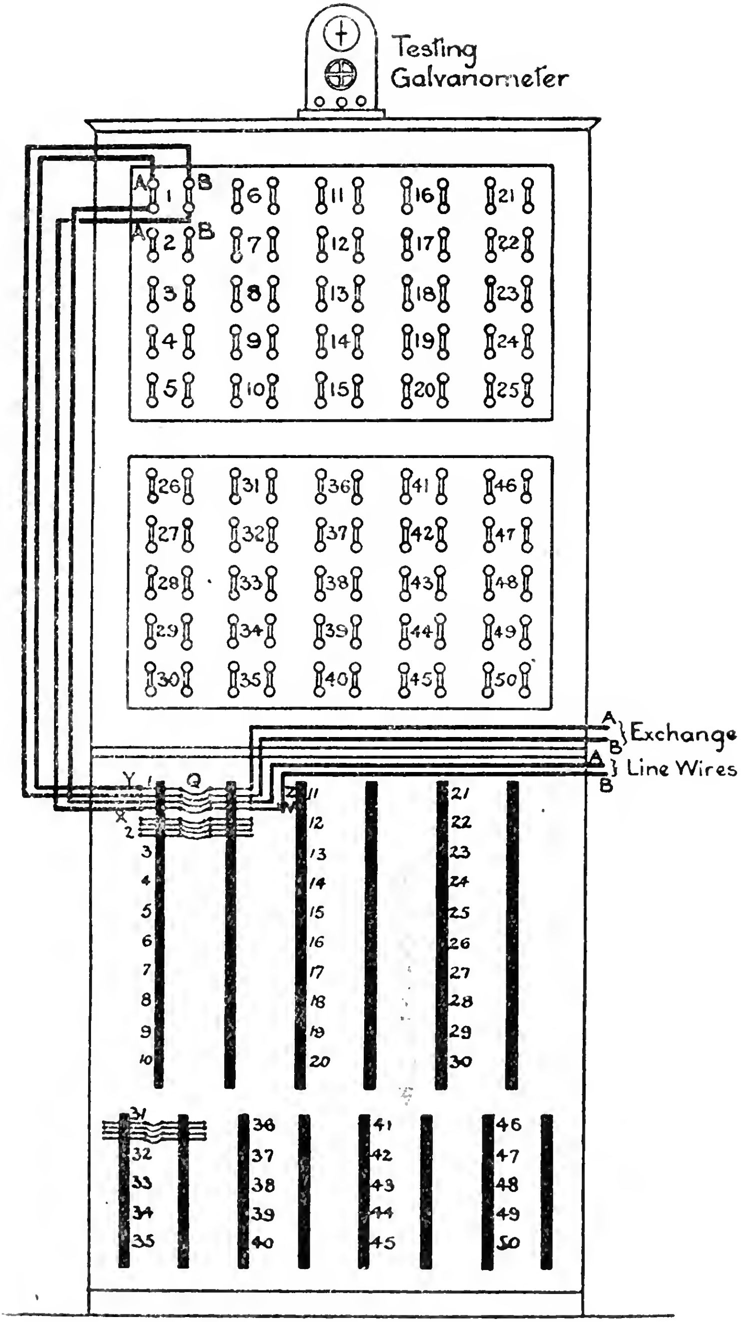


FIG. 6.—G.P.O. Telephone Test Board.

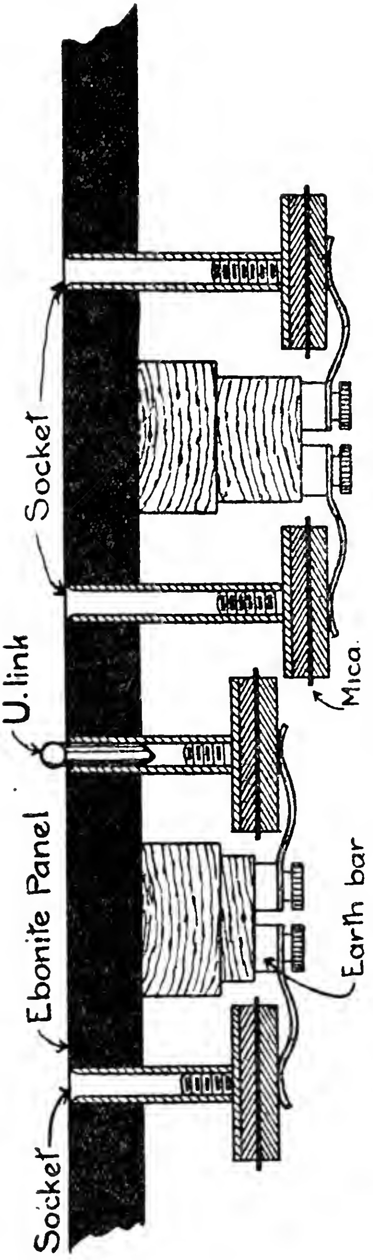


FIG. 7.—Sectional Plan of Carbon Lightning Discharger fitted to back of G.P.O. Telephone Test Board.

WX and YZ are not continuous brass strips, but have breaks in the space between the battens, bridged across by wires, Q. These wires are soldered to the inner extremities of the tags, and can, if necessary, be removed by melting the solder.

The course of the circuit is now as follows :—Line wires to tags, W, through cross-connecting wires, Q, to tags, X, hence to lower sockets, 1, through U links to tags, Y, through Q to tags, Z, and then to the switchboard.

By removing the U links the lines are disconnected, and by means of plugs and flexible leads either the line or switchboard side can be connected to a testing telephone, or to a test box galvanometer (para. 11), or to earth. The wires, Q, are normally joined straight across as shown, but if for any reason it is desired to connect a line to a different exchange number it can be done by altering the connections, Q, without rearranging the leading in wires or the cables from the test board to the exchange. Such a cross might be required if an office connected to the exchange was moved, and the lines came in by a new route, while it was desirable for the office to still retain its old number on the switchboard.

Temporary crosses of this nature could, of course, be made by removing the U links, and connecting on the face of the board with flexible leads.

Protection from lightning is afforded by circular carbon dischargers (dischargers, lightning, circular, Mark II) which are fixed to the two lower sockets of a set of four (an area).

The space being limited, the dischargers are arranged as shown in Fig. 7, the shank of one socket being $\frac{3}{8}$ inch longer than that of the other in order that the dischargers may clear each other.

The carbon plate next the ebonite panel is mounted on a screwed spindle, which screws into the socket. The other carbon plate, separated from the first by the usual mica disc, is held in place by the metal spring, which at its other end is secured to the earth bar.

If protection from power circuits is also required, dischargers, lighting, D, or similar protection must be provided separately, and should be placed in the line wires before they reach the test board, and as near the point of entry into the building as possible.

Later patterns.

15. In some later pattern Post Office test boards the connections are slightly different, as shown in Fig. 8, and a smaller lightning discharger, similar to the plate discharger part of "dischargers, lightning, D," is placed on the ebonite strip, as marked LD in Fig. 8. In this pattern each panel has room for 40 circuits instead of 25.

The Post Office practice in the newest installations is to separate the protecting devices from the test board, and place the former as near as possible to the point of entry of the wires into the building.

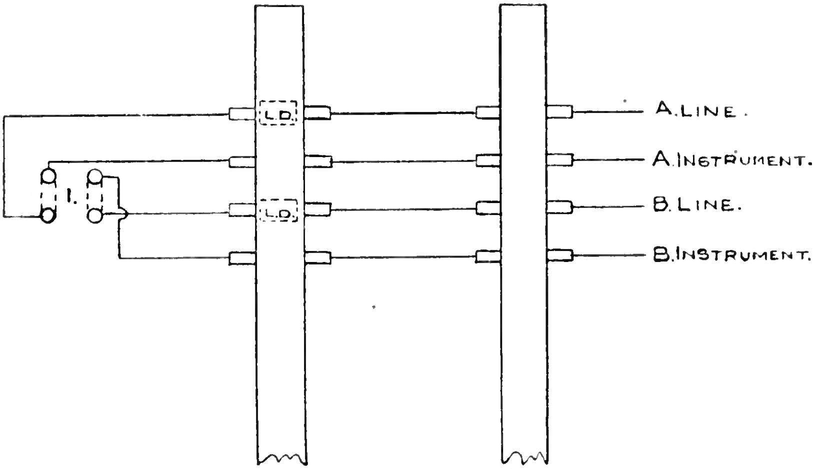


FIG. 8.

Test and cross connecting frame.

16. A pattern of test board, also called a cross-connecting frame, has been provided for some of the larger military exchanges, and is largely used in civil exchanges and by the Post Office in some of the principal telegraph offices. This board consists of an iron framework; the height and length depend on the number of circuits. On the one side are horizontal rows of spring jacks, similar to those of a telephone exchange, to the tags of which the incoming wires are soldered, in what may be termed geographical order, *i.e.*, in the order which allows the neatest arrangement of the leading-in wires. On the other side of the frame are vertical rows of lightning dischargers, heat coils, and fuses, similar to "dischargers, lightning, D," only mounted on strips and having tags instead of terminals. To the instrument side of these dischargers are soldered the wires leading to the switchboard, these wires being made up into suitable cables. The horizontal and vertical strips are connected by single or twin conductors, as required. This arrangement enables any line wire to be connected to any number on the switchboard without interfering with the leading-in wires or internal cabling.

By means of suitable plugs the lines can be disconnected and tested at the spring jacks on the horizontal strips.

If the complete protection given by the "D" type of discharger is not required, simpler dischargers can be fitted.

Pole test-boxes, &c.

17. Pole test-boxes for use where aerial and underground lines join, and test-boxes for underground work in fortresses, &c., are dealt with in Vol. II.

CHAPTER XIX.

TESTING.

Objects of and necessity for tests.

1. Faults frequently commence as slight defects which will not at once appreciably affect the working, but will gradually increase till the circuit is altogether interrupted. These defects can be detected by suitable tests, and can then often be removed before they have interfered with the working of the circuits. It is, therefore, desirable to make careful periodical tests of all circuits. In permanent systems much more elaborate and systematic tests can be made than on temporary field lines, but systematic and regular tests should always be carried out as far as the circumstances permit.

Nature of faults.

2. The faults that may interfere with the working of a circuit may be divided into the following classes :—

- (i) A break or disconnection in the conductor of the circuit ; this may be either partial, owing to high resistance at joints in the conductor, &c., or complete. The effect of this nature of fault is to increase the resistance of the circuit.
- (ii) A break in the insulation of the circuit, causing a portion of the circuit to be shunted through a greater or less resistance. The effect of this is to lower the resistance of the circuit as measured from one end, but it prevents to a greater or less extent the current flowing round its proper path. Examples : A leak to earth on an earthed telegraph circuit, a contact between two wires that should not be in contact.
- (iii) A defect in the battery.
- (iv) A defect in adjustment of an instrument.
- (v) A mechanical defect in an instrument.

Two or more of these faults may occur together.

Faults (iv) and (v) can often be discovered by inspection ; methods of testing for these depend on the type of instrument.

Tests for batteries are given in Chap. XX, para. 27.

Testing for faults (i) and (ii) resolves itself into ascertaining whether the resistance between two points that should be connected electrically is not too large, and that the resistance between two points that should not be connected is not too small (except for long lines this resistance should be so large that it appears to be infinite except when measured with very sensitive instruments); thus all tests for these faults consist in more or less accurately measuring resistances.

Accurate methods of measuring resistances are given in Chap. XX, and these methods should be used when circumstances allow, and the results compared with what is known to be correct.

Simple tests.

3. The simplest tests of the above nature do not involve actual measurement. They are made with a battery and galvanometer connected up as shown in Fig. 1, where ACB is the portion of the circuit to be tested. If the circuit is complete a current will flow, and if the battery and galvanometer are suitable for the particular case the galvanometer will deflect.

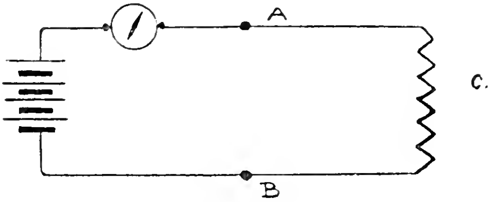


FIG. 1.

If we know what the deflection should be in any particular case, and we get that deflection, the circuit is probably correct. If we get too large a deflection the resistance of the circuit ACB is too low, which means a portion of the circuit is short circuited, *e.g.*, on a circuit with an earth return, by a leak to earth. If we get too small a deflection the resistance is too high, which means a broken wire, loose terminal, or bad joint, &c. It would, of course, be possible for a partial disconnection and an earth fault to neutralize each other as far as such a test is concerned, but this rarely happens.

The following simple tests can be made with a galvanometer and battery. The test box galvanometer (Chap. XVIII, para. 11) is specially arranged for carrying out these tests quickly, but the "Galvanometer detector," and the "Galvanometer, single and duplex," are also suitable and are more often available.

Simple test for earth.

4. To test for an earth fault, disconnect the line at the far end, connect a battery and galvanometer as shown in Fig. 2. If the line is clear there should be no deflection. If there is a deflection disconnect the line at any intermediate test point, P, that is available; if the line now tests clear the fault is beyond P. By this means a fault can be localized between two test points.

Simple test for disconnection.

5. To test for a disconnection, connect galvanometer and battery as in Fig. 2, and earth the line at the far end. If the line is clear the galvanometer should deflect. If no deflection is obtained, the fault can be localized by earthing the line at intermediate points.

Simple test for contact.

6. To test for contact between two lines, disconnect the lines at the far end and connect the galvanometer and battery as shown in Fig. 3. If the lines are clear there will be no deflection. If there is a deflection the fault can be localized by disconnecting the lines at intermediate points. If the earth connection shown in Fig. 3 be omitted, an earth fault on both lines will give a deflection, even though the lines be not in contact.

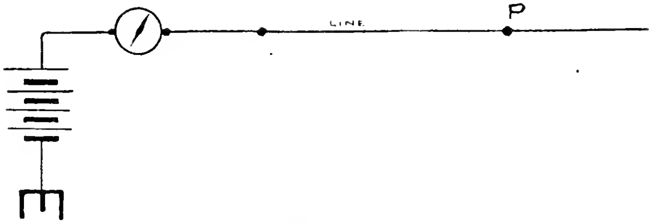


FIG. 2.—Test for earth fault or disconnection.

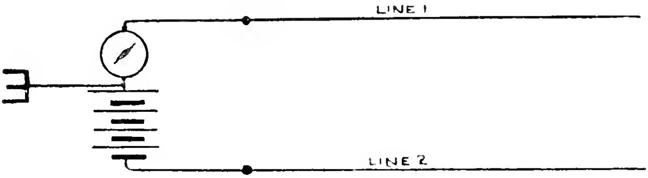


FIG. 3.—Test for contact.

Precautions before testing.

7. Before commencing to make a test it is necessary to consider what instruments are required, and what results it is expected to obtain with these instruments.

Always make sure that the testing apparatus is in good order before proceeding to test.*

In connecting up a circuit containing a battery and key, always connect one terminal of the battery to the key before making any other connection. This is to avoid accidentally short circuiting the battery.

After connecting up and before depressing the key, trace the circuit through from one pole of the battery to the other.

Never keep a key depressed or a circuit completed for a longer period than necessary, especially if the circuit be of low resistance. By not attending to this the battery may be exhausted, and the coils of the testing instruments may be damaged by being heated (see Chap. I, para. 26).

Galvanometer for testing.

8. It should be remembered that an absence of deflection on a galvanometer does not necessarily mean an absence of current, but only that the

---

* In testing, as indicated in Fig. 1, this is proved by touching A and B together, when a deflection should be obtained.

current is not strong enough to move the needle; also that if a low resistance, such as a short length of wire, be tested with a high resistance galvanometer, the resistance of the wire may be considerably higher than it should be, without much reducing the current or deflection, and thus give misleading results. For example, if a bobbin lightning discharger were being tested for continuity with the "I" coil of the detector, the resistance of the circuit would be 100 ohms for the galvanometer and about ·2 ohms for the bobbin. If the battery used were one good Leclanché cell, with a resistance of ·1 ohm, the current would be $\frac{1\cdot5}{100\cdot3}$ ampere, *i.e.*, ·01494 ampere; if, however, the resistance of the bobbin were 2 ohms, or 10 times too large, the current would only be reduced to ·0147 ampere, which would have no appreciable effect on the deflection. Suppose, however, instead of the "I" coil, the "Q" coil (with a resistance of ·2 ohm) were used, the current with a correct bobbin would be $\frac{1\cdot5}{\cdot5}$ amperes, or 3 amperes, but with the bobbin having a resistance of 2 ohms, the current would be only $\frac{1\cdot5}{3\cdot3}$, or ·45 ampere, a difference that would be very clearly marked. Thus we see that for testing a low resistance we must use a low resistance galvanometer.

On the other hand, if we were testing the insulation resistance of the bobbin, *i.e.*, the resistance between the wire on the bobbin and the metal bobbin itself, the "Q" coil might give very misleading results. The resistance should be many thousand ohms, but if it were only 100 ohms (which might be low enough to entirely stop the working of a circuit), the cell used above and the "Q" coil would give a current of $\frac{1\cdot5}{100\cdot3}$, or ·0149 ampere, which would give no deflection, or a very small one, while, if the "I" coil were used, though the current is then only $\frac{1\cdot5}{200}$ ampere, or 0·007 ampere, the deflection would be 20 or more, owing to the larger number of turns of wire on the galvanometer coil. Thus we see that for testing a high resistance a galvanometer of high resistance should be used, as the increased resistance does not matter and the galvanometer is more sensitive.

Battery for testing.

9. The battery for the above tests for continuity should be such as to give a deflection of at least 30° when A and B (Fig. 1) are connected together; and for insulation testing the battery should be at least sufficient to give a full deflection when A and B are connected.

Routine Tests of Telegraph Circuits.

Morning test.

10. In large commercial telegraph systems it is usual to carry out daily insulation tests of all the more important circuits, for which purpose work is suspended for a fixed period, and by means of more or less elaborate testing arrangements, the necessary results are obtained with considerable ease and celerity.

P.O. practice.

11. In the British Post Office the more important circuits are also tested weekly for conductivity, by means of the Wheatstone bridge (Chap. XX). At the larger offices battery testing instruments may be found specially designed to measure the E.M.F. and resistance of primary cells with the minimum of trouble and calculation.

A detailed description of the above system of tests is outside the scope of this book, but the general principle of periodical tests of lines, batteries, and apparatus is one which can be applied with advantage to most systems, however roughly organized and poorly equipped.

Accuracy tests.

12. Absolutely accurate results are as a rule neither possible nor essential under military conditions and with the apparatus likely to be available, but valuable comparative figures as to insulation can be obtained, as described above, with the apparatus on an ordinary telegraph circuit. It must be borne in mind that from the military point of view there are serious objections to any daily or periodical system of testing which involves interference with connections of instruments for any length of time.

Morning tests on military circuits.

13. The following application of the simple tests described in paras. 3—6 is recommended when practicable for military lines :—

For lines working D.C. simplex (baseboards simplex) the up station of the circuit sends the signal "CQ test," at the time of testing which is detailed by the responsible officer. This is acknowledged by each other station sending in succession his call, and "RT."

The up station then puts his switch to "send" for half a minute, and notes the deflection of his galvanometer. All other stations simultaneously note the deflection of their galvanometers. At the end of the half minute the up station signals his reading, which is entered by the other stations.

The remaining stations signal their readings in turn, and they are similarly entered by all stations.

The next station then puts his switch to "send" for half a minute, and the galvanometer readings are similarly signalled and entered, and so on till all the stations have sent currents.

The form on p. 260 has been filled in for six days as a guide, and also to show the advantage that may be derived from the system. The remarks column shows the conclusions to be drawn from the figures.

As all the readings shown in the above-mentioned tables are entered at each station on the circuit, the state of the lines and batteries is at once evident to an officer visiting any station.

If time and circumstances permit, both spacing and marking deflections may be noted ; this ensures that the D.C. keys are making proper contacts.

In dry countries, where insulation faults are of rare occurrence, a sufficient test may be obtained by the head office receiving currents in succession from all stations, having first tested the insulation of the line.

S.C. circuits.

14. The procedure with S.C. working, where a galvanometer is included in the line, is similar to the above, only the key is held down for half a minute, instead of the switch being placed to "send."

Morning Tests for Week ending 28.9.05.

Date.	Time.	Weather conditions.	XE sending				AM sending				BN sending				CO sending.				Remarks.
			XE	AM	BN	CO	XE	AM	BN	CO	XE	AM	BN	CO	XE	AM	BN	CO	
23.9.05	A.M. 6·0	Fine, heavy dew.	65	60	45	40	60	70	44	40	45	40	65	60	44	40	60	64	Slight general leakage, excessive between AM and BN.
24.9.05	6.10	Dull, windy.	54	53	53	52	40	42	42	40	53	52	55	55	53	50	50	53	Defective battery at AM.
25.9.05	6.0	Steady rain.	Full	50	40	34	40	Full	50	40	50	40	Full	50	50	45	45	70	Heavy leakage, due to rain.
26.9.05	6.5	Fine	5	—	—	—	—	65	64	62	—	60	63	60	—	62	63	65	Line broken between XE and AM, AM side making earth.
27.9.05	6.0	Fine	65	60	58	—	60	63	62	—	55	58	Full	—	—	—	—	Full	Full earth between BN and CO.
28.9.05	6.0	Fine	55	54	52	52	55	56	56	55	54	53	55	55	55	55	54	57	No interruption.

15. In the case of circuits worked by direct sounder or inker without separate galvanometer, this system of testing is not applicable, but at the time for testing, calls should be interchanged between all stations, and the battery power equalised as far as possible, so that the same adjustment of instruments will do for receiving from all stations. This is, of course, impossible with any serious leak on the line.

Direct sounder circuits.

16. If worked on continuous current, calls should be interchanged every half hour when the line is not working, as a main advantage of this system is that warning is at once given of the line being cut, and to secure this it is necessary that the clerks should be continually on the alert. Furthermore, there is a tendency with this system, if powerful currents be employed, for the armatures to stick from the effects of residual magnetism, and this must be guarded against, or delay will result.

Continuous current working.

17. In the case of vibrator circuits, a daily interchange of calls will be sufficient, the strength of signal from each station being reported as very loud, loud, moderate, weak, or very weak, and sent to other stations to be entered in a form similar to that already given, in place of the deflections there noted. For vibrator circuits on field cable for tactical purposes, see also Chap. I, Vol. II.

Vibrator circuits.

18. Under fairly permanent conditions conductivity tests with a resistance bridge may be undertaken at suitable intervals.

Conductivity tests.

Under service conditions, repairs are apt to be hastily carried out, and a series of unsoldered joints may in course of time raise the line resistance of a circuit by a very appreciable amount. The results of all such tests should be carefully recorded and preserved.

19. In large telegraph organisations the principle of division of labour has resulted in the separation of the clerical and engineering branches, but under military conditions this will usually be both inadvisable and impracticable; and the Telegraph master is held responsible for the detection and localisation of all faults, for the actual removal of office faults, and for the maintenance of office connections and batteries in good order.

Responsibility for testing.

Cases may arise in war of extensive permanent telegraph systems being seized and worked during occupation of the enemy's territory. In such cases the conditions may approximate to those of a large civil administration, and the distinction between clerical and engineering functions will be evolved almost automatically. It may, however, be accepted as a sound principle, that under all circumstances localisation tests should be made by the clerical staff.

In the larger offices the latter would cease to have responsibility for the maintenance of batteries and instruments; which duties would be carried out by the engineering staff.

It will be seen, then, that a sound knowledge of the principles of testing is a requisite of efficiency for all military telegraphists.

The prevention of office faults.

20. See that all contacts are clean and all connections tight. Make sure that the main and local batteries are in good order, and that connections between cells are properly made. See that lightning discharges are not causing earth, especially after a thunderstorm. With D.C. keys verify the switch connections. Test all local circuits.

In the case of a disconnection in the compensation circuit of a duplex set, inspect the rheostat.

Pay special attention to the adjustment of relays under the different conditions of working.

Localisation of Faults on Telegraph Circuits.

Classification of faults.

21. Faults on a circuit are either outside the office, when they are known as Line Faults, or inside it, when they are known as Office Faults. In an earthed circuit the earth is considered as part of the office.

Faults may be classified as follows :—

Line Faults.—(1) A leak, or breakdown of the insulation of the line, generally called an "earth fault," either partial, or what is termed "dead earth."

(2) A disconnection, or breakdown of the continuity of the line ; this may also be either partial, owing to high resistance at one or more joints, or complete ; and in the latter case the broken ends may or may not make connection with earth.

(3) A contact with some other line, intermittent, owing to the wires moving, or complete.

Office Faults.—Any of the three above-mentioned faults may occur in the internal connection of the office.

(4) A defect in the battery.

(5) A defect in an instrument.

(6) A defect in the adjustment of an instrument, due to inattention or carelessness.

(7) A bad earth, in earthed circuits.

In a military system the Telegraph Master is normally solely responsible for the prevention, detection, and removal of office faults ; in the case of Line Faults he is only responsible for their detection and report, and for assisting the Lineman by any information he can give as to their nature and locality.

Procedure or breakdown.

22. Immediately on a breakdown occurring, the fault must be localised as far as possible. This is to a large extent done automatically by the galvanometer of the telegraph set in use. An earth fault is shown by the normal deflection being exceeded. If the communication is still good to the next office

the fault is beyond that office. A disconnection is shown by the normal deflection being diminished or ceasing altogether. In this case communication is interrupted all along the line, and no definite indication is given as to the position of the fault. If the office is intermediate, the Telegraph Master should ascertain in which direction the fault lies, by putting earth on each line in turn; when earth is on the faulty line the signals should be obtainable from the next station on the side which is correct. If when calling a station during this test the clerk sees his deflection suddenly increase, he will know that it is one of the other stations putting earth against him for the same test, and must wait till it is taken off.

Unless the fault has been proved to be beyond the next office, the first thing for the Telegraph Master to do is to ascertain whether the trouble is caused by a line or office fault, *i.e.*, to prove his office.

Testing for office faults.

23. Telegraph offices vary so much in formation and arrangement that it is impossible to lay down hard and fast rules applicable to all offices. The method described below is applicable to a 2nd class office (D.C. Simplex on baseboard with Vibrator, Separator, and Commutator) joined up as shown in Diagram A, Chap. XVIII; but the principles involved are applicable to any Telegraph Circuit.

Test 1.—Examine by hand and eye the internal connections of the office, to ascertain whether earth, disconnection, or contact, exists in any of the leads. See that all terminals are screwed down tight on their leads.

Test 2.—Short circuit the two lines, or line and earth in an earthed circuit, at the commutator. With switch to "send," the galvanometer should deflect freely in both directions as the key is pressed and raised.

Remove the short circuit piece.

This tests:—

(*a*) Continuity of sending portion, including leads to commutator.
(*b*) Main battery.
(*c*) Key (sending portion), galvanometer, and continuity of bobbin lightning discharger.

This does not test the freedom from earth of the lightning dischargers.

And if a fault is observed it should be sought in these—the most likely places are the lightning protectors, the contacts of the key, and the battery.

Test 3.—Remove the battery leads from C and Z terminals, and connect them, copper to U terminal and zinc to D terminal of baseboard. With switch at "receive," the galvanometer should be deflected, and the relay and sounder should work.

Restore the leads.

This tests :—

(*a*) Continuity of receiving portion,
(*b*) Local battery,
(*c*) Relay and sounder,
(*d*) Key (receiving portion),

in addition to the instruments tested in Test 2. The adjustments of the relay and sounder should be carefully looked to, in accordance with instructions on pp. 81 and 63.

Test 4.—Disconnect both lines (or line and earth) at the commutator, and disconnect the copper lead of the battery, from terminal C. Connect the copper lead through a detector direct to earth. There should be no deflection.

Restore the leads.

If a deflection, it shows there is an earth fault in the office. This must be looked for in detail, by tracing up the circuits from the Z terminal. Disconnect the zinc lead from the Z terminal and touch each instrument in turn with it, taking care to disconnect the instrument or part of the set already tested. When the deflection ceases the earth will be in the instrument last disconnected.

Test 5.—Go outside the office and examine the earth ; see if it requires wetting, or if the lead is broken or loose on the terminal. When possible join the two lines (or line and the earth pipe) direct by a piece of wire, and repeat Test 2.

If office correct.

24. If the office is proved correct the lineman should be warned to go out, and the Telegraph Master should give him as much information as possible as to the nature and locality of the fault. He must inform the lineman in which direction to go, and whether the fault is an earth, disconnection or contact. A contact is shown by the receipt of signals from the line in contact. Care must, however, be taken to look out for a case of mixed signals which sometimes occurs owing to an earth common to two circuits being of too high a resistance, and the signals of one circuit going to earth at the earth of the next office on the other circuit.

It may very likely be possible to continue working through a small leak or earth fault by increasing the battery power. Frequently the vibrator will work through a leak when the Morse fails.

Assistance to lineman.

25. The nature of the assistance that the Telegraph Master can give the lineman depends on whether the latter is equipped with a portable telephone or not.

If such is the case, careful attention should be given for his calls on the vibrator, and arrangements can be made with him for disconnecting or earthing the line at suitable places to enable the Telegraph Master to test to that place ; or his report can be received when he has found and removed the fault.

If no telephone is available, a current should be put on the faulty line, through a galvanometer, by means of a spare battery,

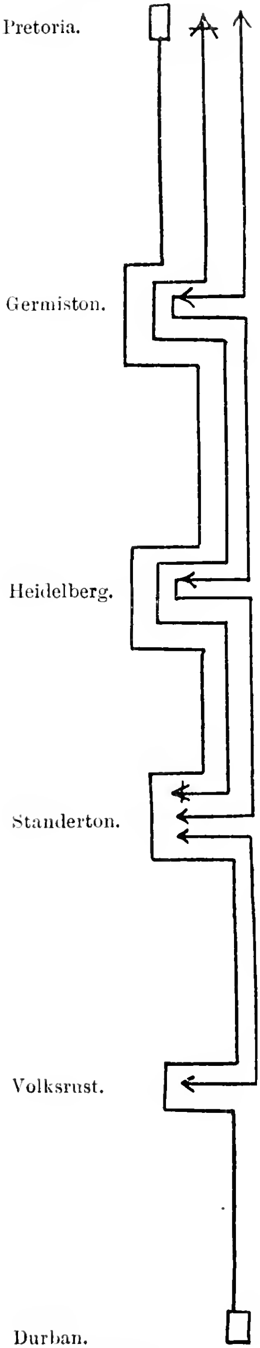

Pretoria.
Germiston.
Heidelberg.
Standerton.
Volksrust.
Durban.

FIG. 4.

or the office set if at a terminal office. This current should be in the same direction as the working current, viz., copper to down, or zinc to up. This current enables the lineman to test with a detector as to whether he has passed the fault or not, and also, by the deflection or movement of the galvanometer at the office, serves as an indication of what is happening (see also Vol. II, Chap. III).

Localising faults on a through circuit.

26. It may frequently happen in war that a line of poles carrying a number of circuits has to be worked by the Army Telegraphs. In this case there is generally, at least, one through wire, the traffic on which is of greater importance than that on the local lines. This through wire is led in to the offices which it passes for testing. In such cases the directions for testing emanate from the Head Office.

In the diagram of an imaginary line (Fig. 4), Pretoria is the Head Office. Three wires are shown, No. 1 a through wire, Pretoria to Durban, working Wheatstone; No. 2 a through wire, Pretoria to Standerton, working duplex; No. 3 a local wire, working simplex, and divided at Standerton.

If a fault occurs on No. 1 circuit, the procedure is as follows :—

Telegraph Master Pretoria sends a service message to each office in turn, directing them to disconnect (or earth if the fault is a disconnection) for half a minute. During this half minute he tests the line, and so is enabled to localise the fault between two offices. Let us assume that it is thus proved to be an earth fault between Heidelberg and Standerton.

In this case the portion of the local line (No. 3) between these two places can be utilised for the important through line, the local work between Heidelberg and Standerton circulating in the meantime *via* Pretoria.

Telegraph Master Pretoria, therefore, wires to Heidelberg and Standerton "Cross Nos. 1 and 3," and work on the through line continues.

He then advises by wire :—

1. Telegraph Officer in charge of the line.
2. The Inspector in charge of the faulty portion.
3. The linemen at Heidelberg and Standerton.

"No. 1 earth Heidelberg and Standerton section crossed to No. 3. D.A.T., inspector and linemen advised."

Telephone Circuits.

Routine tests.

27. Telephone circuits do not lend themselves to routine tests in the same way as telegraph circuits, as the operators using them are seldom qualified to make, or assist in, electrical tests. Where the circuits are concentrated, as at an exchange, and a qualified lineman is available, rough insulation tests should be made at regular intervals, if possible, daily.

All important military circuits should, in any case, be called up and tested by speaking over them, at stated intervals. This ensures a bad fault or breakdown being detected as early as possible, and this test can be carried out by anyone capable of using the telephone at all. In using a telephone, speak distinctly and close into the transmitter, but *do not shout;* if the circuit is in good order a low distinct voice can be heard better than a loud voice.

Line tests for metallic circuits.

28. Metallic circuits can be tested without the assistance of a lineman at the far end, as follows :—

(i) Connect battery and galvanometer as shown in Fig. 5, using a battery of 20 or more cells. If there is no considerable earth leakage there will be no deflection.

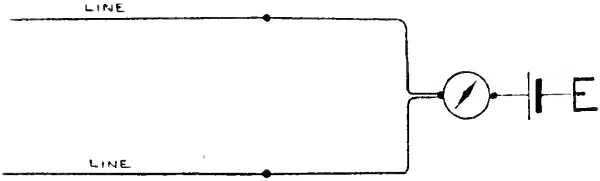


FIG. 5.

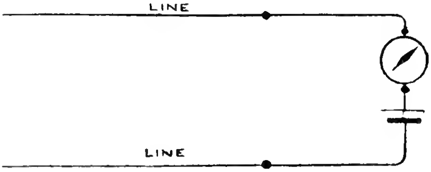


FIG. 6.

(ii)* Connect battery and galvanometer as shown in Fig. 6, using a battery of two or three cells with the test board galvanometer, or five or six cells with a galvanometer, single and duplex." A deflection should be obtained. The deflection will depend on the normal resistance of the line and pattern of telephone at the far end, as well as the galvanometer and battery used, and the battery power used should be selected to suit the average of the lines to be tested. A disconnection will show by a smaller deflection than normal, or by no deflection at all, and a contact between the wires by a larger deflection than normal.

---

* If the instrument contains a condenser so that there is not normally metallic connection between its terminals, this test for continuity is useless.

By means of suitable test plugs and cords, these tests can be rapidly made at the exchange board or test board without removing wires from terminals. Such arrangements should be provided at all exchanges of any size.

At large exchanges it is usually desirable to provide similar arrangements of test plugs and cords for accurate measurements of resistance. The above tests do not show whether a fault is in the line or instrument.

If a lineman is available at the far office to disconnect or earth the lines, rough or accurate tests of the lines, without the instruments, can be taken in the same way as for telegraph circuits (*see* para. 3).

If test (i) above shows an earth fault, an idea of its position can be obtained by connecting the galvanometer to each line in turn, and leaving the other line disconnected. The fault will be on the line showing the greatest deflection, and the greater the difference between the deflections the nearer the fault to the office.

Line tests, earthed circuits.

29. In the case of earthed circuits, the rough test with battery and galvanometer is only of value if the normal deflection given, by the testing galvanometer and battery used, on that particular line is known; and in any case this test will not give as valuable results as the tests given above for metallic circuits. If a lineman is present at the far end, the line should, of course, be disconnected or earthed by him, and the tests can then be made in the usual manner, and this is necessary for accurate results.

Lineman's tests for telephone sets.

30. When a lineman visits a telephone office, either in search of a fault or on ordinary maintenance work, he should always examine, and as far as possible test, the instruments. The following points should be attended to:—

(*a*) See that all terminals are tightly screwed up, and that the ends of the leads round the terminals are clean, and free from insulating material.

(*b*) See that the insulation is not stripped too far from the ends of the leads, so that they are liable to make contact, and that the insulation has not been damaged by forcing wires through holes in the backboard of the telephone, &c.

(*c*) See that the leads have not been broken where bent, and, in the case of stranded conductors, that no strands are either broken off or sticking out, when they should be round the terminals. The cords of the hand telephones should be specially examined.

(*d*) Test the batteries with a detector if available; in any case examine the batteries, refresh wet cells if necessary, and see that the connections are clean and tight (*see* Chap. II, para. 32 *et seq.*).

(*e*) Last thing before leaving, call up the distant office and make sure that the speaking is good; the lineman should not be satisfied by just making himself heard.

There are various simple tests that can be applied to telephone instruments to localise faults in them, or to ascertain whether a fault is in the instrument or line. These tests vary slightly with different patterns of telephones, and are described for the service instruments in Chap. XII after the description of each type of instrument.

Special telephone faults.

31. In addition to interruptions due to ordinary causes, telephone circuits (owing to the great sensitiveness of the telephone receiver) are liable to disturbances that have little or no effect on telegraph instruments, but result in noises in the receiver which interfere more or less seriously with the speaking.

Noisy circuit.

32. A sharp crackling noise in the receiver is usually caused by atmospheric electricity or earth currents; it is unavoidable to some extent on earthed circuits, but should not occur on revolved metallic circuits unless there is an earth fault.

Noise or buzzer signals heard in the receiver may be due to bad earths, contacts, or induction from neighbouring lines; they should not occur on revolved metallic circuits unless the lines are earthy or in contact.

A uniform hum is caused by induction or leakage from a power or Wheatstone circuit, or is occasionally set up in the microphone of the telephone instrument; in the latter case it is generally a high note, and can be stopped by tapping the microphone.

A little experience is necessary to distinguish these different noises.

Overhearing.

33. Overhearing is caused by lines running near each other, and not properly revolved and crossed (*see* Vol. II), or in earthed circuits by bad earths. In exchange systems, overhearing or "cross talk" may also be caused by partial contacts at the switchboard, due to dust or damp, or to actual contacts, or by the indicator coils not being properly shielded.

Noise or overhearing on revolved circuits may also occur if the A and B lines are not symmetrical, *i.e.*, if they are of different gauge wires, or if the line indicator at the exchange is only disconnected from one side, &c.

CHAPTER XX.

ELECTRICAL MEASUREMENTS AND ACCURATE TESTING.

1. The objects and general principles of testing have been described in Chap. XIX, and methods of making rough tests were there given. It was stated that for accurate testing measurements of electrical quantities (usually resistance) are required.

Measurement.

2. As stated in Chap. I, para. 12, quantities are measured in units, *e.g.*, length in yards or miles, time in seconds or hours, &c., that is, the quantity to be measured is compared with a standard amount of the same quantity, and this standard amount is called the *unit.* For example, when we say a distance is 4 yards, we mean it is four times as long as the distance between two marks on a particular metal rod kept in London, when measured at a certain temperature; this distance being the legal unit of length in the British Empire. As measurements of length cannot be referred to this standard, measuring tapes, or other scales, are made whose length bears a definite and known relation to the standard yard. These scales are made in many sizes and of many different forms and materials, and in many different degrees of accuracy, according to the use for which they are required.

Similarly electrical units have been determined and defined by theoretical considerations which need not be considered here, and suitable practical scales have been provided.

Electrical units and measurement.

3. The principal electrical units are (*a*) the *ohm* (unit of resistance), (*b*) the *volt* (unit of E.M.F. and electrical pressure), (*c*) the *ampere* (unit of current).

For ordinary purposes of measuring resistance, lengths of metal wire are used as standards, the lengths having been carefully adjusted to have a given resistance at a given temperature. The lengths are generally made up into coils having a resistance of a multiple or submultiple of one ohm.

For accurate work in a laboratory the standard of E.M.F. used is a "standard" cell, which is a small primary cell very carefully constructed of pure materials. As stated in Chap. II the E.M.F. of a cell depends solely on the materials of which it is composed, and the temperature. For ordinary work special standard cells will not usually be available, but it will generally suffice to use a Daniell or a Leclanché cell, which is carefully made up and known to be in good condition.

Current is usually measured either by an accurate instrument known as an "ampere balance"; or by a specially constructed "ammeter"; or by a voltameter (see Chap. I, para. 40); or by calculation (the resistance of a portion of the circuit, and the difference of potential at the ends of that portion being known or measured).

Every galvanometer is a more or less accurate ammeter, as the deflection produced by a current depends on the construction of the galvanometer and the current passing.

The methods of measuring capacity, self-induction, &c., need not be considered here as they are not required by the practical telegraphist.

Galvanometers.

4. The galvanometers described in Chap. III consist in each case of a pivoted magnetic needle inside a coil. If the needle were perfectly free to move in any direction, any current, however small, would be able to turn the needle at right angles to the direction of the current, so that to enable an instrument of this description to record an alteration of the strength of the current, it is necessary to provide some controlling force which will tend to draw the needle back to its normal position.

In the galvanometers already described in this book this controlling force is furnished by pivoting and weighting the needle and the pointer attached to it so that they hang vertically, thus using gravity as the controlling force.

With a needle pivoted to swing horizontally, such a force is always present in the earth's magnetism, in which case all that is necessary is to set the magnetic needle and the wire conveying the current in the direction of the magnetic force, that is, using the ordinary conventional meaning of the words, to set the magnet pointing north and south. This directive force is often supplemented by placing permanent magnets near the magnetic needle. The result is to give a combined directive force from the earth's magnetism and that of the permanent magnet.

To obtain the greatest deflection the galvanometer must be so placed that, when no current is passing, the needle is parallel to the coils; if the earth's magnetism is the directive force, this means that the galvanometer must be placed with its coil and needle directed north and south. If a permanent magnet is used it should be moved till the galvanometer needle is in the proper position.

A spring is sometimes used to provide the controlling force.

Ammeters.

5. The deflection of a galvanometer depends on the ampere-turns of its coil, the strength of its needle, the proximity of the needle to the coil, and the strength of the controlling force. If the controlling force is constant the deflection of a given galvanometer depends only on the current, and the deflection is a measure of the current passing through it. If the galvanometer scale is suitably marked, the current passing can be directly read off on the scale; such an instrument is called an "ammeter."

In instruments where the controlling force is a magnetic field this force is not constant unless the field is provided by fixed permanent magnets which are so strong that their field is little affected by that due to the earth or to any stray currents or magnets that may happen to be near it. Where the controlling force is provided by gravity it is more constant, but it still depends, to a certain extent, on the position of the instrument.

Moving coil instruments.

6. The most suitable type of galvanometer for use as an ammeter is known as the "moving coil" type. In these instruments the coil is pivoted or suspended between the poles of a strong permanent magnet; when a current passes through the coil the coil tends to set itself at right angles to the lines of force of the magnet; the controlling force is generally provided by a spring.

Voltmeters.

7. Any instrument that can be used as an ammeter can also have its scale graduated in volts, as the current flowing depends simply on the difference of potential at the terminals of the instrument, and the resistance of the instrument, which latter is constant. In practice it is also necessary for the instrument to have a high resistance, so that the current flowing in the circuit, and therefore the difference of potential to be measured, may not be affected by the instrument being connected. Such an instrument is called a "voltmeter."

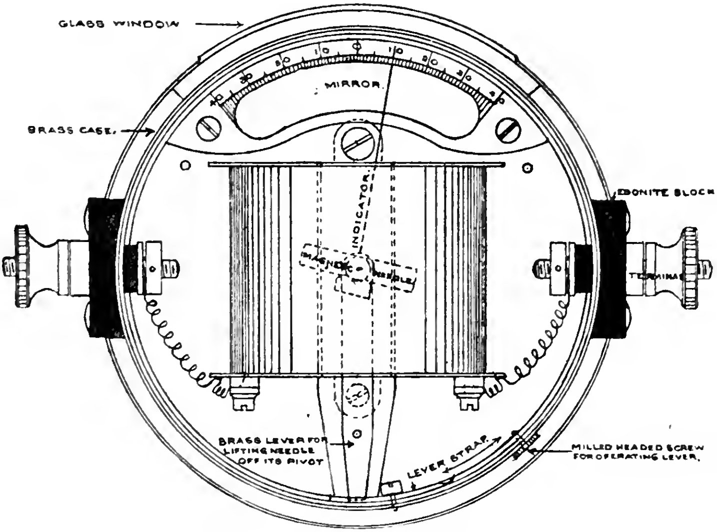


FIG. 1.—Galvanometer, Horizontal.

"Galvanometer, horizontal."

8. The only service pattern galvanometer likely to be of use for telegraph purposes that has not already been described is known as the "galvanometer, horizontal," and has a small

horizontal needle and light pointer set at right angles, the opening of the coil allowing a movement of about 90°. To improve the accuracy of the readings a mirror is placed below the pointer, the readings should be taken when the reflected image appears under the pointer. The galvanometer is illustrated in Fig. 1. It is enclosed in a dust tight brass case provided with windows so that the movement of the needle can be seen either from the top or side. A brass lever, operated by a sliding milled headed screw, is provided to lift the needle off its pivot when not in use; the needle should always be so lifted when the galvanometer is moved. The coil is wound from the centre to a resistance of 800 ohms with copper wire ·0049 to ·0051 inch thick, single silk covered, the six outer turns of each end of the coil being of double silk covered copper wire of No. 29, S.W.G.

This galvanometer is chiefly used for Wheatstone's bridge tests; a deflection of 10° should be given by a current of 1/40000 of an ampere.

Resistance Boxes.

9. The standard resistance coils available in the service are "Coils, resistance, 100 ohms," and "Coils resistance, 10,000 ohms." The former is designed for tests by "Wheatstone's bridge" up to 100 ohms, and for tests of firing batteries, &c., by fuzing wires, in connection with demolitions, &c., and is described in "Instructions in Military Engineering, Part IV"; as it is of little use for telegraph purposes it will not be described here.

"Rheostats" (Chap. VII, paras. 4 and 5) can also be used as standard resistances, but are not so accurate as the above-mentioned resistance coils. The rheostat coils may, however, be taken as not deviating more than 1 or 2 per cent. from their marked values.

Coils, resistance, 10,000 ohms, Mark III.

10. The "Coils, resistance, 10,000 ohms" are mainly designed for use when balancing a resistance by "Wheatstone's bridge" but can be used simply as a resistance, or for other tests. Fig. 2 gives a plan of the top of the Mark III box, which is the pattern described below.

The resistance coils are contained in the body of the box and are connected to brass plates on the top so as to form two distinct series, with terminals at either end, one from F to C¹, the other from C to D. These can be connected or disconnected by the copper strap between C and C¹. There are also two contact keys at H and A called key 1 and key 2 respectively.

The series from F to C¹ includes six resistances, 1,000 ohms, 100 ohms, 10 ohms, 10 ohms, 100 ohms, 1,000 ohms, and the centre brass plate between the two 10-ohm resistances is connected to the underside of key 2; there are thus on either side of the centre a symmetrical series of 10 ohms, 100 ohms, and 1,000 ohms. These series are usually called the "arms" of the bridge.

The other series is from 1 ohm to 4,000 ohms with an "infinity" resistance (*i.e.*, complete disconnection) between the 300 ohm and 400 ohm coils. The total resistance in this series is 11,110 ohms, and by using suitable combinations of resistance any amount between this and 1 ohm can be obtained. This is usually spoken of as the variable resistance. The end at C is connected to the lower contact of key 1.

It may be observed that, should the resistances provided be inadequate for any tests, other resistances can be added to either bridge arm at F or C^1, or to the variable resistance at D, the copper strap at C being removed if the left arm has to be altered.

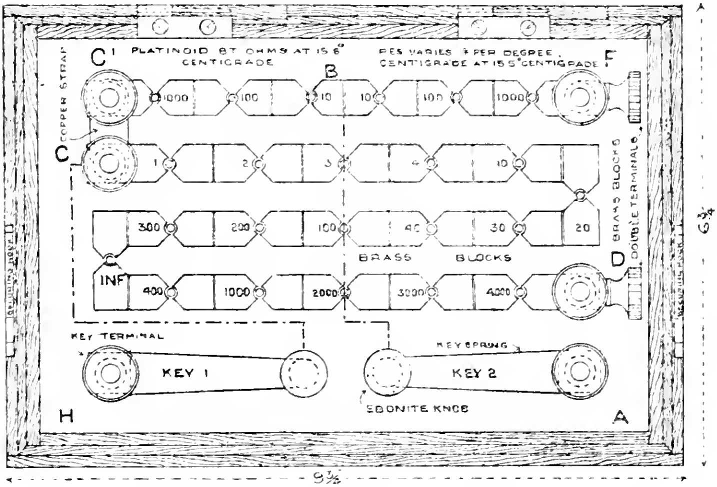


FIG. 2.—Coils, Resistance, 10,000 ohms.

The method of fixing the resistance coils is shown in Fig. 3; the ends of each coil are connected by means of nuts to two contiguous brass plates, a peg hole being formed between the plates to take a small peg of standard size. When the peg is inserted the resistance is short-circuited, and thus, to insert any resistance required, it is necessary to remove the corresponding peg.

To increase the insulation resistance between the brass plates and to facilitate cleaning, the ends of the plates are undercut as shown at M in Fig. 3. The terminals at F and D have two heads as, when used for Wheatstone's bridge, two connections are required at each of these points.

The keys are of sheet brass steady-pinned to the terminals, with ebonite handles and platinum contacts. The ordinary connections for Wheatstone's bridge are engraved on the brass blocks of each terminal. The box is made with a lid which can be easily slipped off its hinges; the lid, when in place, is secured by hooks at either side.

The resistances are made of platinoid, and are carefully tested and adjusted to Board of Trade, or standard,* ohms at a temperature of 15·5° C. (60° F.), and, when issued, are correct to within ·1 per cent. for the smaller coils, and less for those of higher value. The temperature coefficient of all the coils does not exceed ·035 per cent. per degree C., *i.e.*, the resistance will not rise more than ·035 ohm for each 100 ohms of the resistance for a rise in temperature of 1° C., and other resistances and temperatures in proportion. The material of which the coils are made, the temperature at which they have their correct values, and the temperature coefficient are marked on each box.

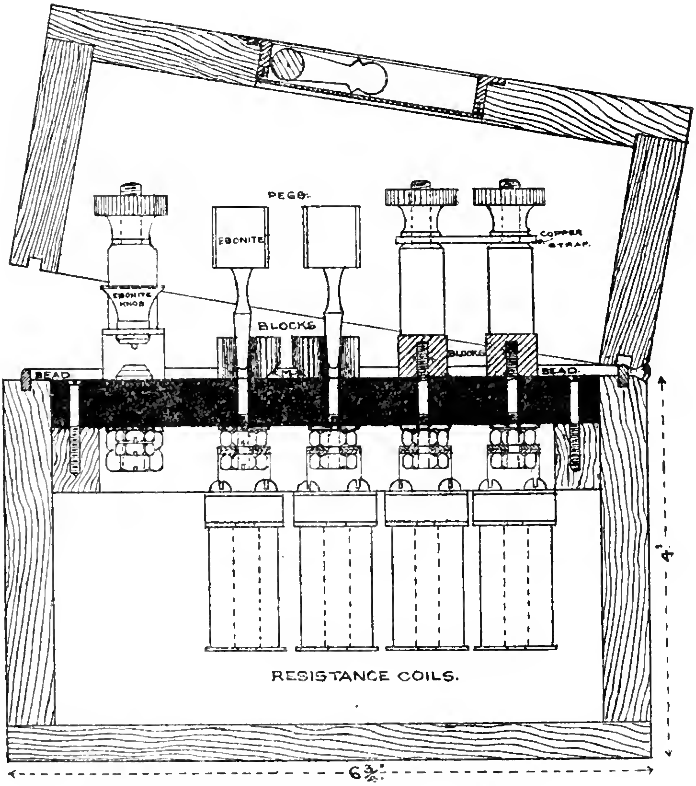


FIG. 3.—Coils Resistance, 10,000 ohms, Mark III.

Coils, resistance, 10,000 ohms, Mark IV.

11. The latest pattern box (Mark IV) is similar in appearance and arrangement, the differences being as follows:—

(*a*) The resistance coils are made of manganin, which has been found to be more constant than platinoid, and which has

---

* "Board of Trade" and "Standard" ohms are the same.

a temperature coefficient of only 0·005 per cent. per degree Centigrade, *i.e.*, for all practical purposes it is not affected by any alteration in temperature ; the temperature coefficient is not marked on the box.

(*b*) The ends of the coils are soldered to brass pins, which are screwed and soldered into the brass blocks, thus obviating screwed contacts in the box (*see* Fig. 4).

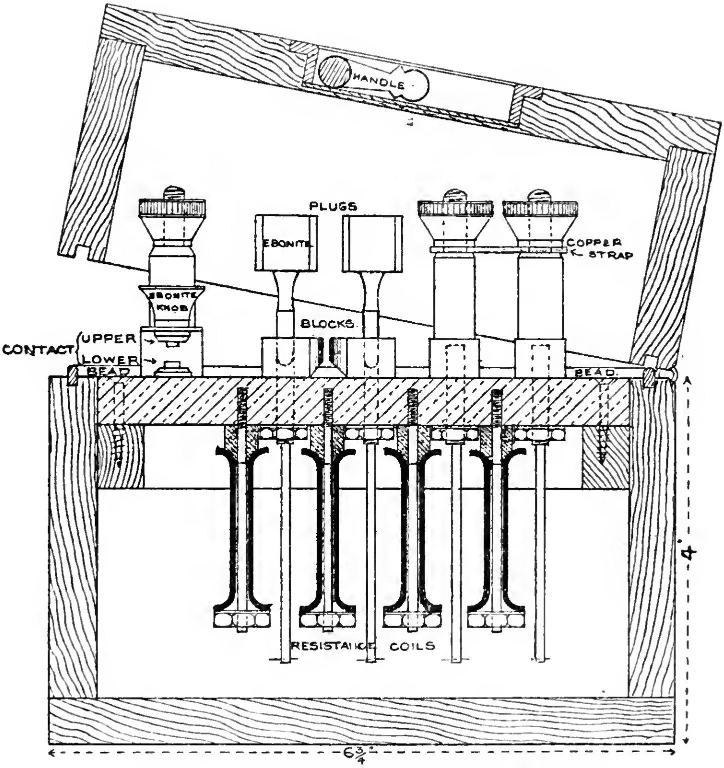


FIG. 4.—Coils, Resistance, 10,000 ohms, Mark IV.

(*c*) The contacts of the keys are slightly different.

The wire forming the coils has a minimum diameter of ·006 inch, and is double silk covered. As paraffin wax has a deleterious effect on manganin the coils are coated with shellac, and paraffin wax must on no account be used if it is necessary to repair these boxes.

The margin of error allowed in the adjustment of the coils is 1 per cent. for the coils below 40 ohms and ·1 per cent. for the coils above 40 ohms ; the ratio between each and every pair of "bridge" coils must be correct within ·1 per cent. This degree of accuracy enables resistances to be measured to an accuracy of 1 part in 1,000, which is quite sufficient for all service purposes.

Coils, resistance, 10,000 ohms, Mark II.

12. The Mark II box may still be met with, it is generally similar to the later patterns, the principal differences being as follows :—

(*a*) The box containing the coils has no lid, but is contained in a separate case fitted with a lid. The box should normally be used without removing it from this case.

(*b*) The two parts of the double terminals at F and D (Fig. 2) are insulated from each other, the lower terminal only being connected to the brass block ; the two parts are connected to a commutator at the side of the box as shown in Fig. 5, if the pegs provided are inserted in the two holes of the commutator in a horizontal line, the connections are the same as those in the newer pattern boxes.

(*c*) The bottom contact of key 1 is connected to C^1 instead of C (Fig. 2).

(*d*) The pegs have round, instead of flattened heads.

(*e*) The values of the resistances are engraved on the ebonite instead of on the brass blocks.

(*f*) Some of the boxes may be found marked "B.A. ohms," the "B.A. ohm" is ·9866 of the standard ohm to which the later boxes are adjusted.

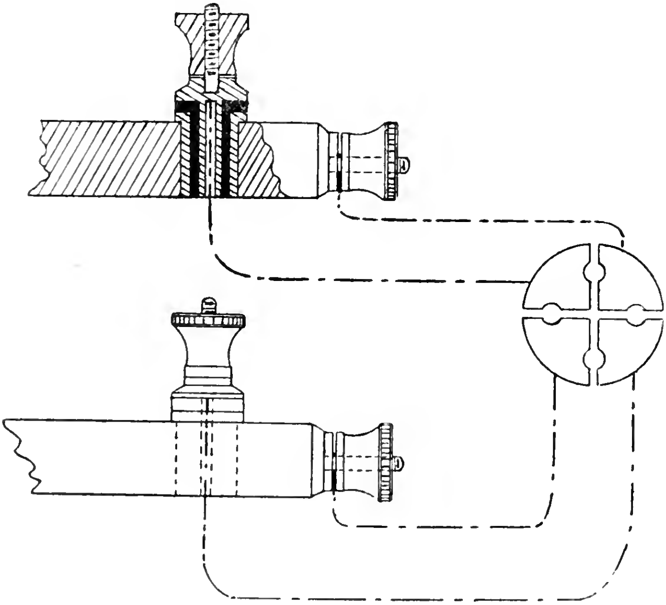


FIG. 5.

Precautions when using resistance boxes.

13. These resistance boxes are accurate instruments, and must be treated with care. The following points should be attended to :—

(*a*) The pegs should be inserted and withdrawn with a slight turning motion, as if they were screwed ; this will ensure the tight fit necessary for accurate work without using undue force or damaging the box. Pegs must on no account be hammered in, or inserted or withdrawn by other means than the fingers.

(*b*) The pegs must be kept clean, and when withdrawn should be placed in the lid, and not allowed to lie on the table or ground. They must only be handled by the ebonite head.

(*c*) The box must be kept free from dust and damp, or leakage will occur over the surface of the ebonite top, and the accuracy of the tests will be impaired.

(*d*) On no account must a current of over 0·05 ampere be passed through the coils. Special care must be taken when using a powerful battery for testing.

Measurement of Resistance.

Substitution method.

14. The simplest method of measuring a resistance is by the substitution method. A battery, galvanometer, key, and the unknown resistance are joined up as shown in Fig. 6. The deflection on pressing the key is then noted, and a box of resistance coils substituted for the unknown resistance. The resistance in the box is then adjusted till (on depressing the key) the deflection is the same as before.

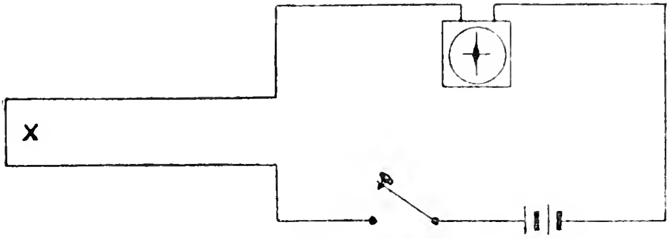


FIG. 6.—Substitution Method.

This method is obviously not applicable when there is a source of E.M.F. in the unknown resistance X.

This is practically the same method of testing as that given in Chap. XIX. It will give accurate results only when a sensitive galvanometer is used, and when the combined resistance of the galvanometer and battery is small compared with the unknown resistance. It has also the disadvantage of necessitating a definite deflection being reproduced—this cannot be done accurately with the ordinary galvanometers used in telegraphy, owing to the size of the pointer, its distance from the scale, &c.

Differential method.

15. The differential method involves the use of a differential galvanometer, such as the "Galvanometer, single and duplex." This is joined up, as shown in Fig. 7, with the unknown resistance x, a known adjustable resistance R, a battery and a key. The resistance R is then so adjusted that on depressing the key no deflection is obtained on the galvanometer. When

this is the case the current is dividing equally between the two paths, hence the resistances of the two paths are the same, and as the resistances of the two coils of the galvanometer are the same, the resistance *x* must equal R.

This method is also not applicable when *x* contains an E.M.F., and is not accurate when *x* has much capacity.

This method (and the Wheatstone's bridge method described below) has the advantage that the galvanometer deflection has not to be read. It is far easier to notice a slight movement of the needle, than to actually read the deflection; consequently methods which involve balancing the circuit so that no movement is produced on the galvanometer when a key is depressed are more accurate than those which involve reading, or reproducing a deflection.

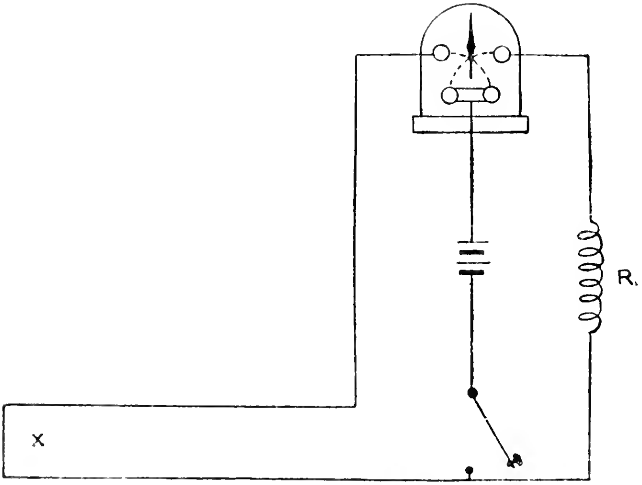


FIG. 7.—Differential Method.

Adjusting the rheostat in a duplex set is an example of the differential method of measuring resistance.

Wheatstone's bridge.

16. The Wheatstone's bridge method of measuring resistances is the most accurate method in all cases where it is applicable, and should consequently be used whenever the apparatus and time required are available. The service instruments used for this test are the "coils, resistance, 10,000 ohms," the "galvanometer, horizontal, 800 ohms," and a battery. This apparatus will measure any resistance between $\frac{1}{100}$ ohm and 1,000,000 ohms. If the "galvanometer, horizontal" is not available, any other moderately sensitive galvanometer can be used.

The battery used should be of 10 to 30 cells, 10 cells should be sufficient except for high resistance of over 1,000 ohms;

30 cells should only be used for resistance of 100,000 ohms and upwards.

Theory of Wheatstone's bridge.

17. Fig. 8 shows the arrangement of the circuit for the Wheatstone's bridge test. "G" is the galvanometer, "*a*" and "*b*" are known resistances, "*d*" is a known adjustable resistance, and "*x*" the unknown resistance. The resistance "*d*" is then adjusted till, on depressing both keys, no deflection is obtained in the galvanometer.

When the resistances are adjusted as above mentioned, it means that there is no current through G, and consequently the current (C_1) through "*a*" equals the current (C_3) through "*x*"; that the current (C_2) through "*b*" equals the current (C_4) through "*d*"; also that there is no difference of potential between "F" and "C."

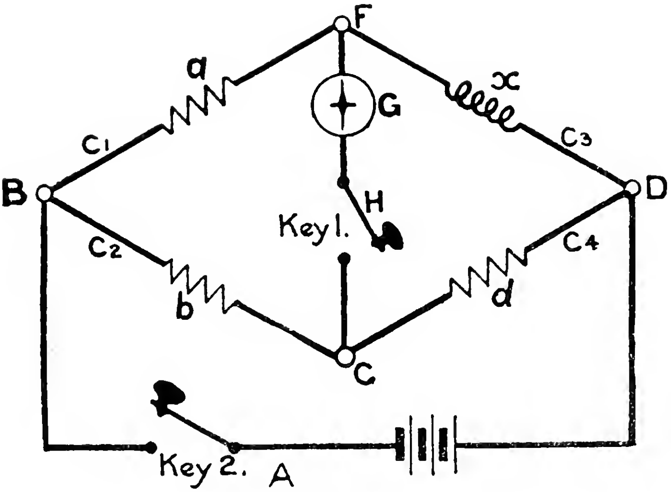


FIG. 8.—Theoretical Diagram.

The difference of potential between B and F is C_1a, and between B and C is C_2b (*see* Chap. I, para. 25), hence as C and F are at the same potential:

$$C_1a = C_2b$$

similarly $$C_3x = C_4d,$$

but $$C_1 = C_3 \text{ and } C_2 = C_4$$

hence $$\frac{a}{x} = \frac{b}{d},$$

or $$x = \frac{a}{b}d,$$

hence as *a*, *b*, and *d* are all known *x* is also known.

Connections of Wheatstone's bridge.

18. Fig. 9 shows how the service instruments mentioned in para. 16 are joined up for the Wheatstone's bridge test. In comparing this figure with Fig. 8 we see that the portions of the box FB and BC form the resistance "a" and "b," and the main portion of the box CD forms the resistance "d." The terminals H, A, F, and D, on the box are marked "Galv.," "Zinc," "Galv. and Line," and "Copper and Earth," respectively, to facilitate correct joining up; the unknown resistance being connected between "Line" and "Earth."

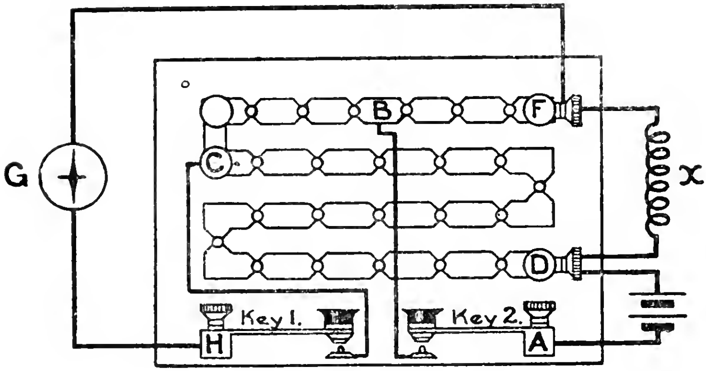


FIG. 9.—Wheatstone Bridge.

As the resistances "a" and "b" can each be given the values 10, 100, or 1,000 ohms, the ratio $\frac{a}{b}$ can be made either $\frac{1}{100}$, $\frac{1}{10}$, 1, 10, or 100, and as "d" can be any number of ohms between 1 and 11,110 we can measure any resistance between $\frac{1}{100}$ ohm and 1,111,000 ohms.

In most cases it is sufficient to make "a" = "b," in which case they should be of the same order of magnitude as x; *i.e.*,

If x is small (below 30 ohms) make $a = b =$ 10 ohms;
If x is medium (between 30 and 300 ohms) make $a = b =$ 100 ohms;
If x is large (above 300 ohms) make $a = b =$ 1,000 ohms.

When unknown resistance contains E.M.F.

19. If the unknown resistance x (Fig 8) contains an E.M.F. it will be seen that a current will flow through the galvanometer when Key 1 is closed but Key 2 open; in this case a modified procedure must be adopted. The Key 1 must be kept depressed, and the needle allowed to come to rest. The resistance is then adjusted till there is no further movement of the galvanometer needle when Key 2 is first depressed. The

formula $x = \frac{a}{b} d$ then holds, though the proof given in para. 17 does not hold in this case; the complete proof is too complicated for insertion here. This procedure is termed "balancing to a false zero."

When unknown resistance contains capacity or self-induction.

20. If the unknown resistance contain capacity, or self-induction, the current wlll take longer to grow to its proper value through "x" than through "d," hence even if the resistances are properly adjusted there will be a difference of potential between F and C for a moment after Key 2 is depressed. If, therefore, Key 1 be depressed before Key 2, the galvanometer needle will move. In consequence of this, Key 2 should always (except when "x" contains an E.M.F.) be depressed before Key 1, thus allowing time for the current through "x" to reach its steady value.

Rules for testing with Wheatstone's bridge.

21. The procedure when testing with Wheatstone's bridge is usually as follows :—

(i) Connect up the circuit as shown in Fig. 9.

(ii) Unplug suitable resistances in the arms a and b. Unequal arms should only be used when the resistance to be measured is under 1 ohm or over 10,000 ohms, or when the result is required to a fraction of an ohm.

(iii) Depress Key 1, and note if there is any deflection. This is to ascertain if there is an E.M.F. in the unknown resistance—if there is a deflection, proceed as in (vi) below.

(iv) If there is no deflection release Key 1, and unplug the "infinity" plug, depress Key 2 and, while holding it down, depress Key 1 momentarily; note the direction of the throw of the galvanometer needle. If the galvanometer needle does not move, the unknown resistance is very great, the testing set is wrongly joined up, or some portion of it is out of order.

(v) Plug the infinity plug, and unplug a resistance in "d" which will probably be rather greater than that to be balanced. Press the keys again in the same way as above (iv) and note the direction of the galvanometer deflection. If in the same direction as before there is too much resistance in the box, if in the reverse direction there is too little. Then adjust the resistance in the box till there is no deflection on depressing the keys. The unknown resistance is then $\frac{a}{b} d$.

(vi) *Variation.*—If in (iii) above there is a deflection, proceed by keeping Key 1 depressed, and adjust the resistances in "d" until on first depressing Key 2, no alteration in the deflection is produced. The unknown resistance is then calculated as before.

It is very important in making these tests to get actual deflections on the galvanometer and not to be satisfied with a purely negative result. The absence of deflection may be due to a loose peg, bad contact, a broken connection, or a sluggish galvanometer and, by itself, gives no information. If, however, deflections are obtained for values of "*d*" slightly above and below the value giving no deflection, it is practically certain that no such defects exist.

Insulation Testing.

With Wheatstone's bridge.

22. Testing the insulation of a circuit is simply measuring a very high resistance. This can be done by Wheatstone's bridge as already described, but only if the resistance is below 1 megohm (1,000,000 ohms); if the resistance is above this figure it cannot be measured unless a coil of 1 ohm resistance is available, in which case it can be inserted between C and C^1 (Fig. 2) and used instead of the "*b*" arm of the bridge, or unless a high resistance, such as a second box of coils, be attached at F to increase the resistance of "*a*." This will enable resistances up to 10 megohms to be measured with a fair degree of accuracy, and thus give a range sufficient for most cases.

The "Megger."

23. An instrument called the "Megger" has recently been introduced for the purpose of measuring resistances from 50,000 ohms to 100 megohms, and this instrument should be used when available, as it is simpler to use and more accurate for high resistances than Wheatstone's bridge.

The instrument is issued in sealed boxes, and as the makers guarantee the instrument if the seals are not broken, they should be kept intact, and if repairs are required the "Megger" should be returned to Woolwich and not be repaired locally. The "Megger" consists of a generator which will give an E.M.F. of 500 volts, and a specially constructed galvanometer of the moving coil type, the scale of which is graduated in ohms so that the resistance can be read off without any calculation. The generator is driven through a friction clutch, and above a certain critical speed (about 100 revolutions a minute) the handle is felt to slip, and above this speed the voltage is constant; the importance of constant voltage in testing the insulation of cables is dealt with below.

Use of "Megger."

24. To use the Megger the line is connected to the terminal marked "line," and earth is connected to the terminal marked "earth," the handle is then turned till it is felt to slip, and the resistance is read off direct on the scale. If the resistance between two lines is required they are connected to the two terminals. The Megger should be approximately level when in use.

Construction of "Megger."

25. The galvanometer consists of two coils rigidly connected together and to the pointer, the coils being pivoted in the field of a powerful permanent magnet. The coils are connected electrically as shown in Fig. 10 where C and P are the coils, "rr" resistances in series with them, and R the resistance to be measured. The coil C is so arranged that a current flowing through it tends to set the pointer to the zero of the scale, and

the coil P tends to move the pointer along the scale. If the unknown resistance R is infinite no current flows through C, while if R is reduced the current in C increases while the current through P is. if anything. reduced. As the deflection of the pointer depends simply on the currents flowing in the two coils and these currents depend simply on the value of R, the scale can be graduated to give the value of R in ohms or megohms; the readings are independent of the E.M.F.

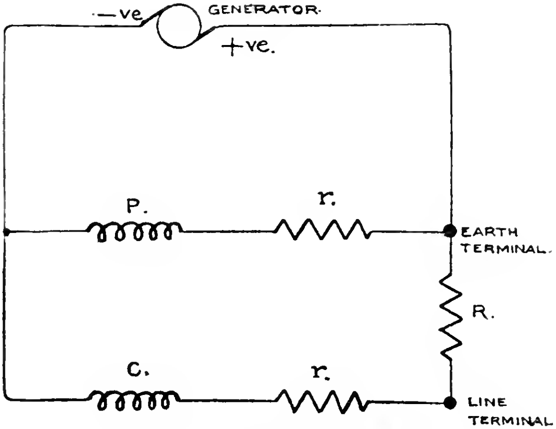


FIG. 10.—Connections of "Megger."

"Electrification" of cables.

26. Long lengths of cable act as condensers, and thus, even when the insulation is perfect, there is, on first closing the circuit, a flow of current into the cable, and this continues until the cable is fully "charged." As it becomes charged or "electrified" the current decreases gradually, and thus some time elapses before the "electrification," as it is generally called, is complete. If an insulation test is taken before this is complete, the result will be lower than the true value of the insulation resistance. For very accurate work it is necessary to wait some considerable time before taking readings after completing the circuit. This charging current also depends on the voltage applied to the cable, and consequently the voltage must be kept constant during the test. For ordinary tests it is sufficient to take the readings after one minute's electrification, but for results to be useful for comparisons the voltage used and the times allowed for the electrification must be stated. The movement of the galvanometer needle during the test also gives an idea of the state of the insulation; the apparent resistance should rise in a uniform manner, and without jerks; if this is not so the insulation is not in proper condition. The figures given in this book for the correct insulation resistance of the various service pattern cables are when tested at 500 volts after an electrification of one minute. If it is desired to repeat a test for insulation of a cable, care must be taken to

fully discharge the cable before the second test, by connecting the conductor to earth and leaving it so for some little time.

Directions for preparing cables for test, &c., are given in Vol. II.

Testing Batteries.

Terminal P.D. method, with voltmeter.

27. To make a complete test of a battery or cell it is necessary to measure both its internal resistance and its E.M.F. If a voltmeter of suitable range is available these can be best measured as follows: The voltmeter is first connected to the terminals of the battery to be tested, and the volts read off the scale; call this reading V_1. A low resistance of known value (R) is then connected as shown in Fig. 11, with a key in circuit, and the difference of potential at the terminals is again read; call this reading V_2; call the resistance of the battery r, and its E.M.F., E.

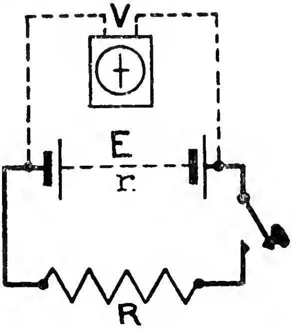


FIG. 11.

The reading V_1, strictly speaking, gives the difference of potential at the terminals of the battery, but if the voltmeter is of high resistance the current flowing is small, and the E.M.F. is practically the same as the difference of potential at the terminals (*see* Chap. I, para 25).

Hence practically $E = V_1$.

If the resistance R is small compared with the resistance of the voltmeter, the current through the resistance is $\frac{E}{R + r}$, *i.e.*, $\frac{V_1}{R + r}$.

But the current through the resistance is $\frac{V_2}{R}$.

Therefore $\frac{V_1}{R + r} = \frac{V_2}{R}$, or, $r = R\frac{V_1 - V_2}{V_2}$.

Thus both the resistance and the E.M.F. of the battery can be found. *Note* that the resistance R should not be one of the coils of the "Coils, resistance, 10,000 ohms" as the comparatively large current furnished by the battery in this test would probably damage the coil. Also the second reading should be taken as quickly as possible, or the battery will become polarised and its resistance altered.

If the galvanometer has not a high resistance compared with the battery and the resistance R used, the accurate formulæ for E.M.F. and internal resistance are :—

$$E = \frac{(G - A)V_1V_2}{GV_2 - AV_1} \text{ and } r = \frac{V_1 - V_2}{\frac{V_2}{A} - \frac{V_1}{G}},$$

where V_1 and V_2 are the first and second readings of the voltmeter, G the resistance of the voltmeter, and where A is the combined resistance of the voltmeter and the resistance R, *i.e.*, where $A = \frac{G\,R}{G + R}$. The proof of this is a simple application of Ohm's law and need not be given here.

"Instrument, testing primary batteries."

28. The "Instrument, testing, primary batteries" (Fig. 12) is designed for testing single cells by the above method. It consists of a small voltmeter reading to 1·5 volts, having a resistance of 8 ohms, and provided with a shunt with a resistance of $2\frac{2}{3}$ ohms, the combined resistance of the voltmeter and shunt being therefore 2 ohms. As the voltmeter has not a high resistance the more complicated formulæ given at the end of para. 27 must be used. The shunt is introduced by pressing a button at the side of the case. The formulæ for E.M.F. and internal resistance consequently reduce to $r = \frac{8\,(V_1 - V_2)}{4\,V_2 - V_1}$ and $E = \frac{3\,V_1\,V_2}{4\,V_2 - V_1}$, from which the constants of the cell can be calculated. A table giving the values of E and r for different values of V_1 and V_2 is fixed to the side of the case.

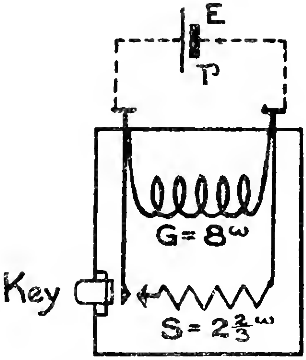


FIG. 12.—Instrument Testing Primary Batteries.

Volt-ammeter.

29. An instrument called the "Volt-ammeter" has been introduced to supersede the above and is illustrated in Fig. 13. The instrument is of the moving coil type. When the button marked "volts" is pressed the terminals are connected to the moving coil through an added resistance of about 1,500 ohms (wound on two bobbins, B_1 and B_2), and the scale is graduated to read the volts at the terminals when connected in this manner, and will read up to 10 volts. When the button marked "amps" is pressed the terminals are connected by a resistance of about ·02 ohm, in parallel with the coil and an added resistance (bobbin B_3) of about 13 ohms; the scale now reads the amperes passing through the instrument, the resistance being only about ·02 ohm. If the instrument is connected to the terminals of a cell or battery, and the reading taken with the "volt" button pressed, the reading gives the

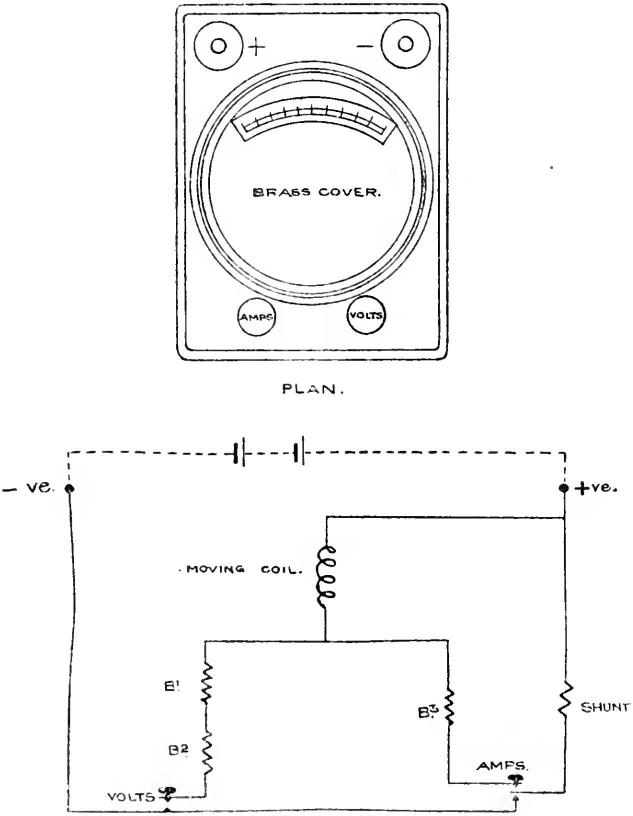


FIG. 13.—Volt-ammeter.

E.M.F. of the battery without furthur calculation (strictly it gives the difference of potential at the terminals, but as the resistance of the instrument is large this is practically the same thing). If the "amps" button is then pressed the reading gives the current produced by the battery when connected to a resistance of ·02 ohm, hence if E and C are the two readings, and "r" the resistance of the battery, we have $C = \frac{E}{r + \cdot 02}$, or in other words, $r = \frac{E}{C} - \cdot 02$, or practically $r = \frac{E}{C}$. In using this instrument care must be taken not to test at one time a battery that has a higher E.M.F. than 10 volts or one that is capable of giving a larger current than 10 amperes when short circuited, and the "amps" button must not be kept pressed for longer than is absolutely necessary to obtain the reading.

Other methods of measuring E.M.F.

30. Other methods of measuring E.M.F. require the use of a standard cell, and as this will not be generally available these methods will not be described here. It will generally be sufficient to note the deflection given by a cell on the "I" coil of a detector and compare it with that given by another cell of the same description that is known to be in good order.

Other method of measuring internal resistance.

31. The only other method of measuring the internal resistance of a battery that need be considered here is a modification of Wheatstone's bridge. The bridge is joined up as for an ordinary test, only the battery under test is substituted for the unknown resistance, and the terminals B and D are joined by a wire. The balance is then obtained in the manner usually employed when the unknown resistance contains an E.M.F.

Localisation of Faults with Wheatstone's Bridge.

Test for distance of earth fault.

32. If a good line is available to form a loop with the faulty one at a point beyond the fault, an earth fault can be localised as follows. The two wires are looped (*i.e.*, joined together) at the far end and the resistance of the complete loop is measured in the usual way. The battery is now disconnected from D (Fig. 14) and connected to earth and a balance obtained. By referring to Fig. 14 and comparing it with Fig. 8 we see that the following relation now holds—

$$\frac{a}{b} = \frac{l - x}{d + x}$$

where l is the resistance of the loop as already measured, and x the resistance of the faulty wire up to the fault. As "a" can always be taken equal to "b" it follows in this case that $x = \frac{1}{2}(l - d)$. To ascertain the distance of the fault from the testing station from the resistance "x" in ohms, the material and gauge of the wire must be known. If the gauge and material are not uniform an approximate result can be arrived

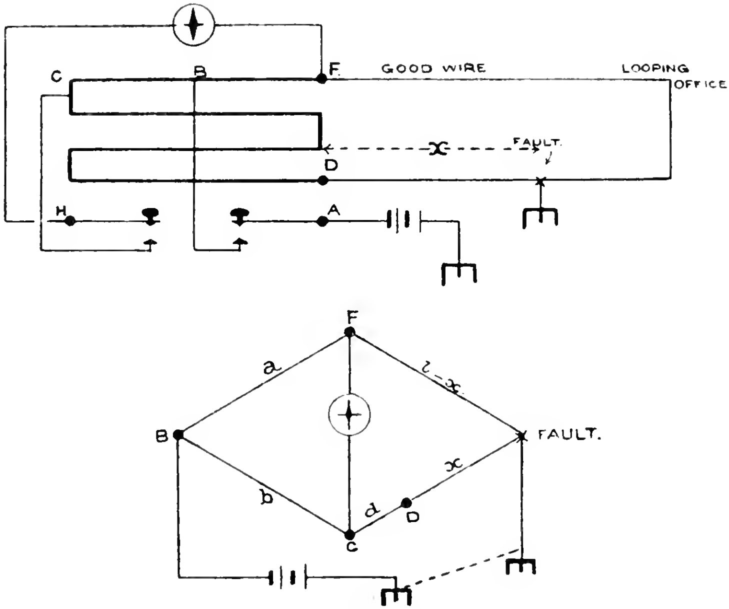


FIG. 14.—Loop Test for Earth Fault.

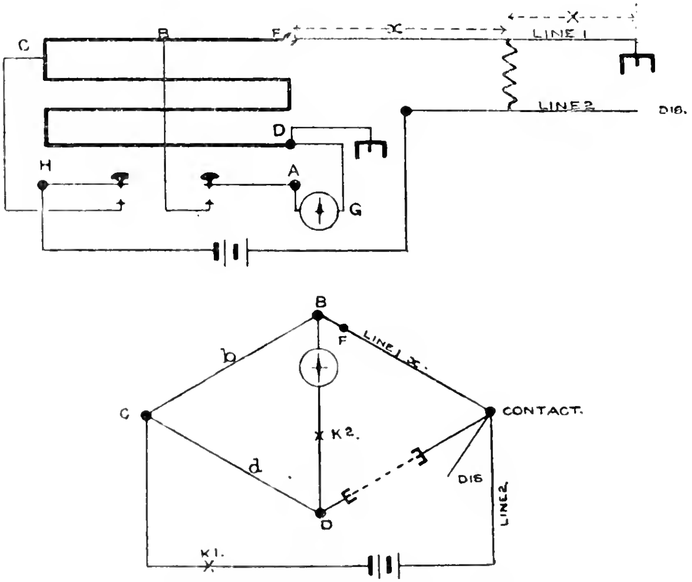


FIG. 15.—Test for Distance of a Contact.

at if the extent and distribution of the various sections are known.

Test for distance of a contact.

33. The distance of a contact can be arrived at in a similar way, one of the lines is earthed at the far end and the other is left dis. The connections are as shown in Fig. 15. X and x are the resistances of the portions of the earthed wire between the contact and the earth, and the contact and the testing office respectively. It should be noted that the keys in this test are reversed and that the arm "a" of the bridge is not used—the three holes in this arm must be plugged. When the balance has been obtained $\frac{b}{d} = \frac{x}{X}$; if the line is of a uniform gauge the lengths are proportional to the resistances, and if the distance of the far station is known the distance of the contact can easily be calculated.

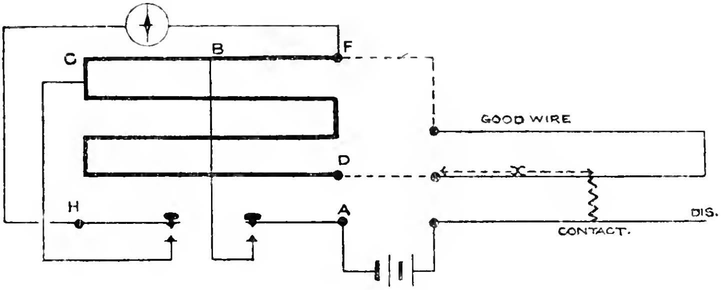


FIG. 16.—Loop Test for Distance of a Contact.

If a good wire is available for looping to a point beyond the fault the distance of the fault can be found by the same method as that explained above for an earth fault. The connections for this test are shown in Fig. 16.

Testing Earths.

34. All earths on a permanent system should be tested occasionally. The resistance of earths on a permanent telegraph system should not exceed 10 ohms.

To test the resistance of an earth two other earths are required, and these should be not less than 20 yards apart. In the case of telegraph offices these earths may conveniently be those of neighbouring offices, provided a line is available to each of these offices.

Two tests are required, and the current should flow through the earth under test in the same direction in each case, and also should be of about the same strength in each case, this will necessitate increasing the battery for the second test; a detector inserted in the battery circuit assists in obtaining this. The lines are connected as shown in Fig. 17 and a balance obtained, we then have the relation $\frac{a}{b} = \frac{L_1 + x}{d}$, where L_1 is the resistance of the one line and its earth, and x the resistance of the earth under test. The second line is then joined up as shown in Fig. 18 and a balance again obtained, if the balancing resistance is now d^1 we have $\frac{a}{b} = \frac{L_1}{d^1 + x}$; from these two equations we get $x = \frac{a\,(d - d^1)}{a + b}$, or if $a = b$, $x = \frac{1}{2}\,(d - d^1)$.

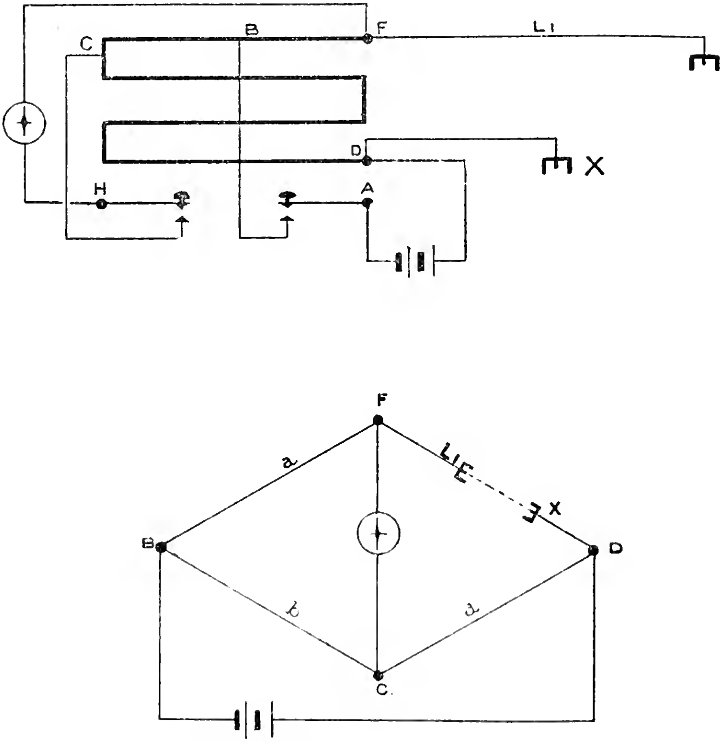


FIG. 17.—Testing Earths—1st Test.

Another method of testing is to measure the resistance of each pair of earths in turn. Then if $x + L_1 = A$, $x + L_2 = B$, and $L_1 + L_2 = C$ we have $x = \frac{1}{2}\,(A + B - C)$. This value of x includes the resistance of the wire connecting the earth to the testing apparatus, which can be ascertained separately, and allowed for. If this method be employed the current should flow for as short a time as possible, to avoid polarizing the earths, or else the "apparatus, testing lightning conductors" should be used.

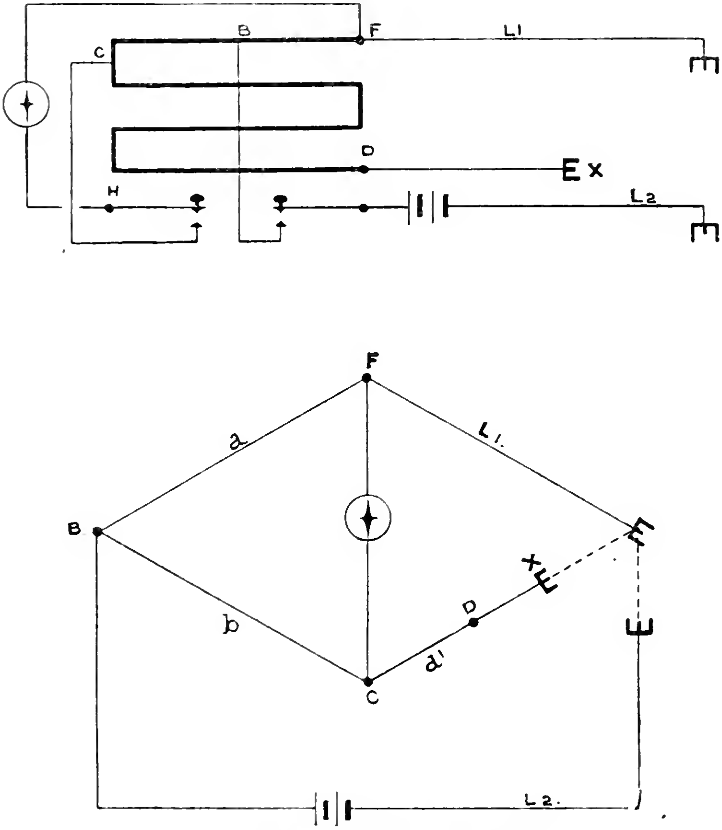


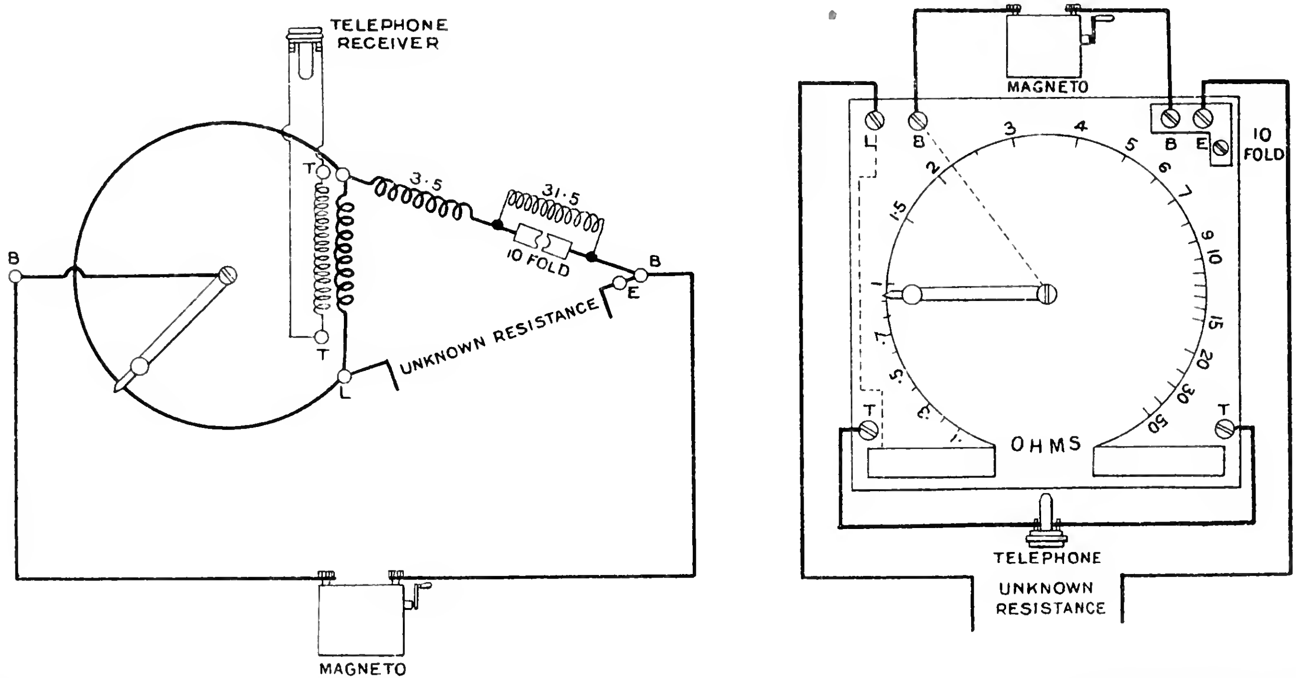
FIG. 18.—Testing Earths—2nd Test.

Apparatus, testing lightning conductors.

35. The "apparatus, testing lightning conductors" consists of a special form of Wheatstone's bridge, with the necessary accessories for connecting up. In this apparatus a magneto generator is used instead of a battery, and a telephone receiver instead of a galvanometer, the point of balance being when no noise is heard in the receiver when the generator handle is being turned. The apparatus is illustrated in Fig. 19. The arms "*a*" and "*b*" (Fig. 8) of the bridge are composed of a piece of German silver wire, and balance is obtained by moving the point "B" (Fig. 8, this point B is the contact between the sliding arm and the wire) along this wire. The arm "*d*" is a fixed resistance of 3·5 ohms. The wire forming the arms "*a*"

Fig. 19. Chapter XX.

APPARATUS, TESTING LIGHTNING CONDUCTORS.



To face p 294.

H & C. GRAHAM LTD, LITHRS. LONDON, S.E

and "*b*" is placed on a graduated scale, so that the resistance corresponding to the point of balance can be read off. If the screw marked "10 fold" be removed, the resistance of "*d*" is increased to 35 ohms, and the resistance read off on the scale must then be multiplied by ten. This screw should be removed when the unknown resistance is over 10 ohms.

The use of an alternating current for the test prevents the polarization of the earths, but it will not give accurate results unless the self-induction of the various arms of the bridge is negligible, as if this is not the case the apparent resistance will be greater than the actual resistance (*see* Chap. I, para. 61). Consequently it is necessary that the wire used to connect up should not be in coils, unless the coils are differentially wound. The drum of wire supplied with the apparatus is wound double for this reason, and also to enable it to be paid out from a central position in the two directions it is required to connect, it should always be recoiled after use in the same manner. Short lengths of wire used should always be straightened out. The moving arm should always be handled by the insulated knob, or the tester's body will provide a path to earth, and so prove a source of error.

In some cases it may be found impossible to obtain absolute silence in the receiver when making the test. This may be due to :—

(*a*) Induction in the testing circuit.
(*b*) Leakage in the apparatus, probably due to dampness.
(*c*) A faulty (*i.e.*, leaky) receiver.

Defect (*a*) may be removed or lessened by attending to the instructions already given regarding coiling of test wires, &c.

Defect (*b*) if due to dampness, may be prevented by keeping the apparatus in a dry place, and exposing it to the weather as little as possible.

Defect (*c*) may be remedied temporarily by insulating the handle of the telephone receiver with indiarubber tape.

CHAPTER XXI.

METHOD OF DEALING WITH MESSAGES, OFFICE ROUTINE, AND ORGANIZATION.

NOTE.—*Nothing in this chapter is to be taken as overruling any regulations contained in "Telegraph Manual—War," or other official "regulations," or any amendments thereof.*

The instructions here given are, at the time of writing, in agreement with the regulations, and are written to explain and amplify them. They are to be complied with when not inconsistent with the regulations above mentioned.

When paid telegraph work is dealt with in military telegraph offices at home, in peace time, the "Instructions" of the Post Office telegraphs must be adhered to.

Operating.

Morse signals.

1. The Morse Alphabet, which is now invariably used for telegraphy by all countries using the Roman Alphabet,* is formed by various combinations of two distinct signals arranged on the principle that the most commonly used letters are formed by the shortest signals. In the system used for military telegraphy, the difference between the two signals is a difference of duration; one signal, known as a "dash," being three times the length of the other, known as a "dot." The interval between the component dots and dashes forming a letter is equal in duration to one dot; that between each complete letter forming a word to two dots; and that between words to three dots. (*See* Fig. 1.)

Good sending, and therefore easy reading, depends upon the accuracy with which the correct lengths of the dots and dashes, and of the separating intervals and pauses are maintained. Whatever the rate of telegraphing may be, these relative lengths should be strictly adhered to.

Single needle system.

2. In the single needle system, although the alphabet is the same, the different signals are formed by right and left deflections of a galvanometer needle representing dashes and dots respectively and not by difference of duration.

Morse symbols for signs of punctuation, &c.

3. Full stop (.) ▪ ▬ ▪ ▬ ▪ ▬
Break signal or fresh line ▬ ▪ ▪ ▪ ▬
Apostrophe (') ▪ ▬ ▬ ▬ ▬ ▪
Hyphen (-) ▬ ▪ ▪ ▪ ▪ ▬
Exclamation (!) ▬ ▬ ▪ ▪ ▬ ▬
Interrogation (?) ▪ ▪ ▬ ▬ ▪ ▪

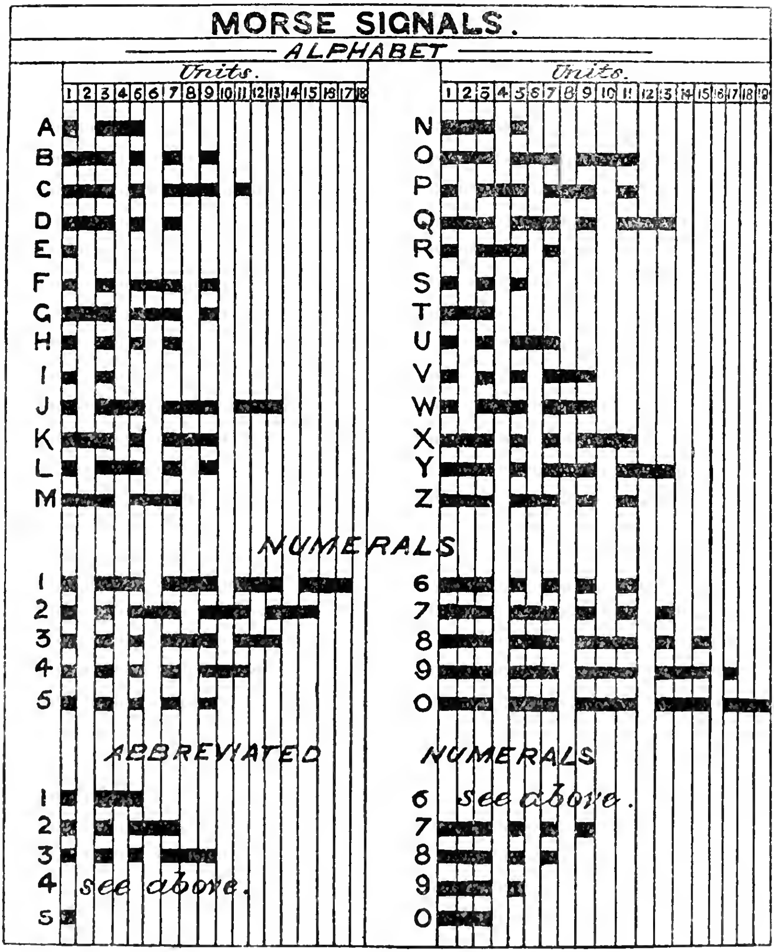
---

* A modification of the Morse alphabet is used in America, some of the letters being slightly different. Some of the latest automatic telegraph systems use a different alphabet.

Underline (———) ▪ ▪ ▬ ▬ ▪ ▬
Parenthesis ( ) ▬ ▪ ▬ ▬ ▪ ▬
Inverted commas (“ ”) ▪ ▬ ▪ ▪ ▬ ▪
Completion of telegram or “understand” ▪ ▪ ▪ ▬ ▪
Rub out ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪
Bar of division (/ or |) ▪ ▬ ▪ ▪ ▬
Fractional or horizontal bar (—) ▬ ▪ ▪ ▬ ▪
Symbol to be used between whole numbers and fractions ▬ ▬ ▬ ▬

Symbol to be used before and after a word or words in block letters ▬ ▬ ▪ ▪

FIG. 1.



Signalling bar of division, horizontal bar, &c.

4. The bar of division used in the symbols, "$^a/_c$" (account), "$^b/_l$" (bill of lading), "$^c/_o$" (care of), and "$^o/_o$" (per cent.), or with any letters, whole numbers, or fractions, or as a division between shillings and pence is to be signalled ▪▬▪▪▬, thus :—

"$^a/_c$" ▪▬ ▪▬▪▪▬ ▬▪▬▪
$^{15}/_{16}$ ▪▬▬▬▬ ▪▪▪▪▪ ▪▬▪▪▬
▪▬▬▬▬ ▬▪▪▪▪
18/6 ▪▬▬▬▬ ▬▬▬▪▪ ▪▬▪▪▬
▬▪▪▪▪

The fractional or horizontal bar used to separate the numerator from the denominator is to be signalled ▬▪▪▬▪ thus :—

$\frac{15}{16}$ ▪▬▬▬▬ ▪▪▪▪▪ ▬▪▪▬▪
▪▬▬▬▬ ▬▪▪▪▪

This signal must also be used in all cases in which a horizontal bar is written by the sender.

In a whole number followed by a fraction, the whole number must be separated from the fraction by the signal ▬▬▬▬, the bar of division or the fractional bar being signalled as written by the sender in accordance with the above instructions, and similarly in the case of a fraction followed by a whole number, thus :—

$29^{15}/_{16}$ ▪▪▬▬▬ ▬▬▬▬▪ ▬▬▬▬
▪▬▬▬▬ ▪▪▪▪▪ ▪▬▪▪▬
▪▬▬▬▬ ▬▪▪▪▪
$29\frac{15}{16}$ ▪▪▬▬▬ ▬▬▬▬▪ ▬▬▬▬
▪▬▬▬▬ ▪▪▪▪▪ ▬▪▪▬▪
▪▬▬▬▬ ▬▪▪▪▪
$^6/_7$ 2 ▬▪▪▪▪ ▪▬▪▪▬ ▬▬▪▪▪
▬▬▬▬ ▪▪▬▬▬
$\frac{6}{7}$ 2 ▬▪▪▪▪ ▬▪▪▬▪ ▬▬▪▪▪
▬▬▬▬ ▪▪▬▬▬

A double or combined mixed group, such as $5\frac{3}{4}$, $6\frac{7}{8}$, must be signalled thus :—

▪▪▪▪▪ ▬▬▬▬ ▪▪▪▬▬ ▬▪▪▬▪
▪▪▪▪▬ ▬▬▬▬ ▬▪▪▪▪
▬▬▬▬ ▬▬▪▪▪ ▬▪▪▬▪
▬▬▬▪▪

When punching Wheatstone slip, mixed groups must always be preceded and followed by four spaces, as an indication that the figures, &c., within those spaces form one group.

The symbol "&c." should be signalled as "etc."

Authorised abbreviations.

5. The following authorised abbreviations are also in use to denote certain phrases which are in constant use between tele-

graph clerks connected with the working of the line, to save time:—

Am I through?	TQ	Attend to switch	ZQ
Not through	IQ	Correction required	RQ
How are your signals?	HQ	All stations	CQ
Direct line free	DF	Two or more stations	YQ
Wait; engaged	MQ	Weather report	ZM
Say when ready	KQ	Daily time signal	TI
Nothing more coming	NN	Greenwich mean time	ME
Attend other circuit	UQ	Go on	G
Acknowledgment	RD		

Prefixes.

6. The first signal sent in a message after having obtained the attention of the distant station is called the "prefix." It enables the receiving clerk to determine on what form to write the message. The various prefixes are as follows:—

Messages to be delivered at Receiving Station.	Messages to be transmitted at Receiving Station.	———	
DS	DX	Telegraph service messages requiring immediate attention	
SA	XA	Military railway service messages requiring immediate attention	
SB	XB	Telegrams O.H.M.S. with priority	
SG	XG	Telegraph service messages	
SM	XM	Telegrams O.H.M.S. without priority	
S	X	Paid telegrams	Equal as regards priority
SRP	XRP	Reply paid telegrams	
SP	XP	Press or news telegrams	

Telegrams take precedence in accordance with their prefixes in the order given above.

Code time.

7. While precedence among different classes of messages is determined by the prefix, the order of transmission among messages of the same class and character must also be determined. For example, a central station may be in communication with several others, and receive two or more messages with the same prefixes for transmission along the same circuit. These must be despatched according to the priority of their *code time*.

This code time represents the hour at which the message was handed in by the sender at the telegraph office of origin.

Time is transmitted by code according to the diagram (Fig. 2).

The twelve letters from A to M (J excepted) denote the twelve hours. They also denote the twelve periods of five minutes, of which each hour is composed. The intervening four minutes are denoted by the letters RSWX. The letters sent *singly* indicate the hours; sent in combinations of two they represent the hours and certain periods of five minutes: sent in connection with the intermediate letters RSWX they represent hours and minutes. The letters A.M. or P.M. are signalled in conjunction with the code, thus:—

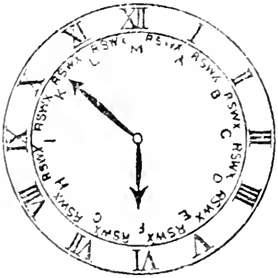


FIG. 2.

M is 12.
F is 6.
MF. is 12.30.
MFS is 12.32.
MFSAM is 12.32 a.m.

B is 2.
I is 9.
BI is 2.45.
BIX is 2.49.
BIXPM is 2.49 p.m.

In order to avoid the difficulty of distinguishing between midnight and noon (both being represented by the letter M), messages are never "coded" M; but if handed in either exactly at midnight or exactly at noon, they are coded MRAM or MRPM, as the case may be.

Forms. 8. A "forwarded" telegram is a telegram handed in for despatch. A "transmitted" telegram is one received by wire for retransmission. A "received" telegram is one received by wire for delivery.

The following special forms, &c., are used in the Service:—

Army Form.	Description and Use.
C 2121	"A" forms for "forwarded" messages, printed on white paper. In pads of 20 forms.
C 2123	"C" forms for received messages, in pads of 100 duplicates, one copy for retention in the office and one for delivery. Printed on pink paper.
C 398	Envelopes for delivery of messages.

The above forms are also used for signalling.

B 118	For "abstracting" telegrams, *see* para. 53.
C 2101	Dockets for bundles of messages sent to the Clearing House.
C 2100	Circuit cards.
C 2102	Notice as to hours office is open, &c.
C 2122	"B" forms for "transmitted" messages, in pads of 150 forms. Printed on yellow paper.

9. Every station will have a distinguishing or call signal, consisting of two or three letters. They should, as far as possible, be abbreviations of the names of the places ; for instance, Newcastle, NC ; Heidelberg, HG ; Pretoria, PR. As there are 650 combinations of two letters of the alphabet, it is generally possible to find suitable combinations of two letters for every military telegraph office ; but where this is impossible or inconvenient, combinations of three letters may be resorted to, thus : Newcastle, NCS ; Heidelberg, HDG ; Pretoria, PTR. There is, however, an inconvenience in the use of three letters, especially when the setting of the office dating stamp has to be considered. The combinations, frequently and carelessly repeated, sound so much like words, that unless the call be carefully made, an inattentive station may conceive that a message is being transmitted between two other stations instead of his own station being called. Call signals.

The call signals for each telegraph office have to be determined by the Telegraph Officer in charge before the office is opened for business, and when once decided on should not be changed.

Permanent calls are frequently arranged for the vibrator offices of cable detachments. For these *see* Vol. II, Chapter I.

*Counting Words.**

10. Telegrams in Latin or in any modern European language, and written in English characters, are to be counted in the same way as telegrams in English ; but words not forming part of such languages are to be counted as five letters to a word. Foreign languages.

---

* Rules for counting words in accordance with the international code are given in Appendix I.

Coined words, cypher.

11. Coined words registered as abbreviated addresses are to be counted as single words in all cases.

Other combinations of letters not forming actual words are to be counted at the rate of five letters to a word when used in the text, and written without stops or spaces between them; when used in the address they are to be counted and transmitted as separate initials.

Compound words.

12. Combinations of two or more words are to be counted as separate words, but combined words, which the usage of the language allows to be written together, or coupled by hyphens, and which are so written by the sender of the telegram, must be counted as single words; as for example, fifty-five, lieutenant-general, father-in-law, linendraper, frostbitten, ironworks, table-cloth.

The intention is that all expressions which, by the usage of the English language, are written as single words (with or without hyphens) shall be accepted as single words in telegrams. Whether they appear in a dictionary or not, if these expressions are usually written as single words, that is to be taken as the guide, and they are to be counted accordingly. It may be difficult to determine sometimes what the usage is. In these cases the benefit of any reasonable doubt is to be given to the sender of the telegram, and if he writes the expression as a single word it is to be accepted as such.

In any case in which an expression of the nature of a compound word is accepted as a single word it must be so written by the sender. For example, if the sender wishes "twenty-five" to pass as a single word, he must write it, not as "twenty five," but as "twenty-five" or "twentyfive." An exception to this occurs in certain names of places, for which *see* para. 13. On no account are words written separately to be joined together by the clerk, otherwise the sense of the message might be destroyed.

It must be clearly understood that the authority to decide in favour of the sender in doubtful cases is not to be regarded as authorising the acceptance of every combination which the sender may write in the form of a single word. For example, such manifestly improper combinations as "verywell," "allright," (or "alright"), or "goodbusiness," must be counted as two words each.

Names.

13. The names of all telegraph offices in England, except town sub-offices, count as single words whatever the actual number of words of which they consist. If they consist of more than one word the clerk should join the words with hyphens, and the hyphens should be signalled.

The names of foreign telegraph offices contained in the Official List of Telegraph Offices, published by the International Telegraph Office at Berne, may also be passed as one word. All other names count according to the number of words of which they are composed.

Illustrations :—

Melton-Mowbray (a telegraph office) ...	1 word.
Hyde Park Road (a town sub-office) ...	3 words.
Great George Street (a street in a town) ...	3 words.
New Orleans (a foreign telegraph office) ...	1 word.

The prefix "St" or "S" always counts as part of a word, and a hyphen should be signalled between it and the rest of the name. If the sender insists on writing "Saint" it must be counted as a separate word.

Names like MacDonald, FitzGerald, O'Neill, De Morgan, De la Rue, St. John, should be counted as one word each, but double names of persons, such as "Bouverie-Tracy," are counted as two, whether written with a hyphen or without.

Abbreviations.

14. Such abbreviations as can't, won't, don't, shan't, and couldn't may be counted as single words. A.M. and P.M., and the initials of the London Postal Districts, count as one word each. All other initial letters must be counted as one word each, whether a full stop follows them or not.

Punctuation marks.

15. When the sender desires words to be underlined, or placed in a parenthesis, or within inverted commas, one extra word for each such underline, &c., must be counted. Signs of punctuation, except when used with numbers, *see* para. 17, must be counted as one word each if the sender requires them to be signalled.

The military sign of punctuation (AAA) should be counted as a word and written by the receiving operator as AAA and not as a full stop.

Numbers.

16. Numbers expressed in figures, whether in the address or the text, must be counted at the rate of five figures to a word. If a sender writes Roman numerals he should be asked to substitute words or figures for them. Ordinal numbers, expressed in words and letters, must be counted at the rate of five signs to a word, the letters being reckoned as figures. Thus 14th is one word, 1522nd two words. When a figure or a group of figures is followed or preceded by a letter or group of letters, the letter or group of letters must be counted separately. For example, "2a," "10cd," "A1," must each be counted as two words.

An exception is made in the case of letters used with figures in the address of a telegram, *e.g.*, 104a, Piccadilly, should be counted as two words.

Stops and signs used with figures.

17. A bar of division, fractional bar, hyphen, or stop used with a figure or group of figures should be counted as a figure. Thus, "1/2" "$\frac{1}{2}$" "1—2" and "1.2" are each counted as three figures or one word. "57/" "/57" "57/." and "./57" are also counted as one word each. The combination "$197^a/199^a$" is counted as four words, "197^a" counting as two words (under para. 16), "/199" as one word (under the present rule), and the letter "a" as one word (under para. 16). Similarly "M. 30" is

counted as two words, ".30" counting (under the present rule) as one word. $^{\circ}/_{\circ}$ is counted as three figures or one word.

Fractions.

18. In fractions the bar, whether horizontal or oblique, between the numerator and the denominator must, in accordance with the foregoing rule, be reckoned as a figure: thus "$\frac{1}{2}$" is equal to three figures or one word, "$2^{3}/_{4}$" "$2\frac{3}{4}$" or "$\frac{3}{4}2$" one word each, and "$709\frac{7}{8}$" two words.

When the affix "st" "th" "rd" or "nd" is used, the mode of counting is as follows:—"1/3rd" "$\frac{1}{3}$rd" "1—3rd" or "1.3rd" would each be counted as one word, and "2/22nds" "$\frac{2}{22}$nds" "2—22nds" "2.22nds" as two words each.

Figures expressing time

19. Groups of figures expressing time are counted in accordance with para. 17. Thus, "12.35" is equal to one word.

Sums of money in figures.

20. Sums of money written in figures are to be counted according to the foregoing rules, one word being added for the symbol "£" when it is used, and one for each of the letters "s" and "d": thus, "7/6" is to count as one word, "7*s* 6*d*" as four words, "2/7/6" as one word, "£10/19/5" as three words, the bar of division counting as a figure.

Money in figures and words.

When sums are expressed partly in figures and partly in words, they must be counted in the same way as shown in the following examples:—"7 pence" must be counted as two words: "10 pounds 17 shillings" as four words. But the words "halfpenny," "twopence," "threepence," &c., when written in full, count each as one word only.

Bar of division and other signs used with letters.

21. A bar of division, fractional bar, hyphen, or stop, used with a letter or group of letters counts as a word. For example, "a/r" "$\frac{a}{r}$" "a—r" or "a.r" would each be counted as three words.

The expressions "$^{A}/_{C}$" "$^{B}/_{L}$" "$^{C}/_{O}$" are, however, counted, by way of exception, as single words.

Treatment of a Message from the Moment of Handing in.

Acceptance.

22. On a telegram being handed in, the counter-clerk reads it through, and counts the words. He is responsible that he can read every word in the message, and should request the sender to initial all alterations and erasures.

Messages which are handed in written on anything but an "A" form should be attached to an "A" form, on which prefix, &c., will be entered. The message must not be copied.

All messages must be signed, and verbal messages must not be accepted.

O.H.M.S. messages.

23. Military messages (to be prefixed S M and X M) will be accepted at all military telegraph offices without payment, but all such messages must be franked by the signature of one of the following officers:—

(i) A commander of a unit, or a detachment of a unit.
(ii) An Officer of the General Staff, Adjutant-General's or Quartermaster-General's Staff.

(iii) The head of an administrative service, or his representative if an officer.

(iv) An officer holding a special or personal appointment.

Priority messages.

24. Military messages marked Priority (to be prefixed S B or X B) will be accepted with the signature of the officer commanding on the spot or of an officer expressly authorised by him. Messages so marked which are handed in without this authority, will not be accepted as priority messages unless the sender, being an officer authorised to send a service message, orders the telegraph master to send such message, and accepts responsibility for the breach of the regulations. In this case the telegraph master must deal with the message as a priority message, and afterwards report to the senior officer commanding on the spot.

Note.—It is quite evident that in exceptional circumstances, and especially urgent cases, messages marked priority will necessarily have to be accepted, and special reports on these will only be vexatious.

Private and Press messages.

25. Private or press messages will not be accepted at a military telegraph office unless the opening of that office for this purpose has been duly authorised and notified, and the orders regarding the censoring of messages, which will be the subject of local orders, have been fully complied with. All such messages will be paid for in cash or by warrants on Army Book 297, unless local orders allow of the acceptance of those bearing local stamps.

If an officer wishes to send as "Free" a message which the clerk considers contravenes the local orders on the subject, the duty of the latter is to point this out to him, and if he still insists, send the message, at the same time informing him that the matter will be reported to Headquarters. The original A form, with a report, should be sent by post or other authorised means to the Officer $^{I}/_{C}$ Army Signals at once, a certified copy taking its place with the other A forms.

Messages from signal stations.

26. All messages handed over to the Signal Service from other methods of transmission, such as Post, Regimental Signallers, &c., will have their origin shown in the space for Service Instructions; such as "By signal from . . . ." Messages sent for part of their route by means other than telegraph within the Signal Service will have no such remark inserted: the office of origin will be the signal office at which the message is originally taken over.

Preamble.

27. When the message has been accepted, the counter clerk enters the number of words; the charge if any; the code time of handing in; the prefix, in accordance with regulations; the office of origin; and the number of the message; and places a clear impression of the office date stamp upon the message, obliterating the stamps if there are any. If the message is "paid" he takes the money according to tariff, and stamps the

message "paid." In a semi-permanent office A forms should be abstracted before they leave the counter; in a temporary office employing a counter clerk the consecutive number should be entered at once, and the abstract completed later; in a small temporary office the abstract should be made out when opportunity admits of it.

S.G. and D.S. messages.

28. S.G. and D.S. messages must be coded, counted, prefixed, &o., in an exactly similar manner to other messages.

Multiple address messages.

29. Messages handed in with several addresses for different offices must be treated as separate messages. Separate A forms should be made out for each address, properly coded and prefixed, and with "For text see No...." written in the space for text.

30. When the message has been coded, &c., it is taken to the clerk at the telegraph instrument.

If the message has to be sent to a "transmitting" office and the clerk is doubtful as to the route, he will refer to the telegraph master, or superintendent, for information. There should be a diagram of the circuits in every office to enable such questions to be answered.

Precedence on the circuit.

31. Messages take precedence on a circuit according to their prefixes and code times, as explained in paras. 6 and 7.

In the case of telegrams handed in at two or more offices on the same circuit simultaneously, the telegram handed in at the office which first calls or offers its code first must have precedence.

Operator calls office.

32. As soon as a telegram reaches the circuit over which it is to be sent, the telegraphist will "call" the attention of the office of destination, or the transmitting office, as the case may be. In the case of circuits with intermediate offices this is done by signalling the code letters representing the office to which the telegram is to be forwarded, not more than three times in succession, followed by the code letters of the forwarding office. For example, if Devizes wants to call TS, the telegraphist will signal: TS, TS, TS—DZ. In reply to the call the office wanted will give its code letters, followed by the letter "G," meaning "go on"; thus "TS, G."

On direct circuits, however, the distant office will be called by signalling merely the prefix, and the office called will reply with "G" only. Transmission is said to have begun when the sending telegraphist has received the signal "G."

No office must interrupt another.

33. No office must interrupt another office in the transmission of a telegram, even if the code time of its telegrams is earlier than that of those at the other office. When working in the field, however, D S and S B messages should be sent immediately, a message of lower precedence being interrupted. The telegraphist in possession of the circuit, after finishing his telegram, by sending the signal ▪ ▪ ▪ ▬ ▪, should signal the prefix and code time of his next telegram. The telegraphist wishing to obtain possession of the circuit should then, if his message has priority, claim his turn by signalling his prefix and code time. A tele-

graphist signalling a telegram is held to be in possession of the circuit until the telegram has been acknowledged, and any necessary repetition given.

Sending message.

34. Having, in the manner described, gained the attention of the office to which the telegram is to be sent, the telegraphist must signal the prefix. This is intended to show the receiving telegraphist on what form the telegram must be written. If it is to be delivered from his office, he will have to write it out on the received form C; if it is to be re-transmitted by wire, he will have to write it out on the transmitted form B. In the first case the prefix contains the letter S; in the second it contains the letter X.

The telegraphist, having sent the prefix, will next signal the code time. When telegrams cannot for any reason be transmitted to the Terminal Office on the same day on which they are handed in, the date of handing in will be added.

Then follow the service instructions (if any), the name of the office of origin, and the number of words in the complete telegram.

Then any special instructions such as "Private";

Then "Reply Paid" or "Reply Paid——words" (if reply has been paid for);

*Then the name and address of the receiver of the telegram;

Then the break signal (▬ ▪ ▪ ▪ ▬); then the "sender's number," "day of month," "in reply to number" and AAA. This last is printed on the form, and if the sender's number, &c., are not used should be erased by the counter clerk.

Then the name and address of the sender, and "time," if they are written by him: care must be taken by the receiving operator to write these in the proper lines as shown on the form;

Then the text to the telegram;

Then the break signal (▬ ▪ ▪ ▪ ▬), if the name or address of the sender is to be signalled;

Then the signal denoting the completion of the telegram, viz.:—

▪ ▪ ▪ ▬ ▪

Corrections.

35. If the sending clerk perceives that he has made an error he should stop, give the "correction in sending" ▪▪▪▪▪▪▪▪, repeat the last word sent correctly, and continue the corrected transmission.

Repetition of figures.

36. On recorder, sounder, and vibrator circuits, all figures in the address and in the body of a telegram, as well as any in the service instructions, must be repeated in the abbreviated form by the *sending* office immediately after the completion of the telegram, and the receiving telegraphist must be careful to compare the figures repeated with those originally sent.

---

* The word "To" printed at the left hand of the address space on the telegram forms is not to be signalled.

The only exception to this rule is in the case of cypher telegrams, which are specially treated, *see* para. 46. To ensure the correct receipt of mixed numbers, *i.e.*, groups of figures which contain both whole numbers and fractions, the numerator of the fractional part should be repeated in words :—for instance, $1\frac{5}{16}$, or $1^{5}/_{16}$, should be repeated "1 five 16" to distinguish it from $\frac{15}{16}$, which should be repeated "fifteen 16 ;" and $\frac{1}{6}$ should be repeated as "one 6." Whenever the bar of division is used with figures in expressions other than fractions, the figures with which it is used must be repeated in "short" at the end of the telegram, the signal · — · · — being used for the stroke, thus :—

18/6 · — — · · · — · · — — · · · ·

20/– · · — — · — · · —

Receiving and acknowledging.

37. The receiving clerk having selected the B or C form, according to the prefix of the message, writes it down as each word in the preamble, address, and text is received, using an H.B. pencil for "B" form and an H.H. pencil for "C" form. A convenient arrangement is to have two pencils jointed together by a "point protector." On the conclusion of the message, the receiving clerk counts the words in the address and text. If he finds the number to correspond with the number signalled in the preamble he sends the acknowledgment, which concludes the correspondence. The acknowledgment consists on simplex, sounder, or vibrator circuits of the signal RD, and on recorder or mixed circuits of the name of the addressee, followed by the signal RD.

If, however, he finds the number of words is not right—for instance, supposing "16" is sent, but only fifteen words are received, he sends "15 W" instead of the acknowledgment. The sending station then sends the first letter of each word until the error is discovered, when the receiving station will send "G," which means "spell out that word." If fifteen is, however, right, "16" having been sent by mistake, the sending station replies "15 RT."

When the number of words is found to be correct, but when some word or words in the telegram appear to the receiving telegraphist to be inaccurate, he must repeat these back when sending the acknowledgment. If he cannot decipher some of the signals, he must ask for repetition of the doubtful words. When giving a repetition, the signalling telegraphist should be careful always to signal the word preceding the doubtful or missing word as well as the latter. For example, if a repetition of the "word after London" is asked for, the word "London" should first be signalled, and then the word of which the repetition is required. When the receiving telegraphist is satisfied that the telegram is correct, he gives the signal of acknowledgment.

Completing form.

38. When the final acknowledgment has been sent, both the sending and receiving clerks note the time and enter it in

figures in the spaces on the forms headed "sent" and "received" respectively. They also enter the call signals of the offices to which or from which the message has been sent, and affix their initials. The sending clerk should enter in the corner of the message the cause of any exceptional delay, for reference in case of enquiry.

Acknowledgments, &c., on duplex circuits.

39. The procedure in working a duplex circuit is somewhat different. The following directions will be adhered to.

Before commencing work, the sending operator will call up the other office and obtain the signal "G." When work is recommenced after the circuit has been clear, the signals ▪ ▪ ▪ ▬ ▪ ▪ ▪ ▪ ▬ ▪ must precede the message. The sending operator will time and fill in each message on its completion, as detailed in para. 38, but will retain it until the acknowledgment has been received as described below.

The receiving operator will record the name of the addressee in each message on a slip of paper called the "RD" slip.

Should there be no message to follow the last message sent, the signal "NN" will be given. Should this signal not be received, and no message follow, the receiving operator will conclude that there is a fault; the sending operator at the receiving office will signal "Getting nothing from you." On receipt of "NN," "RD" must be sent by the receiving office.

"Totals" must be exchanged every quarter of an hour, the up station taking the initiative, and each total must be followed by the name of the addressee of the last message completed and transcribed thus: "ten Wilson." If the numbers agree, the signal "RD" should be sent by each office, and the messages acknowledged placed on the message file. Should the numbers, however, not agree, the names on the "RD" slip must be repeated, in order to show where the discrepancy lies. If one or more of the messages in the series be detained for correction, the total should be given less these non-completed messages. For example, if two messages out of a series of ten were awaiting correction, the acknowledgment would be "eight Wilson." Or, if the message last signalled were awaiting correction, the total would be "nine," followed by the name of the addressee of the ninth message of the series. Messages that have been detained for correction should, after they have been corrected, be acknowledged independently, the name of the addressee being given in each case, so as to identify the message. Only messages that have been transcribed, and are not awaiting correction, are to be included in the totals given. Multiple address messages should only count as one message in totals. When a multiple address message is the last of a batch, the name of the first addressee should be given as the acknowledgment, followed by the word "Multiple," thus: "ten Wilson Multiple."

Repetitions and corrections must be obtained *at once.* On missing a word, the receiving operator must call attention to it, and the sending operator will—after finishing the word on which he is engaged—give the signal "RQ," and then ask for the repetition or correction. On finishing his enquiry he will give the signal · · · — ·, and resume the transmission of the message he was engaged in sending.

Telegram to be re-transmitted.

40. The receipt of the telegram being completed, the telegram, if intended for re-transmission, should then be passed to the circuit over which it is to be re-transmitted. If necessary the prefix is altered from X to S.

When the telegram has been re-transmitted the sending telegraphist must insert the time at which he sends it against the words "Sent at" at the top of the B form, the name of the office (and the number of the circuit if there be more than one) to which he sends it against the word "To," and affix his initials against the word "By." The "B" form is then stamped with the office date stamp and abstracted, *see* para. 53.

Telegram to be delivered.

41. If the message has to be delivered at the receiving station, the receiving clerk inserts a piece of carbonic paper between the original and duplicate forms in the pad of C forms, placing a tin plate beneath the duplicate in order to obtain a good copy. It will be noticed that the carbonic paper should be placed so as only to reproduce the address, the text, and the line above the address. The rest of the preamble not being required by the recipient of the message, is not reproduced. On the conclusion of a received message the receiving clerk fills in the line above the address, writing the name of the office of origin in full, and the times of handing in and of receiving the message in figures.

The received message is then taken to the clerk in charge of delivery, who stamps both copies and numbers them with their proper number. He encloses the duplicate copy in an envelope (Army Form C 398), writes the number of the message on it, and addresses it. He then enters on the envelope, and on the office copy of the message, the time the message is sent out for delivery, and on the office copy the name of the messenger. The message is then sent out for delivery.

Received messages are written down in duplicate in order that a copy may be kept in the office. The message handed in by the sender is also kept in the office of origin as well as any forms that may be used in transmission.

Messages to be handed over.

42. If a message has to be "handed over" to another office for transmission, a duplicate of it must be kept on a transmitted ("B") form, and the receiving clerk should write it down in duplicate by the aid of carbonic paper. In this case the carbonic paper must be placed so as to reproduce the whole of the preamble as well as the address and text. To facilitate this operation it may in special cases be necessary to adopt a special additional letter in the prefixes, which will indicate

that the message has to be handed over to another office, and that therefore a duplicate must be taken.

Miscellaneous Instructions.

Abbreviations forbidden.

43. Every word or figure in a telegram is to be transmitted and written out exactly as written by the sender himself, without abbreviation or addition ; except in cases of obvious misspelling, when discretion is allowed. Words written in block letter are invariably to be so sent. The name and address on the cover in which a telegram is sent out for delivery must also, in all cases, be written in full.

Telegrams occupying more than one sheet.

44. When a telegram occupies more than one sheet, the name of the addressee, as well as the name of the office of origin and the code time, must always be brought forward on the second and subsequent sheets.

Cypher telegrams.

46. Cypher telegrams or portions of telegrams in cypher must be repeated back in all cases. In repeating figure cyphers the short Morse numerals should be used. The repetition is made by the receiving office, and not by the sending office.

"Private," "confidential."

47. When the sender of a telegram desires that instructions, such as "Private," "Confidential," "To be opened at once," or the like, be written on the envelope containing the copy of the telegram delivered to the addressee, he must write the instructions on the A form immediately before the address. The word or words comprising the instructions must be enclosed in a parenthesis by the accepting officer, and must be signalled with the parenthesis immediately before the address throughout the whole course of transmission.

The instructions, *but not the parenthesis*, are to be charged for as part of the telegram, and care must be taken that they are plainly written on the envelope containing the telegram.

The parenthesis, although not charged for, should be counted as a word in transmission.

Special care with certain words.

48. Special care should be used in signalling or receiving the following words, between the signs of which in the Morse code there is a general similarity :—

Hall	and	Half.	Seen	and	Seem.
Found	,,	Pound.	Give	,,	Gave.
Save	,,	Have.	Cash	,,	Cases.
Calls	,,	Calais.	Boys	,,	Boxes.
Your	,,	Four.	To-day	,,	Monday.
Will	,,	Well.	Bad	,,	Dead.
Wheat	,,	What.	Satin	,,	Sateen.
Phelp	,,	Phelan.			

The following words, when written indistinctly, are very liable to be mis-read, viz. :—

Piece	and	Price.	Ale	and	All.
Seven	„	Eleven.	Light	„	Eight.
Seventy	„	Twenty.	Our	„	One.
Send	„	Lend.	Two	„	Ten.
Close	„	Clear.	Bow	„	Boro.

Care must be taken that these words are very clearly written.

Delays in correction and transmission.

49. The attention of the telegraph master must be drawn by the operator to any message for which an RQ cannot be obtained within half an hour in semi-permanent offices, or five minutes in the field. Should it then be evident that the correction will be delayed indefinitely, the message should be sent forward with a footnote "Correction to follow," and special charge taken of the form for completion later. In cases of abnormal delay a short note for the information of the addressee should be made at the foot of the message, such as "Delayed owing to interruptions on the line."

Forwarding messages during breakdown.

50. When it is necessary, owing to a breakdown, to forward messages by means not in the control of the signal service from one office to another, they should be copied on to B or C forms, as the case may be, and these copies sent, with a list giving particulars of code, number of words, station from, name, station to, and number of telegrams, a duplicate list being retained for reference. If possible the authority of the Inspector should be obtained before posting messages. The receiving office should acknowledge the receipt of packet and list by the quickest means possible. When, on communication being restored, it is found that the messages have not reached their destination, they should be repeated by wire, care being taken to prevent duplication. The received messages should be marked "Received by post owing to interruptions on line."

Correspondence.

51. The telegraphic address of Director of Army Signals is "D Sigs"; of an Officer in charge of Signals, "Sigs"; of Superintendent, "Supt."; of Telegraph Master "Tel. Mr." Names are not to be used.

Misuse of word "refuse."

52. As considerable friction and misunderstanding is caused by the use of the word "refuse" in correspondence with officers outside the telegraph service, in connection with the inability of an office to accept a message owing to the addressee not being there, this word should not be used. Instead of saying "Pretoria refuses to accept your message," the expression used should be "Pretoria unable to deliver your message, and so requests reference to sender." Frequently the sender is in a better position to know whether the addressee is due to arrive at a given station than the telegraph master at that station.

Abstracting Messages and Forwarding of Office Copies.

Abstracting.

53. To assist the Clearing House in checking messages and accounting with other administrations, and to enable the telegraph master to check his cash account, all message forms will be abstracted daily. Each class of form is abstracted on a separate abstract sheet each day, commencing daily with No. 1; no general instructions can be given as to the classes into which the forms are to be divided, which will depend on the circumstances under which the telegraph system is worked, but A, B, and C forms are always abstracted on separate sheets. A.F. B 118 will be used.

One line of the abstract form must be taken for each message, and messages will be entered in the order of their numbering. The cash taken for paid work must be entered against each message, and the daily totals carried to the cash account.

When abstracting a multiple address message to one and the same station, the number of words should only be shown against the address containing the greatest number of words. In the case of a multiple address message to several stations, the number of words must be shown against each address, and each address must be regarded and treated as a separate message (*see* para. 29).

Checking.

54. Whenever possible messages should be carefully checked with their abstracts each evening, to save work at the Clearing House.

Forwarding forms.

55. Messages will be made up into packets daily, with their abstracts, and docketed with A.F. C 2101. These packets will be sent to the Inspector or Clearing House daily or weekly as ordered. Forms should be packed flat, not rolled or folded.

The wrappers covering the periodical parcels of finished messages should show the name of the office from which they emanate, together with the inclusive dates to which they refer.

Messages removed from bundle.

56. In every case of finished messages being removed from their place in the bundle, a form with particulars must be substituted, and a reference to the official papers to which the original message is attached, or a note stating for what purpose it has been taken, should be added.

Delivery of Telegrams.

Precedence.

57. Messages will take the same precedence in delivery as they do on the wires (*see* para. 31).

Receipt for telegrams.

58. The receiver of the message should note the time at which it reaches him in the space for "receipt" on the envelope (A.F. C 398) and should return the envelope by the orderly to the office. It is part of the orderly's duty to endeavour to obtain this receipt, and he should hand it in on his return to the office. The envelope should be attached to the back of the top copy of

the C form, by turning the corners down and making a small tear.

When addressee cannot be found.

59. Should it so happen that the addressee is not at his quarters, and that no responsible person can be found to whom the telegram can be delivered, a notice should be left at the addressee's quarters to the effect that a telegram awaits him at the telegraph office.

Undelivered messages.

60. A military message is invariably to be sent to the address supplied by the sender, and is never to be refused because the whereabouts of the addressee is unknown. Every such message which cannot be promptly delivered is to be referred to the Commandant or nearest staff officer. If he is unable to arrange for its delivery, or advise to what office it should be sent, the message will be repeated to the head office, with an SG stating that the message cannot be delivered even after reference. A list of such undelivered messages will be kept posted in a conspicuous place in the public part of the office. If a message has not been claimed after it has been on the list for a week it will be forwarded with the next batch of messages. If it is delivered during the week of waiting the head office will be advised by SG.

It is within the province of the telegraph master who is offered a batch of messages which he believes that he will be unable to deliver, to advise the transmitting office to wait till he has consulted the Commandant, or to advise transmitting office by SG of the whereabouts of addressee if he knows it to be at another office, in order that the address may be changed at the transmitting office.

Messages for moving column.

61. The greatest care is, however, to be taken about messages for a moving column, as frequently the sender is in a better position to know at what station the column will come in than anyone at that station.

Instructions for orderlies and messengers.

62. Every telegraph orderly on joining an office will be instructed by the telegraph master as follows :—

(*a*) On receiving a message you are to start immediately, and deliver it as quickly as you can ; after which you are to return to the office, and upon no consideration are you to go off duty after the delivery of your last message without returning to the office.

(*b*) You are particularly cautioned against loitering when you are engaged in delivering messages, and you must always proceed on your way alone.

(*c*) You are forbidden, under any pretence whatever, to give to another orderly a message which you have received for delivery ; and you are forbidden, under any circumstances, to open a cover in which a message is enclosed.

(*d*) You are at all times, whether by day or night, to deliver your messages personally, if possible—that is, to hand them to the addressee or to his representative.

(*e*) If you have two or more messages, you are to deliver each in its turn; but if, from any cause, there is difficulty in delivering one of them, you are to hasten on with the others; after which you are to return to the neighbourhood and make inquiries respecting the message you could not deliver. If, after full inquiry, you are unable to deliver a message, you are to return with it to the office and give it back to the telegraph master or clerk in charge of delivery.

(*f*) You must, in all cases of doubt as to the address of a message, apply to the telegraph master or clerk in charge for information before leaving the office.

(*g*) On the delivery of a message, you must ask for and endeavour to obtain a receipt for the same on the slip attached to the envelope in which the message was enclosed.

Duties of Telegraph Master.

63. Every Telegraph office is in charge of the senior soldier termed the Telegraph Master, who is directly responsible to the officer or inspector in charge for all that concerns that office. In offices in the field comprising several circuits an officer is frequently placed in charge. He is termed Superintendent. Control of personnel.

His duties are to—

(1) Tell off the personnel available in accordance with the work on each circuit and at each time of the day.

(2) Arrange the duties so that the men may get their meals and sleep.

(3) Exact prompt and absolute obedience from the men under him.

(4) Inform his inspector, or the officer under whom he is working, if his personnel be too small or too large for the average day's work.

(5) Report to his inspector or to the officer under whom he is serving by wire if any of the personnel need replacing through sickness.

64. A most careful system is required in the telegraph office to ensure that messages do not get delayed. A diagram of the circuits is to be hung up in a conspicuous place, and every instrument is to have a circuit card showing the offices with which it is in direct communication. Control of traffic.

Telegraph masters are held responsible for absolutely prohibiting unauthorised conversations on the lines. They will do all in their power to promote smooth and friendly working, and will at once report any case of obstruction which comes to their notice. In cases where it is known that there is an indifferent operator at the other end of the circuit, special care will be taken to ensure slow and distinct sending

Delivery.

65. The telegraph master is responsible for the delivery of all telegrams received in his office, and will be provided with messengers under arrangements made by the telegraph officer in charge, but if such arrangements have not been made he will apply to the senior officer on the spot, who will make necessary arrangements.

It is the duty of a telegraph master to make every endeavour to effect delivery of military messages to addressees, and in cases where difficulty arises, he will ask for the advice of the nearest staff officer. (*See* para. 60.)

Diaries.

66. Every telegraph master will keep a diary in the book provided for the purpose.* In it will be recorded :—

(1) Particulars of the morning test.
(2) Particulars of any fault on the lines, showing time it came on, the time the lineman was sent out, and the time of clearing the fault.
(3) The hours during which the office was open if the office was closed during the day.
(4) A note of the number of messages dealt with during the day.
(5) A note of any undue delays in dealing with messages, and the cause.
(6) Any unusual occurrence.

Abstracting.

67. All messages dealt with in the office will be entered on the abstract sheets A.F. B 118, received, forwarded and transmitted messages separately. The cash taken for paid work will be entered against each message, and the daily totals carried to the cash account.

Messages will be made up into packets daily, with their abstracts and docketed.† These packets will be sent to the inspector or Clearing House daily or weekly as ordered. (*See* para. 53.)

Cash Accounts.

68. A telegraph master who has any financial transactions will keep a simple received and expended cash account.‡ On the received side will be shown all sums of money received. As a rule, these will be the sums received for paid messages only. These entries should be daily ones, corresponding with the totals of the daily abstracts, which will be a sufficient voucher. On the expended side will be shown all sums expended. These will usually be—

(1) Surplus cash handed over to the inspector, telegraph officer, or nearest cashier as ordered. Whenever cash is handed over thus, an issue voucher will be handed over with the money, and a receipt voucher signed by the payee and attached to the account.

---

* Army Book 129 or 136.
† Army Form C 2101.
‡ Army Book 69 is provided for the purpose.

(2) Civilian wages and payments for purchases duly authorised. A receipt will be obtained for each payment, and attached to the account. The authority under which payment was made will be entered.

(3) Any payments authorised to be made on account of the pay of the military staff. Receipts for such payments must be taken in duplicate, one to be attached to the account, the other to be forwarded to the office responsible for the pay list. Copies of the cash book with vouchers will be forwarded to the Clearing House as directed. When the cash in hand amounts to £5, it will always, if possible, be paid over to a telegraph officer or to the nearest cashier.

Care of cash.

69. A telegraph master is allowed charge pay when he has custody of cash. It is to be distinctly understood that he is to be responsible for making up deficiencies in his cash, whether due to undercharged telegrams, losses, or any other cause.

Censoring.

70. A telegraph master will make himself thoroughly acquainted with all orders regarding the censoring of messages, and will see that these orders are complied with.

Testing.

71. A telegraph master will test all circuits daily, and keep a record of them.

He is responsible for using all possible tests and means of localising a fault before sending out the lineman.

Frequently long through lines are led in to an office for testing. Telegraph masters must give prompt attention to SGs from the head office directing them to "earth" or "Dis" these for test. *See* Chapter XIX, para. 4 *et seq.*

Maintenance of instruments and batteries.

72. Contrary to the usage of the British Post Office, the maintenance of instruments and batteries is in the hands of the operating staff, unless a special lineman is detailed for this purpose.

A telegraph master is responsible that all instruments and batteries in his charge are in good order and ready for work.

Stationery.

73. A telegraph master is responsible that he has at all times a sufficient supply of stationery.

Charge of stores.

74. A telegraph master is responsible for all Government property in his office, and will keep a list of all such stores. On a change of telegraph master, the stores will be properly handed over and signed for, if possible in the presence of an officer or an inspector.

It is the duty of a telegraph master to look after the comfort of the men under him.

75. The authorised abbreviation for "Telegraph Master" is "Tel. Mr."; "T. M." is on no account to be used, as it denotes "Traffic Manager."

Organisation of Telegraph Offices.

Classification.

76. Military telegraph offices may be roughly divided into semi-permanent and temporary, and each of these divisions again into large and small.

We thus have—

(1) Large semi-permanent offices, employing 10 operators and upwards.
(2) Small semi-permanent offices.
(3) Large temporary offices, containing several circuits, such as would be used at the Headquarters of the larger Units of the Army in the field.
(4) Single vibrator (3rd class) offices, on cable lines.

Vibrator offices.

77. In single vibrator offices the functions of telegraph master, counter clerk, delivery clerk, and operator are frequently combined in one man. Cash is seldom taken, and as they are only open for a short time a good deal of the routine may be dropped. Messages, however, should always be sent to Clearing House, and should be abstracted whenever possible. For further special details, see Vol. II, Chapter I. For description of a large temporary office, see para. 87.

At large temporary offices the tents containing the terminals of the circuits will necessarily be somewhat scattered, so careful arrangements must be made for the movement of messages between them without delay, by means of men detailed for the purpose (checks). A separate tent should be provided for the counter work and the commutator. It is desirable to keep a spare vibrator set joined up on the commutator so that the Assistant Superintendent can at once get into touch with any circuit.

Small Morse offices.

78. Small semi-permanent offices are the ordinary offices containing one or more Morse sets, working on air line or permanent lines. They are usually accommodated in a tent or building. The full routine laid down in this chapter should be adhered to, except that there will seldom be separate men available for counter clerks, &c., and the telegraph master will take other duties as well as supervision work.

Number of operators.

79. The full allowance of operators for an office of this class is three per key for day and night working, but two per key for day working is more usual. The hours found most convenient for single-handed offices in South Africa were 7.30 to 8.30, 9 to 12, and 2 to 6.

Capacity of office.

80. As a rough estimate, a single operator can deal with a total of 60 forwarded and received messages a day, and for larger offices each man can deal with 100. For short periods of pressure many more can be dealt with.

Organisation in instrument room.

81. Most careful system is required in the instrument room to ensure that messages do not get delayed. A diagram of the circuits is to be hung up in a conspicuous place, and every instrument is to have a circuit card* showing the offices with which it is in direct communication. Files for filing messages dealt with are to be provided for every instrument, and a definite place on the table near each key is to be assigned to messages waiting

---

* Army Form C 2106.

their turn to be sent, which should be arranged in order of priority of sending.

Slip diaries.

82. In busy offices with several sets it is convenient to keep a slip diary at each instrument; these are collected by the telegraph master in the evening, and the items entered in his diary.

Stationery units.

83. Office stationery in the field is carried in stationery units A and B, the former holding the more permanent equipment of an office, and the latter the expendable stores. Stationery unit C holds all the stationery required for a small (Vibrator) office.

Large offices.

84. Paras. 80-83 apply also to large semi-permanent offices. In a large office the counter and delivery staffs are completely separated from the staff of the instrument room, and each is organised under an N.C.O. or experienced sapper, who is known as the assistant superintendent. In a large office of 60 or 70 operators the instrument room staff is divided into three reliefs each under an assistant superintendent, and the 24 hours is divided up between them, The assistant superintendent on duty is responsible to the telegraph master for the control of the work, and for testing instruments and lines.

The position of telegraph master in a large office is one of great responsibility, and an experienced man is required to fill it well; upon his organising power depend the smoothness and economy of working of the office. The rule quoted in para. 80 as to the number of operators required, viz., one operator per 100 messages, holds good approximately, but for the instrument room staff only; the counter and delivery should be in addition. Men or boys termed "collectors" or "checks," may also be required to distribute messages to the circuits and collect them for delivery, &c.

Chart of duties

85. A chart of duties, carefully made out in accordance with the pressure of work at different times of the day, should be signed by the telegraph master, and hung up in a conspicuous place in the office. As an illustration of the way in which this should be done, charts have been made out as examples. Example A is for a very large office of 80 men, and Example B for one of 18 men.

Example A.

CONDITIONS OF AN IMAGINARY OFFICE AT PRETORIA.

86. Circuits terminating in Pretoria Office:—

Johannesburg—Three double current Duplex circuits. Working, 7 a.m. to 10 p.m., and later if required. Greatest pressure, 10 to 1 and 2 to 4.

Bloemfontein—Quadruplex. Open 7 a.m. to 8 p.m. Greatest pressure, same as Johannesburg.

Durban—Wheatstone Duplex. Open 8 to 10, and later if required. Pressure, 10 to 1 and 2 to 8.

Capetown—Wheatstone Duplex. Hours and pressure, as for Durban.
Middleburg—Wheatstone Simplex. Hours, 8 to 1 and 2 to 6.
Loureneo Marques—Duplex. Hours, 8 to 1 and 2 to 8.
Rustenburg—SC Simplex. 7 to 1 and 2 to 6.
Standerton ,, ,, ,,
Volksrust ,, ,, ,,
Petersburg ,, ,, ,,
Waterval ,, 7.30 to 8.30, 9 to 12, 2 to 6.
Rietfontein ,, ,, ,, ,,
Eerstefabriken ,, ,, ,, ,,
Irene ,, ,, ,, ,,
Administration ,, Any hour from 7 to 10.
Pretoria Station ,, Any hour.

Staff would be required as follows :—

(*a*) Telegraph Master.
(*b*) Clerk to Telegraph Master.
(*c*) Three Assistant Superintendents, instrument room (shown in chart as I, II, and III).
(*d*) One Assistant Superintendent for busy hours of day (shown as IV).
(*e*) Three reliefs of 11 Operators each (lettered A to K, and numbered 1, 2, 3).
(*f*) Two reliefs of 12 Operators each (lettered L to W, and numbered 1, 2).
(*g*) Four Collectors in instrument room (boys).
(*h*) Assistant Superintendent of Counter. Hours, 9 to 1 and 2 to 5. He would be responsible for all accounts.
(*i*) Three Counter Clerks.
(*j*) Delivery Assistant Superintendent and three Assistants.

Note.—*b*, *g*, *h*, *i*, and *j* need not be skilled operators.

This gives a total personnel of 81, excluding orderlies, and the office would be capable of dealing with about 6,000 messages a day.

The duties are arranged so that there are only two dinner hours, 1 to 2 for part of the men, and 2 to 3 for the remainder. The operators on duty between 5 and 6 are replaced by spare men for half an hour for tea. The reliefs rotate week about, and the duties are calculated at 8 hours a day.

“87. Large temporary offices in the field are usually situated at the Headquarters of the larger units of the Army, and form part of the Signal Office. The Signal Office controls all methods of communication, and, if in a town, may very probably have several telegraph offices under it. An officer—styled Superintendent—would generally be in charge of a large telegraph office of several circuits under these conditions, and an Assistant Superintendent (in reliefs) and counter and delivery clerks (in reliefs) would be detailed. If it is not possible to place the telegraph office next to the Signal Office, messengers will be required to carry the messages between them. All messages arriving or going by hand will pass through the Signal Office. Messages for delivery will be placed in envelopes at the telegraph office, but the envelopes of military messages will not be closed, to allow of the Signal Clerk booking the 'sender's number.'"

"88. As an example may be taken an imaginary office at General Headquarters. Communication to the Strategic Cavalry would probably be by wireless, and this would very likely be worked as a separate telegraph office under the Signal Office, as it would frequently be impossible to bring it close enough for inclusion in the telegraph office.

For the sake of the example, the other circuits terminating at G H Q may be assumed to be :—

(1) Base. Double circuit Duplex (1st class office).
(2) Adv. Base and stations to it. DC simplex and vibrator (2nd class office).
(3) 1st Army Headquarters. 2nd class office working on a cable line.
(4) 2nd Army Headquarters. 3rd class office working on a cable line.
(5) Reserve Division. 3rd class office working on a cable line.
(6) Next position of G H Q. 2nd class office working on airline already laid to the front.

For these circuits personnel would be required as follows :—

(*a*) Superintendent (an officer).
(*b*) Three Assistant Superintendents.
(*c*) Three Counter Clerks (Forwarded Messages).
(*d*) Three Delivery Clerks (Received and transmitted messages).
(*e*) Three collectors, or checks.
(*f*) Three or more messengers to work to Signal Office.
(*g*) Six operators for (1).
(*h*) Four operators for (2).
(*i*) Four operators for (3).

The above would form part of the Headquarter detachment.

(*j*) One operator each from cable detachments working on (3), (4) and (5).
(*k*) Two or three operators from airline detachment working on (6).

This gives a total personnel of 1 officer and 29 N.C.O.s and men forming part of Headquarters, and 6 from detachments, and is exclusive of linemen.

It is impossible to give a duty chart, as the hours would be very variable.

(1) might possibly be Wheatstone if the traffic warranted it, in which case the numbers in (*g*) would rise, possibly to 12 or even more."

Example A.

Pretoria Instrument Room.—Duty Chart.

Hours:	7—8.	8—9.	9—10.	10—11.	11—12.	12—1.	1—2.	2—3.	3—4.	4—5.	5—6.	6—7.	7—8.	8—9.	9—10.	10—3.	3—7.
Assistant Superintendents.	I	I	I	I IV	I IV	I IV	I	II IV	II IV	II IV	II IV	II IV	II IV	II	II	III	III
Johannesburg, 3 Duplex.	A1 B1	A1 B1	A1 B1 V2 W2	A1 B1 V2 W2 A3 B3	A1 B1 V2 W2 A3 B3	A1 BI V2 W2 A3 B3	A1 B1	A2 B2 L1 M1 R1 S1	A2 B2 L1 M1 A1 B1	A2 B2 L1 M1	A2 B2	A2 B2	A2 B2	A2 B2	A2 B2	A3 B3 C3 D3 E3 F3	G3 H3 I3
Bloemfontein, Quadruplex.	C1	C1	C1 T1	C1 T1 C3 D3	C1 TI C3 D3	C1 TI C3 D3	C1 T1	C2 S2 P1 Q1	C2 S2 P1 Q1	C2 S2	C2 S2	C2	C2	C2	C2	Night work as required.	Night work as required.
Durban, Wheatstone.	D1 E1	D1 E1	D1 E1	D1 E1	D1 E1	D1 E1	D1 E1	D2 E2	D2 E2	D2 E2	D2 E2	D2 E2	D2 E2	D2 E2	D2 E2		
Cape Town, Wheatstone.	F1 G1	F1 G1	F1 G1	F1 G1	F1 G1	FI G1	F1 G1	F2 G2	F2 G2	F2 G2	F2 G2	F2 G2	F2 G2	F2 G2	F2 G2		
Punchers.	H1 I1	H1 I1 LI M1	H1 I1 L1 M1 N1 O1	H1 I1 L1 M1 N1 O1	H1 I1 L1 M1 N1 O1 E3 F3	H1 I1 LI M1 N1 O1 E3 F3	H1 I1 E3 F3	H2 I2 L2 M2 N2 O2 P2 Q2	H2 I2 L2 M2 N2 O2 P2 Q2	H2 I2 L2 M2 N2 O2 P2 Q2	H2 I2 L2 M2 N2 O2 P2 Q2	H2 I2 L2 M2 N2 O2 P2 Q2	H2 I2 L2 M2 N2 O2 P2 Q2	H2 I2 L2 M2 N2 O2	H2 I2 L2 M2 N2 O2		
Slip Writers.	J1 K1	J1 K1	J1 K1	J1 K1 J2	J1 K1 J3 K3	J1 K1 J3 K3	J1 K1 K3	J2 K2 J3	J2 K2 J3 K3	J2 K2 J3 K3	J2 K2 J3 K3	J2 K2 J3 K3	J2 K2 K3	J2 K2	J2 K2		
Middlesburg, Wheatstone.	V1	V1	V1	V1	V1	V1		U2	U2	U2	U2						
Lourenço Marques, Duplex.		W1	W1	W1 G3	W1 G3	W1 G3		R2 VI	R2 VI	R2	R2	R2	R2				
Rustenburg, Simplex.	P1	P1	P1	P1	P1	P1		N1	N1	N1	N1						
Standerton, Simplex.	Q1	Q1	Q1	Q1	Q1	Q1		O1	O1	O1	O1						
Volksrust, Simplex.	R1	R1	R1	R1	R1	R1		V2	V2	V2	V2						
Pietersburg, Simplex.	S1	S1	S1	SI	S1	SI			T1	T1	T1						
Waterval, Simplex.	S2		S2	S2	S2			W2	W2	W2	W2						
Rietfontein, Simplex.			H3	H3	H3												
Eerstefabrieken, Simplex.			I3	I3	I3			W1	W1	W1							
Irene, Simplex.	U2		U2	U2	U2												
Administration, Simplex.	U1	U1	U1	U1	U1	UI	U1	T2	T2	T2	T2	T2	T2				
Pretoria Station, Simplex.																	

C1 D1 E1 F1 G1 H1 I1 U1, available for an hour, 5—6, at tea time.
C2 P2 Q2 R2 T2, available for 2 hours each before 1 p.m., if required.
Reliefs rotate weekly.

Example B.

CONDITIONS OF AN IMAGINARY OFFICE AT STANDERTON.

Circuits terminating in Standerton Office :—

Durban—DC Duplex, 7-10.
Pretoria—SC Simplex, 7-1 and 2-6.
Johannesburg do. do.
Volksrust do. do.
Ermelo—SC Simplex, 7.30-8.30, 9-12, 2-6.
Greylingstadt do. do.
Krondraai do. do.
Vlaklaagte do. do.
Standerskop do. do.

Staff required as follows :—

a. Telegraph Master.
b. Two reliefs of 5 Operators each (lettered A to E, and numbered 1 and 2).
c. One relief of 5 Operators, to include the less experienced men.
d. Counter Clerk.
e. Delivery Clerk.

Giving a total personnel of 18 men.

STANDERTON INSTRUMENT ROOM.—DUTY CHART.

Hours	7—7.30.	7.30—8.	8—8.30.	8.30—9.	9—10.	10—11.	11—12.	12—1.	1—2.	2—3.	3—4.	4—5.	5—6.	6—7.	7—8.	8—9.	9—10.	10—2.	2—7.
Pretoria	A1	A1	A1	A1	A1	A1	A1	A1	A1	A2	A2	A2	A2	A2	A2	A2	A2	B2	C2
Johannesburg ...	B1	B1	B1	B1	B1	B1	B1	B1	B1	B2	B2	B2	B2						
Volksrust	C1	C1	C1	C1	C1	C1	C1	C1	C1	C2	C2	C2	C2						
Durban	D1	D1	D1	D1	D1	D1	D1	D1	D1	D2	D2	D2	D2	D2	D2	D2	D2		
... ...	E1	E1	E1	E1	E1	E1	E1	E1	E1	E2	E2	E2	E2	E2	E2	E2	E2		
Ermelo		F	F		F	F	F			F	F	F	F						
Greylingstadt ...		G	G		G	G	G			G	G	G	G						
Krondraai		H	H		H	H	H			H	H	H	H						
Vlaklaagte		I	I		I	I	I			I	I	I	I						
Standerskop ...		J	J		J	J	J			J	J	J	J						

APPENDIX I.

INSTRUCTIONS REGARDING FOREIGN AND COLONIAL TELEGRAMS.

Prefix.

1. It will frequently be necessary for special prefixes to be used, denoting the route by which cablegrams should be sent. This will be a matter for local arrangement by the telegraph officer in charge.

Code time in inward telegrams.

2. In inward foreign and colonial telegrams the code time (which is inserted at the handing-over office, and must not be confused with the actual time of handing in at the office of origin abroad) must be signalled to the delivery office, but only the time at which the telegram is handed in at the office of origin (as telegraphed in the service instructions) should appear on the delivered copy. It must be inserted in the space provided for it on the form.

The code time inserted at the handing-over office, besides indicating the order of transmission, serves to identify inward telegrams in any communication between that office and the office of delivery.

Rates of charge.

3. Foreign and colonial telegrams are charged for at a certain rate per word (every word being charged for, whether in the address, text, or signature). Tables showing the rates must be supplied locally to offices dealing with paid work.

Route, selection of.

4. When there are two or more routes available, the sender must be asked to select one of them, and to write it down at the foot of the form; and the route selected must be entered in the service instructions, and telegraphed, but not charged for.

Classes of telegrams.

5. Telegrams may be written in *plain* language or in *secret* language, the latter including: (1) code language; and (2) letter or figure cypher.

Plain language.

6. Telegrams in plain language may be sent to any country. Certain countries refuse telegrams written wholly or partly in code language, or in cypher. Telegrams in plain language are those which offer an intelligible meaning. They may be expressed in one or more of the principal European languages, in certain of the extra-European languages (Annamite, Arabic, Armenian, Japanese, Malay, Persian, and Siamese), or in Hebrew or Latin. The words must be written in Roman characters.

Numbers written in figures, groups of figures used in commercial marks, groups of letters forming commercial marks or commercial or other analogous expressions in current use, can be employed in plain language telegrams. Such expressions are not considered as cypher, although they are charged for at the rate of 5 figures or letters to a word. (See para. 25.)

Code language.

7.—(*a*) Code language is composed of real words not forming intelligible phrases or of artificial words having the appearance of real words. The words, real or artificial, must not exceed 10 letters in length.* The real words may be drawn from any of the following

---

* In reckoning the maximum number of letters, "Ch" and the German modified vowels *ä*, *ö*, and *ü* are counted as one letter each. The modified vowels *ä*, *ö*, and *ü* are signalled respectively as *ae*, *oe*, and *ue* (see also para. 18).

languages:—English, French, German, Italian, Spanish, Portuguese, Dutch, and Latin; whilst the artificial words must be pronounceable according to the usage of one of those languages.

(*b*) In applying the test of pronounceability to artificial words used as code, a liberal attitude should be adopted towards the public. The intention of the test is to exclude pure cypher (such as *xptgabd*), made up without regard to the rules of pronunciation.

(*c*) If a sender asserts that expressions are pronounceable which do not appear so to the counter clerk, the telegram should not be refused, but the attention of the telegraph officer in charge should be called to the matter by means of a slip attached to the A form.

(*d*) Expressions which are undoubted unpronounceable, fall into the category of cypher, and must be counted at 5 letters per word. (See paras. 8 and 25.)

(*e*) Expressions formed by the running together of two or more real words contrary to the usage of the language must not be used as code words. Telegrams containing such expressions must be refused unless the sender is willing that they should be separated into their component parts and charged for accordingly.

Cypher language.

8.—(*a*) Cypher language is composed of groups of letters or figures having a secret meaning. It also includes groups of letters which cannot be pronounced according to the standard for code words (para. 7), groups of letters which although pronounceable exceed the limit of 10 letters for code words (para. 7), and generally any expressions which do not fulfil the conditions of plain language or of code language as defined in paras. 6 and 7.

(*b*) Cypher may not be formed by the running together of two or more real words.

(*c*) The mixture in one telegram of letter and figure cypher is not permissible.

Combination of different kinds of language.

9. Telegrams may be expressed in plain language, code language, or cypher, employed alone or conjointly in the same telegram.

For the counting of the words in such mixed telegrams, see para. 19.

Sender's instructions.

10.—(*a*) The sender must write on the form, immediately before the address, any instructions relative to delivery, prepayment of reply, repetition, &c. These instructions may be expressed in the following abbreviated form:—

Telegram with reply paid (*Réponse payée*) ...	RP—*
Telegram to be repeated (*Collationnement*) ...	TC
Telegram, the delivery of which has to be notified by telegraph (*Accusé de réception télégraphique*)	PC
Telegram, the delivery of which has to be notified by post (*Accusé de réception postal*)	PCP
Telegram "to follow" (*Faire suivre*)	FS
Telegram to be posted as a registered letter (*Poste recommandée*)	PR
Charge for porterage prepaid (*Exprès payé*——)	XP—†
Deposit for porterage paid, with notification by telegraph (*Exprès payé télégraphe*)	XPT

---

* Number of words to be inserted here (for example, RP 10, the whole expression counting as one word).

† Here insert amount paid (for example, "XP 2*s.* 6*d*" the whole expression counting as one word).

Deposit for porterage paid, with notification by post (*Exprès payé lettre*)	XPP
Telegram to be called for at a telegraph office (*Télégraphe restant*)	TR
Telegram to be called for at a post office (*Poste restante*)	GP
Telegram to be called for at a post office, registered (*Poste restante recommandée*) ...	GPR
Telegram with multiple addresses (—— *adresses*)	TM—*
Telegram not to be delivered during the night time (*Jour*)	J

(*b*) These authorised abbreviations are chargeable as one word each. They should be placed between hyphens or dashes, which are used as a sign of separation. The hyphens or dashes are to be transmitted but not charged for.

(*c*) If the instructions are expressed otherwise than by the authorised abbreviations, they should be written in French or in the language of the country of destination, and are chargeable according to the number of words used; but the attention of the sender should in that case be called to the fact that the abbreviation may be used.

(*d*) Special instructions, for which there are no authorised abbreviations, may also be used, as for example, "To be opened at once," "Private," "Confidential," "To await arrival," &c. These instructions should be written in French ("Ouvrir immédiatement," "Privé," "Confidentiel," "Attendre arrivée") or in the language of the country of destination. They are charged for according to the number of words used. They should precede the address, and be placed between hyphens or dashes. The hyphens or dashes are transmitted but not charged for.

(*e*) The instruction "urgent" (or its equivalent in German, "dringend") must not under any circumstances be accepted either in front of, or in, the address.

(*f*) The word "immediate," or its equivalent in another language, may be accepted before the address, as an instruction for the guidance of the addressee, but the sender should be informed that the use of this word does not secure any priority of treatment either in transmission or delivery.

(*g*) In the case of multiple address telegrams (see para. 37) instructions of this kind should be written in front of each address to which they apply; but by way of exception instructions for repetition—TC—need precede the first address only.

Sender's address.

11.—The name and address of the sender must be charged for if they are to be transmitted. In any case, the name and any address must appear at the foot of the form.

Addresses.

12.—(*a*) The address of every telegram must contain at least two words. When it is expressed in two words, the first should designate the receiver, and the second the name of the telegraph office of destination.

(*b*) The name of the telegraph office of destination should be written in the form in which it appears in the first column of the

---

* Here insert number of addresses (for example, "TM 5," the whole expression counting as one word).

International List of Telegraph Offices,[*] and when so written [†] it is in all cases (whatever the number of words or letters which it contains) chargeable as one word only (para. 20).

(*c*) In telegrams for a place bearing a name common to more than one locality, the indication (if any) of the name of the country, state, province, or district which follows the name of the place in the first column of the International List, must be added in the address. This indication is transmitted without cost to the sender. If no indication is given in the first column of the List, the name of the town is sufficient in itself to distinguish it from other places of the same name, as only one town of each name appears without such an indication. For example, the name "Orleans" alone, as entered in the first column, is sufficient in the case of telegrams for the town of Orleans, which is described in the second column as situated in the Department of the Loiret, in France, while the names of the places named "Orleans" which are entered in the first column as "Orleans Illinois," "Orleans Indiana," "Orleans Massachusetts," "Orleans Michigan," "Orleans Nebraska," and "Orleans New York," respectively, should appear in that extended form in the address, and when so written are chargeable as single words (para. 20.)

(*d*) If the sender wishes to add the name of the country, state, province, or district with a view to avoid confusion with another place of the same name, he should be informed that it is unnecessary to do more than insert the indication (if any) appearing in the first column of the International List. If he insists, no objection should be made; but the name of the country, state, province, or district (being added unnecessarily) must be charged for. For example, if he insists upon describing Orleans in France as "Orleans France" or "Orleans Loiret" the name will be chargeable as two words (para. 20). If he insists on giving it as "Orleans Loiret France" it will be chargeable as three words, the names of the province and country being charged for separately (para. 20).

---

[*] In all references to the International List of Telegraph Offices in this Appendix the annexes to that List issued from time to time are included.

[†] The rule that the name must be written as it appears in the first column of the International List is to be read subject to the remarks in the preface relating to—

(1) Alternative names shown in italics. In such cases one name only should be used.

(2) The mode of spelling adopted in the case of names beginning with the word "Saint" or its equivalent, under which, for example, St. Johns appears as S. Johns, but may be written as St. Johns or Saint Johns.

(3) The addition of the definite article The, le, la, &c., in certain cases as, for example, Lizard (The). In such cases the article may be omitted.

(4) The descriptive designations, such as "Ile de" (Island of) inserted in brackets after the name of certain offices as, for example, Aegina (Ile de). If used, these should be prefixed to the name, but they may be omitted.

It should also be noted that dashes, commas, full-stops, apostrophes, and accents are to be disregarded, the whole expression being signalled as one word without break. An exception must, however, be made in the case of the German modified vowels *ä*, *ö*, and *ü*, which must be signalled as *ae*, *oe*, and *ue* respectively as prescribed in para. 18—for example, Bärendorf, which is signalled as Baerendorf.

(*e*) The composite names inserted in the first column of the International List must, in order to pass as single words, be written *exactly* in the form in which they appear in that column. For example, Almena in the State of Lippe-Detmold, which is entered in the first column as "Almena Deutschland," should be so described in telegrams and not as "Almena Germany." In cases where the indication added to the name of the town is not given in the English language (as in the above case, where "Deutschland" is used and not "Germany"), or is expressed by an abbreviation, the meaning of which is not self-evident (as in the case of "Alma Cun" for Alma in the district of Cuneo in Italy), the translation or explanation appears in the preface to the List.

(*f*) The name of the country, state, province, or district (where this is used by the sender, although not appearing in the first column) should be written as it appears in the second column of the International List, or in the alternative form shown in the preface to that List. In that case it is chargeable (whatever the number of words or letters which it contains) as one word only (para. 20). For example, when the name of the country is added in a telegram for Sydney in New South Wales (which stands without supplementary indication in the first column simply as "Sydney") it may be written as "Nouvelle Galles du Sud" (the form given in the second column) or as "New South Wales" (the form given in the preface), the whole expression "Sydney Nouvelle Galles du Sud" or "Sydney New South Wales," counting as two words.

(*g*) The sender should, in his own interest, be invited to write the names in the manner shown in the foregoing paragraphs. If he insists upon writing them in a different form, the telegram may be accepted at his risk. But in that case each name must be charged for separately. The name of the country, state, province, or district cannot be combined with the name of a telegraph office otherwise than in strict accordance with the form in which the whole expression appears in the first column of the International List.

(*h*) When a telegram is handed in by a person other than the actual sender, and the instructions of the latter cannot be readily obtained, the telegram may be accepted notwithstanding that the address is not written in exact conformity with the particulars given in the International List *provided that there is no doubt as to the office for which the telegram is intended.* If the discrepancy consists in the addition of the name of the country or province, or both, to a town which stands without supplementary indication in the first column (as, for example, "Orleans France," "Orleans Loiret," or "Orleans Loiret France," instead of "Orleans"), the additional name or names must be charged for separately. If the only discrepancy consists in the use of a supplementary indication differing from that shown in the first column of the List (as, for example, "Almena Germany" or "Almena Lippe Detmold" instead of "Almena Deutschland"), the accepting telegraphist may alter this indication so as to bring it into conformity with the International List, and thus render the whole expression chargeable as a single word. *Great care should, however, be taken not to make such alteration unless it is quite certain that the office which appears in a given form in the International List is that which is really intended.* If there is any uncertainty on this point the telegram can only be accepted at the sender's risk, and each name must be charged for separately.

(*i*) In the case of islands which appear in the first column of the

International List (such as Bermuda, Turks Island, Barbados), the name of the island is regarded as sufficient; but in the case of other islands (those, namely, which contain more than one telegraph office), the name of the office of destination must appear in the address. Hence telegrams addressed, for example, to "Wilson Cyprus" "Brown Ceylon" "Smith Jamaica" "Jones Newfoundland" or "Robinson Mauritius" must not be accepted. Neither can telegrams bearing as the sole address the name of a country (as, for example, "Jones Venezuela") be accepted.

(*k*) If, in the case of telegrams addressed to a place bearing a name common to more than one locality, the sender declines or is unable to state which office of the name is intended, the telegram can only be accepted at his risk, and where the rates to the several places of the name are different, the higher or highest rate must be charged, the words "higher rate paid" or "highest rate paid" being in that case entered in the service instructions and telegraphed.

(*l*) Telegrams for places not in the International List of telegraph offices may be accepted at the sender's risk if the name of the country appears in the address. In that case the names of the place and of the country of destination must each be charged for separately.

(*m*) Whenever a telegram is accepted at the sender's risk, the words "Sender's risk" must be inserted in the service instructions and telegraphed, but not charged for. In such cases no complaint respecting the fate of the telegram is entertained, and the sender should be informed to that effect before the telegram is accepted.

Name of office of origin.

13.—(*a*) In outward telegrams the office of origin is to be indicated in the preamble by the name given to that office in the International List, accompanied by any supplementary indication following the name of the office in the first column of the List, the whole being signalled as one word without break. For example, Newport in Monmouthshire will be indicated as "Newport," while Newport in the Isle of Wight will be indicated as "Newport Isle of Wight" Beeston in Yorkshire will appear as "Beeston Yorks" Ellington in Northumberland will appear as "Ellington Northumberland" Abingdon in Berkshire will appear as "Abingdon England" Arrochar in Dumbartonshire will appear as "Arrochar Scotland" and Bandon in County Cork will appear as "Bandon Ireland." These names should be signalled respectively as "Newport" "Newport-isleofwight" "Beestonyorks" "Ellingtonnorthumberland" "Abingdonengland" "Arrocharscotland" and "Bandonireland."

(*b*) In the case of branch and military sub-offices which do not appear in the International List of telegraph offices, the names of such offices should continue to be given as the office of origin, followed by the name of the head office in the form in which the latter appears in the International List: thus, Baxenden, a town sub-office in Accrington, should be described as "Baxenden Accrington" as the latter office appears in the International List simply as "Accrington" while Bonhill, a town sub-office in Alexandria in Scotland, should be described as "Bonhill Alexandria Scotland" as the latter office appears in the International List as "Alexandria Scotland."

Addresses to be in full.

14. In telegrams addressed to large towns, the name of the street and number of the house in which the addressee resides should be given. When these particulars cannot be furnished, the profession, trade, or calling of the addressee, or similar information, should be given. Telegrams which do not contain information sufficient to

enable the terminal office to effect delivery without difficulty are forwarded, but in case of non-delivery the sender must bear the consequences. The addresses (excepting, of course, the name of the addressee) should be in French or in the language of the country of destination. In the case of telegrams addressed to one person at the house of another, whose name is also given, the word "chez" (care of) or an equivalent expression in the language of the country of destination should be inserted between the two names. The same course should be followed if the name of the addressee is prefixed to a registered address. It is undesirable to use the expression c/o as the equivalent of "care of," as its meaning is not universally understood. Senders of telegrams should be warned accordingly.

If the sender declines to insert "chez" or an equivalent expression in such cases, the telegram must only be accepted at his risk (*see* para. 12 (*m*)).

Telegrams without text.

15. Telegrams which do not contain any text may be accepted for transmission.

Enquiry or correction.

16.—(*a*) The sender or receiver of a telegram may cause enquiry to be made, or instructions to be given respecting it, by telegraph. He may also, with a view of rectifying errors, have the telegram repeated wholly or in part, either by the delivery or sending office, or by an intermediate office.

(*b*) For these objects he must pay the following amounts :—

(1) The price of a telegram conveying his request.
(2) The price of a telegram for the reply, if a reply by telegraph is required.

(*c*) Every telegram exchanged between two telegraph offices at the request of the sender or addressee is to be regarded as a paid service message, charged for according to the ordinary rates and prefixed ST. In such messages the name of the office of destination and the name of the office of origin (which is used as the name of the sender) are not charged for.

(*d*) The sender may prepay the cost of a reply to an ST telegram making enquiry or giving instructions. He must necessarily do so in the case of an ST telegram asking for repetition with a view to rectifying supposed errors. In the former case the instruction RP—— (stating the number of words paid for in the reply) is charged for, but not in the latter. The number of words to be paid for in the reply is arrived at by adding one word, for the name of the addressee, to the number of words which the text of the reply will contain. When the reply repeats part or the whole of the original telegram, its text will only need to contain (in addition to the name of the addressee) the words repeated.

(*e*) A paid service message must be transmitted in the form of a service message, that is, with the name of the office of origin as the signature only. These messages take precedence as S.G.s.

(*f*) Replies to inward ST telegrams must also be prefixed ST.

(1) *Corrections of Text.*

Examples of corrections and enquiries.

17. (Form to be used when the sender discovers that he has made an error in the original telegram.)

ST Hamburg viâ ————————

L twentysixth Schulz replace third 20 by 2000
Dewsbury

[*Chargeable* as 8 *words*—see para. 16.]

In this example "third" indicates the position in the text of the original telegram of the word which the sender wishes to rectify. It is in fact the third word. "L" denotes the code time of the original telegram, "twenty-sixth" the date, and "Schulz" the name of the addressee: and similarly in the other examples which follow.

(2) *Corrections of Text.*

(Form to be used in cases where the sender learns from the addressee that a mistake has been made in transmission which renders the telegram unintelligible).

ST Hamburg viâ ————
L twentyfirst Muller read third 56
Normanton

[*Chargeable as* 6 *words—see* para. 16.]

(3) *Correction of Address.*

(Form to be used when the sender wishes to correct or complete the address of a telegram which has failed to be delivered. Para. 32.)

ST Paris viâ ————
M twentysixth Dubois deliver 102 Rue Royale
Dewsbury

[*Chargeable as* 7 *words—see* para. 16.]

(4) *Request for confirmation of delivery of a telegram.*

ST Hamburg viâ ————RP 5—
K twentyfirst Schmidt confirm delivery
Wakefield

[*Chargeable as* 11 *words including* 1 *word for the indication—RP* 5— *and* 5 *for the number of words in the reply.*]

The reply to such an enquiry takes the following form:—

ST Wakefield
Schmidt delivered twentyfirst 5.30 p.m.
Hamburg

(5) *Request for repetition, whole text only.*

ST Hamburg viâ ———— —RP 9—
KLX twentysixth Simon repeat text
Blackburn

[*Chargeable as* 14 *words*: 5 in the message plus 9 for the reply—*see* para. 16.]

18. In plain language, the maximum number of letters allowed to pass at the charge for a single word is 15, any excess being charged for at the rate of 15 letters to a word. Length of words.

In code language, the maximum number of letters allowed to pass at the charge for a single word is 10. Words or expressions of more than 10 letters in length, when used in a code sense, are not accepted otherwise than as cypher at 5 letters per word (para. 8).

"Ch" and the German modified vowels *ä*, *ö*, and *ü* are each counted as one letter except when they occur in groups of letters charged for at 5 letters to the word (para. 25), when they count as two letters each. The German modified vowels *ä*, *ö*, and *ü* must be signalled respectively as *ae*, *oe*, and *ue*.

Mixed telegrams.

19. Words in plain language (including proper names in their natural sense) in the text of a mixed telegram (composed of words in plain language and words in code language) must be charged for at the rate of 10 letters to a word, any excess being charged for at the rate of 10 letters to a word. If the telegram contains also a part in cypher, this part should be charged for in accordance with para. 25.

If a telegram is composed partly of plain language and partly of cypher, and does not contain code language, the words in plain language are charged for at the rate of 15 letters to a word.

Counting.

20. The following must be charged for as single words :—

(*a*) *In the address* of every telegram the name of the telegraph office of destination, including any indication of the country, state, province, or district added *in the first column* of the International List to distinguish it from other offices of the same name ; also the name of the country, state, province, or district in which the office of destination is situated, when such a name (although not appearing in the first column) is inserted by the sender (para. 12, paras. *d* and *l*). These names, whatever the number of words or letters employed to express them, must *in the address* be counted respectively as single words. But in order that they may be so counted, it is essential (1) as regards the name of the telegraph office of destination that it should be written as it appears in the first column of the International List with the proper supplementary indication (if any) appearing in that column, and (2) as regards the name of the country, state, province, or district (where such name, as not appearing in the first column of the List, is charged for separately) that it should be written as it appears in the second column of the List or in the alternative form shown in the preface to the List.

For examples, see paras. 12 and 26.

The component parts of names (including any supplementary indication appearing in the first column of the International List) counted under the above rule as single words must be joined together by the accepting telegraphist, and the whole should be signalled without break, thus "Riodejaneiro" "Nouvellegallesdusud" "Newsouthwales" "Abbevillesouthcarolina" "Alburynewsouthwales" "Almenadeutschland" and "Almacun"

(*b*) Each separate letter and figure :

(*c*) An underline :

(*d*) The two signs used in forming a parenthesis ( ) :

(*e*) Inverted commas :

(*f*) Sender's instructions written in the abbreviated form as given in para. 10.

The hyphens used to enclose the instructions "RP," "TC," &c. (see para. 10) are neither charged for nor counted.

Punctuation.

21. Signs of punctuation (other than full stops, hyphens, or dashes forming parts of groups of figures or letters, para. 25) are transmitted free of charge in European telegrams if the sender makes a special request for their transmission. In the absence of such a request they are not transmitted. If the sender makes no remark, it is to be assumed that he does not wish them to be transmitted.

In Extra-European telegrams such signs of punctuation are only transmitted if the sender pays for them as isolated figures or letters. (Para. 20.)

Full stops after initial letters.

22. Full stops are sometimes used after initial letters as an indication that such letters are to be transmitted separately, as, for example, H.M.S. standing for "His Majesty's Ship." In such cases they need not be transmitted, but the letters must be charged for and transmitted as separate words (para. 20) as, for example, H M S. If the sender wishes such an expression to pass as a single word *in the text* (in accordance with para. 25) it should be transmitted in a group as *hms* without full stops. *In the address*, letters forming such expressions must always be written and transmitted as separate words (para. 25).

Compound words.

23.—(*a*) Two or more words joined by hyphens are charged for as so many separate words, as are also words separated by an apostrophe.

(*b*) Ordinary compound words are, however, passed as single words, subject to the limit of 15 or 10 letters, as the case may be (para. 18), provided their employment is authorised by the usage of the language, and that in the telegram they are written without break or hyphen. Thus the compound word "Post-office," being authorised by the usage of the English language, is counted as one word if written as "Postoffice"; if written as "Post-Office" (with a hyphen), or as "Post Office" (with a break) it is counted as two words.

(*c*) Combinations of words written together without break or alterations of words contrary in either case to the usage of the language to which such words belong (other than the special classes of combinations admissible under para. 24) are not admitted.

(*d*) As in inland telegrams, the abbreviated expressions "can't," "won't," "don't," "shan't," and "couldn't," &c., are passed as single words. They must, however, be written without apostrophe as "cant," "wont," "dont," "shant," and "couldnt."

Names.

24—(*a*) Subject to the limit of 15 letters, names of towns, countries, or provinces and places (when not already admissible, *in the address only*, as single words, whatever the number of words or letters employed to express them, under para. 20 (*a*)); family names, names of squares, boulevards, streets, and other public places,* and names of ships, are to be charged for in the text, address, or signature according to the number of words used by the sender. Thus the

---

* The words "street," "square," &c., or their equivalents in other languages are not considered to form part of the name of the street or square, and cannot be combined, contrary to the usage of the language, with such names so as to form a single chargeable word. Thus, in the combination "Newoxfordstreet," "Newoxford," being the name of the street, is counted as one word, while the word "street" must be charged for separately. Similarly, in the combination "ruedelapaix," the word "rue" must be charged for separately from the name "delapaix." On the other hand, the combination "Neumarktstrasse" is counted as one word, it being in accordance with the usage of the German language to write the word "strasse" in combination with the name "Neumarkt."

name "New York" if written as "New York" or as "New-York" (as to hyphens see para. 23) is counted as two words; but if written as "Newyork" it is counted as one word.

Similarly the name "De la Rue" is counted as three words, if so written; but if written without break as "Delarue" it is counted as one word.

(*b*) Such names, if used in their natural sense in the text of telegrams in code language, may be similarly combined; but in that case they are chargeable at 10 letters per word, under para. 19.

(*c*) Whole, fractional and decimal numbers may be written in words without break or hyphen (as, for example, "twoandahalf"); and in that case such expressions are chargeable at 15 letters per word, except in the text of code telegrams in which they are chargeable at 10 letters per word under para. 19.

(*d*) This exceptional counting does not apply to the names of horses, hotels, railway stations, or mines, which must in all cases be counted according to the number of words of which they are composed.

(*e*) Compound names and expressions used as abbreviated addresses, such as "Grandhotel," should not be accepted as single words, save on the express assurance of the sender that they are really registered as such. The attention of the telegraph officer in charge should be called to any such cases by means of a docket attached to the "A" form.

These instructions also apply to registered abbreviated addresses occurring in the text, as, for example, in a telegram reading: "Telegraph to Grandhotel Paris to reserve rooms."

(*f*) Corresponding expressions used as part of a full address (as, for example, "Grandhotel" in such an address as "Smith Grandhotel Avenue de l'Opéra Paris") should in no case be accepted as single words.

Cypher, &c.

25.—(*a*) Groups of letters forming letter cypher (para. 8); groups of letters forming commercial marks or commercial or other analogous expressions in current use (para. 6 and examples in para. 26), and groups of figures are charged for at the rate of 5 letters or figures to the word, any excess being charged for at the rate of 5 letters or figures to a word. Letters and figures (in cases where a mixture of letters and figures in one telegram is not prohibited under para. 8) must not be considered as forming one group for purposes of counting except in the cases specified in paragraph (*c*). For example, ch23 (a commercial mark) is considered for purposes of counting as two groups and charged for as two words.

(*b*) This method of counting (at five letters to a word) does not apply to improper combinations or alterations of words accepted inadvertently in contravention of para. 23. Every care should be taken to avoid the acceptance of such combinations or alterations, but if they should be accepted inadvertently and the error be subsequently discovered, the sender should be required to pay for the words in the same manner as if they had been properly written.

(*c*) Full stops, hyphens or dashes, and bars of division are each counted as a figure or letter in the group in which they occur. Ordinal numbers expressed in figures and letters and combinations of figures and letters representing the number of a house must be counted at the rate of five characters to a word, the letters being reckoned as figures. For example, the English ordinal number "17th" (4 signs) the French ordinal number "17me" (4 signs), and the German ordinal number "17ten" (5 signs) are each counted as a single word, as well as such combinations as "15A," "12bis," when used to denote the numbers of houses.

(*d*) Groups of letters must on no account be accepted in the address. All letters other than those forming names or words must, in the address, be separated, and paid for as one word each, para. 20 (*b*). They are then transmitted as separate words. For examples, see para. 26.

Examples of counting.

26. The following examples show how the rules as to the counting of words, &c., are to be interpreted :—

NAMES OF TOWNS, COUNTRIES, PROVINCES AND PLACES (Paras. 20 and 24).

—	Number of Words.		—	Number of Words.	
	In the Address.	In the Text or Signature.		In the Address.	In the Text or Signature.
New York	1	2	Lippe Detmold... ...	1	2
New-York	1	2	Lippe-Detmold... ...	1	2
Newyork	1	1	Lippedetmold*	1	1
Frankfurt Main ...	1	2	Abbeville South Carolina†	1	3
Frankfurt-Main ...	1	2	Albury New South Wales†	1	4
Frankfurtmain* ...	1	1	Almena Deutschland†...	1	2
Rio de Janeiro ...	1	3	Alma Cunt	1	2
Riodejaneiro* ...	1	1	Acampo California‡ ...	2	2

GENERAL.

—	Number of Words.	—	Number of Words.
Responsibility* (14 characters) ...	1	Johns (without apostrophe)	1
Kriegsgeschichten * (15 characters, "ch" counting as one character) ...	1	A-t-il	3
Incomprehensible (16 characters) ...	2	Atil (contrary to usage of language)	3
		C'est à dire	4
		Cestadire(contrary to usage of language)	4
Hyphens and Apostrophes (para. 23).		Post-office	2
To-day	2	Postoffice (without hyphen)	1
Today (without hyphen)	1	Porte-monnaie	2
Aujourd'hui	2	Portemonnaie* (without hyphen) ...	1
Aujourdhui (without apostrophe) ...	1	Grand'mère	2
John's	2	Grandmère (without apostrophe) ...	1

---

* If used (in its natural sense) in the text of a telegram containing code, to be charged for as one word more than the number given above, being counted, under para. 19, at the rate of 10 letters to a word.

† Name of office with name of country or province appearing in the first column of the International List.

‡ Name of office with name of country or province not appearing in the first column of the International List.

—	Number of Words.
Family Names (para. 24).	
Van de Brande	3
Vandebrande *	1
Von Bülow	2
Vonbülow	1
Du Bois	2
Dubois	1
De la Rue	3
Delarue	1
Names of Squares, Boulevards, Streets, &c. (para. 24).	
Belgrave Square	2
Belgravesquare (contrary to usage of language)	2
Hyde Park	2
Hydepark (contrary to usage of language)	2
Hydepark Square †	2
Hydeparksquare (contrary to usage of language)	2
St. James Street	3
Saintjames Street	2
Portland Place	2
New Oxford Street	3
Newoxford Street	2
Newoxfordstreet (contrary to usage of language)	2
Rue de la Paix	4
Rue delapaix	2
Ruedelapaix (contrary to usage of language)	2
Names of Ships (para. 24).	
Prince of Wales	3
Princeofwales *	1
City of Glasgow	3
Cityofglasgow *	1

—	Number of Words.
Numbers written at Length (para. 24).	
Two hundred and thirty four	5
Twohundredandthirtyfour * (23 characters)	2
Deux cent trente quatre	4
Deuxcenttrentequatre (20 characters)	2
Two thousand one hundred and ninety four	7
Twothousandonehundredandninetyfour* (34 characters)	3
Three-eighths	2
Threeeighths *	1
Dreiviertel *	1
Deux tiers	2
Deuxtiers	1
Two and a half	4
Twoandahalf *	1
Trois deux tiers	3
Troisdeuxtiers *	1
Figures and Signs or Letters, &c. (para. 25).	
$44\frac{1}{2}$ (5 characters) ‡	1
$44^1/_2$,,	1
$444\frac{1}{2}$ (5 characters) ‡	2
$444^1/_2$,,	2
444.5 (5 characters)	1
444.55 (6 characters)	2
44/2 (4 characters)	1
44/ (3 characters)	1
2% (4 characters)	1
2p%	3
54–58 (5 characters)	1
54/58 ,,	1
17th (4 characters)	1
The 17th (one word and a group of 4 characters)	2
The 1529th (one word and a group of 6 characters)	3
17me (4 characters)	1
le 17me (one word and a group of 4 characters)	2

---

* If used (in its natural sense) in the text of a telegram containing code, to be charged for as one word more than the number given above, being counted, under para. 19, at the rate of 10 letters to a word.

† In this case, the expression "Hydepark" in a single word is only counted as one word, because the word "park" forms an integral portion of the name of the square.

‡ In foreign and colonial telegrams these expressions can only be signalled in the form $44^1/_2$, $444^1/_2$.

—	Number of Words.
15A (number of house)	1
15A (commercial mark)	2
5bis (number of house)	1
5bis (commercial mark)	2
10 pounds 10 shillings or 10*l* 10*s*	1
£10	2
19*s* 10	3
19 fr 50	3
fr 10.50	2
Rs 793.8	2
11h30	3
11.30	1
11R30	3
eight/10	2
huit/10	2
5/twelfths	2
5/douzièmes	2
15 × 6 *	4
Isolated Letters (para. 20*b*).	
E	1
E M	2
H M S	3
G P O	3
K C M G	4
M P	2
R A	2
S S	2
N E R	3
Groups of Letters in the Text † (*Letter Cypher, Commercial Marks, &c.*) (para. 25).	
tmrlz (letter cypher or commercial marks)	1
emvthf " "	2
emvehf " "	2

—	Number of Words.
ch 23 (letters and figures forming commercial marks)	2
ap/m (group of letters forming commercial marks)	1
$\frac{ap}{m}$ ‡ " "	1
3/m (figures and letters forming commercial marks)	2
$\frac{3}{m}$ ‡ " "	2
erand (commercial expression in current use)	1
canpac (over 5 letters)—commercial expression in current use	2
cif (commercial expression in current use)	1
caf " "	1
fob " "	1
fga " "	1
fpa " "	1
hms § (group of letters in current use)	1
gpo § " "	1
kcmg § " "	1
mp § " "	1
ra § " "	1
ss § " "	1
ner § " "	1
pm § " "	1
Underline and Parenthesis (para. 20).	
The matter is urgent leave at once (7 words and 2 underlines) ‖	9
Have heard of you indirectly (bad accounts) telegraph direct (9 words and 1 parenthesis) ¶	10

---

* Telegraph instruments cannot reproduce such expressions as 15 × 6. Senders must be asked to substitute for them the explicit meaning "15 multiplié par 6" (15 multiplied by 6).

† Such groups, especially those forming commercial marks, are sometimes written in capital letters for the sake of clearness. The letters are in that case accepted, counted, and transmitted as a group. They will, however, probably be reproduced in small letters on the telegram form made out at the office of destination.

‡ In foreign and colonial telegrams such expressions can only be reproduced in the form ap/m and 3/m.

§ Such letters must on no account be accepted as groups in the address, but must be written and charged for as isolated letters (para. 25).

‖ The signal for an underline must be transmitted before and after each word or passage to be underlined.

¶ The signal for parenthesis must be transmitted before and after each sentence or word placed in parenthesis.

Under and over-charges.

27. Telegraphists must use every endeavour to calculate the charges for telegrams correctly at the time of handing in. Should in any case too few words be charged for, and the mistake be pointed out by the handing-over office, the sender should be applied to for the difference. If he refuses to pay, or if it is not possible to find him, the handing-over office should be informed of the fact. Instructions should not be given to the handing-over office to increase the number of words unless the deficiency has been collected.

Should too many words be charged for, or should too many stamps be affixed to the form of a telegram, the telegraphist should put an explanatory note on the form showing whether or not the blame for the over-payment rests with the sender.

Difference between chargeable and actual number of words to be indicated by a fraction.

28. In case of difference between the number of words charged for and the number of the actual words, the number is signalled in the service-instructions in the form of a fraction, of which the numerator indicates *the number of words charged for*, and the denominator the number of actual words.

This rule applies, for instance, when a telegram contains:—

(1) Words in plain language exceeding 15 letters.
(2) Words in plain language exceeding 10 letters, occurring in mixed telegrams, composed of words in plain language and words in code language.
(3) Groups of over five letters.
(4) Groups of over five figures.

The following are examples of telegrams coming under this rule:—

(1) Smith Bombay—
  Letter incomprehensible (number of words $\frac{5}{4}$).
(2) Johansen Berlin.
  Send immediately Incendiary Incinerate (number of words $\frac{7}{6}$).
(3) Dubois Paris.
  Sending two bales marked emvthf (number of words $\frac{8}{7}$).
(4) Parker Pernambuco.
  106523 17839 (number of words $\frac{5}{4}$).

Cancelling.

29. If the sender, after handing the telegram in, desires to cancel it:—

(*a*) The telegraph master must satisfy himself that the person making the application is the sender or his authorised agent.

(*b*) If transmission has not commenced, or if it has commenced, but has not been completed, the telegram must be cancelled by writing across it the words, "cancelled at the request of the sender." In this case only, the amount paid for the telegram, less 2*d*., is returnable by the Telegraph Master.

(*c*) If transmission to the next office is completed, an attempt may be made at the request of the sender to stop the telegram during its subsequent inland transmission or after it has been transmitted abroad. In the former case, the sender must pay the sum of 6*d*. for a service message to the handing-over office; in the latter, he must pay for a service message (ST) to the office of destination.

Alteration.

30. No alteration, erasure, or interlineation must be made in a telegram without the authority of the sender or his representative, save as provided in Para. 12 (*h*), and in para. 20 (*a*).

After transmission to the next office is completed, no alteration can be made otherwise than by paid service messages (ST) as provided in para. 16.

Non-delivery at night.

31. Senders can give instructions that their telegrams should not be delivered during the night hours. In such cases, the indication "Jour" (meaning "day") or —J— must be inserted before the address as an instruction relating to delivery. (See para. 10). The instruction J must also be entered in the service instructions and telegraphed.

Non-delivery.

32.—(*a*) When a telegram cannot be delivered, a notice of non-delivery, giving an exact copy of the address as received, must be forwarded to the office of origin through the handing-over office ; and should any sum be due for attempted delivery, or for redirection, the notice must request that the amount be collected from the person liable to pay this sum.

(*b*) The service message must be drawn up in the terms of the following example :—

SG TSF (or name of other handing-over office *)
Todays HKR (that is, code time of the original telegram as inserted at the handing-over office) from Rotterdam to Smith 6 New Cross Street Bradford undelivered addressee unknown (or "not yet arrived," "gone away," "deceased," &c.)
Bradford

or

SG TSF (or name of other handing-over office *)
Todays HKR from Rotterdam to Smith Bradford undelivered address insufficient
Bradford

(*c*) If the notice of non-delivery is not sent on the date of the original telegram, the service message must give the date of that telegram.

(*d*) When any sum is due for the services referred to above, the words "collect . . . . " must be added to the message.

(*e*) If it becomes possible to deliver a telegram after a notice of non-delivery has be despatched, or if the telegram is claimed by the addressee, a further service message should be sent to the office of origin, informing it of the circumstance, except in cases where this information is communicated to the sender by means of a telegraphic notice of delivery for which he has paid.

(*f*) When a telegram is delivered, say, at an hotel or boarding house, and is subsequently returned within a week, the office of origin should be advised through the handing-over office in the following form :—

SW TSF (or name of other handing-over office)
Telegram of 16th from Paris to Smith Grand Hotel Brighton returned not claimed
Brighton

(*g*) If the telegram is not returned until after the lapse of more than a week from the date of delivery, the office of origin should not be advised unless there appear to be some special grounds for doing so, as, for example, the fact of the telegram having originated in a very distant country.

---

* This will appear from the prefix of the original inward telegram.

(*h*) The sender is responsible for an incorrect or insufficient address. Any alteration in or addition to the address can only be made by means of a paid service-message. (*See* para. 16.)

(*i*) When a notice of non-delivery is received from abroad, the address on the notice must be compared with that on the A form, and should it be found that a mistake has been made this must be at once corrected by a service message to the office of destination through the handing-over office. The telegram itself must not be repeated. If no error has been made, the notice of non-delivery must be communicated to the sender. If the sender, on being advised of non-delivery, wishes to correct or amplify the address, he can only do so on paying for a service-message (S T) to the office of destination. If a subsequent notice is received from abroad that the telegram has been delivered, the sender must be informed accordingly.

Telegrams to be called for.

33. In the case of telegrams intended to be left until called for at telegraph offices or post offices, the words "Télégraphe Restant," "Poste Restante" or "Poste recommandée" (Poste restante registered), as the case may be, must form part of the address or be inserted before the address as instructions relative to delivery (para. 10). The instructions may be written in the abbreviated forms —T R—, —G P— and —G P R— respectively, in which case they count as one word each under para 10.

Telegrams "to be called for" must be kept for a period of six weeks.

Prepaid replies.

34. The sender can prepay a reply of any length; but a less sum than 10*d.* must not be accepted in prepayment of a reply. The delivering office provides the addressee with the means of sending a reply of the length prepaid, free of charge, at any time within six weeks of the date of delivery. The addressee can use the reply form to frank any telegram of equivalent value. Should he not avail himself of the privilege, the amount paid for the reply will be refunded to the sender, provided that the addressee returns the form to the telegraph office within three months of the date of its issue, accompanied by a request that the money may be refunded to the sender. If the reply does not contain the full number of words paid for, the balance of the charges will be refunded to the sender, on application within three months of the date of the issue of the reply form, provided that it is not less than 10*d.* in amount. When the original telegram has not been delivered the amount deposited for the reply will be refunded after six weeks to the sender or earlier should he make application.

The provision with regard to a minimum charge does not apply to the replies to ST telegrams.

35. The instruction RP followed by the number of words prepaid must be written between hyphens before the address. Thus if a reply of 10 words be prepaid —RP 10— is inserted before the address and charged for as one word. (*See* para. 10.)

The instruction RP followed by the number of words prepaid must also be entered in the service instructions and telegraphed. If the sender wishes to prepay replies to a multiple telegram he must write RP— before the address of each addressee whose reply he prepays.

36.—(*a*) When a telegram is received to which a reply has been prepaid abroad, an A form must be filled up as a reply form and delivered with the telegram.

(*b*) At the back of the form the amount to be entered as deposited for the reply represents the charge for a telegram from the receiving office to the office of origin of the inward telegram. It must be understood that the signal —RP— in the service instructions followed by a number means that a reply of that number of words has been paid for.

(*c*) When the inward telegram has originated at a place to which there are two or more routes, the route by which the telegram was received must be inserted in the space provided for it on the reply form. When the rates are not the same by all routes, care must be taken to calculate the amount deposited at the rate applicable to the route by which the inward telegram has been received. This route will be signalled by the handing-over office.

(*d*) If a reply telegram be addressed to the place of origin of the original telegram without any indication of route being inserted on the form by the sender, the reply telegram must be forwarded by the route by which the original telegram was received, and this route must be entered in the service instructions and telegraphed. If, however, the sender should order the reply telegram by a particular route, his instructions must be followed.

(*e*) A reply telegram must not be accepted without prepayment unless a prepaid reply form be used, or unless it be accompanied by such form. If the reply costs more than the amount prepaid, the sender of the reply must pay the balance. Reply forms which do not bear the impression of the date stamp of the office by which they were issued must not be accepted; but the person tendering the form should be referred to the telegraph officer in charge.

Multiple addresses.

37.—(*a*) A telegram addressed to several persons in the same town, or to the same person in different parts of the same town, must be charged for as a single telegram; but a copying fee of 5*d.* per telegram not exceeding 100 words is charged for the copy to each address after the first. Beyond 100 words the copying fee is increased by 5*d.* for every additional 100 words or fractional part of 100 words. In calculating the fee for each copy, all the words in the text and the signature, and in the address applicable to each copy, are counted. The name of the office of destination should appear once only at the end of the address.

(*b*) The following is an example of the mode of charging a telegram with several addresses :—

"—TM5—Dubois
Lefevre 4 Rue Royale
Robinson
Green
Brown 20 Rue delapaix Paris"

"Send following goods &c. &c. &c." (98 words of text and signature together.)

(*c*) There are 13 words in the address, —TM5— counting as one word (see para. 10) and 98 in the text of this telegram; and the initial charge is, therefore, that for 111 words at 2*d.* per word = 18*s.* 6*d.* The charge for the extra copies for "Lefevre" and "Brown" is 10*d.* each, their telegrams containing 103 words (5 words in the address, *i.e.*, "Lefevre 4 Rue Royale Paris" and "Brown 20 Rue delapaix Paris" and 98 in the text); the charge for the extra copies for Robinson and Green 5*d.* each, their telegrams containing only 100 words (2 in the address, viz., "Robinson Paris" and "Green Paris" and 98 in the text). The total charge for the telegram is, therefore, 18*s.* 6*d.* + 10*d.* + 10*d.* + 5*d.* + 5*d.* = 21*s.*

(*d*) The office of destination must write on each copy only one address, viz., that of the person to whom it is to be delivered, unless the sender has requested the contrary by giving instructions to "communicate all addresses."

(*e*) The instructions regarding the number of addresses "— addresses" or TM— and "communiquer toutes adresses" (meaning "communicate all addresses"), as the case may be, must be written before the address and paid for. Under para. 10, the abbreviation TM—* is charged for as one word.

(*f*) All multiple address telegrams should be numbered for inland transmission in the same way as inland telegrams. Handing-over offices, however, must hand over such messages under one number only.

(*g*) Telegrams having multiple addresses are not accepted by the routes of the North Atlantic Cable Companies.

Special delivery.

38.—(*a*) The sender must give instructions how telegrams for places not to be found in the International List of telegraph offices, and telegrams to be delivered by special means beyond the free delivery of the terminal telegraph office, are to be forwarded from that office.

(*b*) He should write these instructions, which must be charged for, before the addressee's name.

(*c*) A telegram may be forwarded from the nearest telegraph office by post. To take as an example the case of a telegram to be forwarded from Hamburg, the address should be worded as follows:—"Post Schmidt Wansbeck Hamburg"—the name of the terminal telegraph office being written last. The word "post" is counted and charged for, but no fee for postage is collected.

(*d*) If a quicker means than the post is to be used, the address must be worded as in the following example:—"Exprès (meaning 'porterage') Schmidt Wansbeck Hamburg." The word "Exprès" (porterage) is counted and charged for.

(*e*) The cost of delivery by special means is, as a rule, to be recovered from the addressee. If the sender desires to prepay the cost of delivery, and the amount is known, the instruction "Exprès payé—" (meaning "porterage paid—") or XP—† should be inserted between hyphens before the address and charged for (para. 10). If the cost of delivery is not known, a deposit can be made for that purpose. The instructions "Exprès payé télégraphe" (meaning "porterage paid telegraph')—XPT—or "Exprès payé lettre" (meaning "porterage paid letter")—XPP—, as the case may be, must then be written between hyphens before the address and charged for (para. 10). The cost of a service-message of five words (ST) to the same destination, or a fee of 2½*d.* for the postal service, as the case may be, must also be prepaid to enable the office of destination to advise the amount expended.

(*f*) When an XPT telegram is received from abroad, the amount expended for delivery must be advised to the handing-over office, the advice being written on an ordinary form, and worded as in the following example:—

SG TSF (or code name of other handing-over office).‡

To-days XPT from Paris GL (that is code time of the original telegram as inserted at the handing-over office) to Smith Porterage 4*s*.

Colchester.

---

* The number of addresses should be inserted in the blank space.

† The amount paid should be inserted in the blank space, the whole expression, for example—XP 2*s*. 6*d*.—, counting as a single word (para. 10).

‡ This will appear from the prefix of the original inward telegram.

(*g*) In the case of an XPP telegram, the amount expended for delivery must be advised by means of an ordinary service-message (SG) to the handing-over office, which informs the office of origin by prepaid registered letter.

(*h*) Particulars of outward XPT or XPP telegrams must be kept by the office of origin to enable it to deal with the telegraphic or postal porterage advices received from abroad.

(*i*) When the sender makes a deposit —XPT— or —XPP— no charge is made to the addressee; any deficiency is subsequently collected from the sender and any excess refunded. When on the other hand the sender prepays what is understood to be the full charge XP—,* any deficiency in the amount signalled as prepaid should be collected from the addressee; any excess is not refunded.

(*k*) If for any reason the deficiency cannot be collected from the addressee, the handing-over office must be advised by service-message (SG) in order that the amount may be recovered from the sender, the words "Collect —" being added to the service-message.

(*l*) In the case of certain offices, the amount charged for porterage is shown in francs and centimes by a special entry in the International List. If the sender desires to prepay this charge, the amount notified should be converted into English money at the rate of 10*d.* to one franc, fractions of a penny being reckoned as a penny. The instruction XP— should be signalled.

Mixed postal and telegraph service.

39.—(*a*) The sender can have his telegram posted abroad. If it is to be forwarded by post from one place to another in the same country, no fee is charged for postage, unless the telegram is to be posted as a registered letter—for which see para. (*c*); if it is to be posted in a country abroad for delivery in another country, a charge of 2½*d.* should be collected from the sender for postage in addition to the charges for the transmission of the telegram to the place at which it is to be posted. In either case the word "Post," which is counted and charged for as a word, should be inserted before the address.

(*b*) The foregoing para. (38) contains an example of a telegram to be forwarded by post within the limits of the country of destination.

The following is an example of a telegram to be posted in one country for delivery in another, namely, a telegram for Calcutta to be posted at Brindisi. The address of such a telegram should be in the form:—"Post Smith Calcutta Brindisi"—the name of the terminal telegraph office being written last.

(*c*) Telegrams can also be posted as registered letters. In this case the words "Poste recommandée" (standing for "Post registered") or the abbreviation —PR— between hyphens must be inserted before the address, and paid for by the sender (Rule 12). A charge of 2½*d.* for registration fee, in addition to the charge (if any) for postage. must be prepaid on such telegrams. Thus, if the above telegrams for Wansbeck Hamburg and for Calcutta viâ Brindisi were to be posted as registered letters, they would be subject to a total charge for registration of 2½*d.* and for postage and registration of 5*d.* respectively.

40. In all matters not provided for in the foregoing instructions, the instructions regarding the treatment of inland telegrams must be observed.

---

* The amount paid should be inserted in the blank space, the whole expression, for example —XP 2*s* 6*d.* —, counting as a single word (para. 10).

INDEX.

The Entries in heavy type are the Vocabulary Nomenclature of Service Pattern Stores.

(As to prices in brackets, see top of page 2.)

HISTORIES, SHORT, OF THE TERRITORIAL REGIMENTS OF THE BRITISH ARMY. 67 numbers, each 1*d.* In one volume, 5*s.* (3*s.* 9*d.*)

Ditto. The Scots Guards. 1*d.* (1*d.*)
Ditto. The 6th (Inniskilling) Dragoons. 1*d.* (1*d.*)
Ditto. Revised Editions. 1*d.* (1*d.*) each:—

- Alexandra, Princess of Wales's Own (Yorkshire Regiment).
- The Bedfordshire Regiment.
- The Black Watch (Royal Highlanders).
- The Cameronians (Scottish Rifles).
- The Cheshire Regiment.
- The Duke of Cornwall's Light Infantry.
- The Duke of Wellington's West Riding Regiment.
- The Durham Light Infantry.
- The East Lancashire Regiment.
- The East Surrey Regiment.
- The Hampshire Regiment.
- The Highland Light Infantry.
- The King's Own (Royal Lancaster Regiment).
- The King's Own Yorkshire Light Infantry.
- The King's Own Scottish Borderers.
- The Lancashire Fusiliers.
- The Leicestershire Regiment.
- The Loyal North Lancashire Regiment.
- The Northamptonshire Regiment.
- The Oxfordshire and Buckinghamshire Light Infantry.
- The Prince Albert's (Somersetshire Light Infantry).
- The Prince of Wales's Leinster Regiment (Royal Canadians).
- The Prince of Wales's Own (West Yorkshire Regiment).
- The Prince of Wales's Volunteers (South Lancashire Regiment).
- The Princess Charlotte of Wales's (The Royal Berkshire Regiment).
- The Princess Louise's Argyll and Sutherland Highlanders.
- The Queen's (Royal West Surrey Regiment).
- The Royal Inniskilling Fusiliers.
- The Royal Sussex Regiment
- The Royal Warwickshire Regiment.
- The Royal Welsh Fusiliers.
- The South Staffordshire Regiment.
- The Suffolk Regiment.
- The Welsh Regiment.
- The Worcestershire Regiment.

HOSPITALS. MILITARY FAMILIES'. Nursing Staff Regulations. Dec. 1909. 1*d.* (1*d.*)

HOSTILITIES WITHOUT DECLARATION OF WAR FROM 1700 TO 1870. 2*s.* (1*s.* 7*d.*)

HYGIENE. ELEMENTARY MILITARY. Manual of. 1912. 6*d.* (6*d.*)

INDIAN EMPIRE. OUR. A Short Review and some Hints for the use of Soldiers proceeding to India. 6*d.* (6*d.*)

INFANTRY TRAINING. (4-Company Organization.) 1914. 6*d* (6*d.*)

INJURIES IN WAR. Memorandum on the Treatment of, based on experience of the present Campaign. July 1915. 4*d.* (4*d.*)

INSTITUTES. Garrison and Regimental. Rules for the Management of. 1915. 1*d.* (1*d.*)

INTELLIGENCE DUTIES IN THE FIELD. Regns. for. 1904. 2*d.* (2*d.*)

ITALIAN CAVALRY TRAINING REGULATIONS. 1911. Training for Marches, Tactics of Minor Units, and Training of Patrols. Translated. 4*d.* (3*d.*)

JAMAICA. Standing Orders. 1912. 1*s.* (9*d.*)

JERSEY. ROYAL MILITIA OF THE ISLAND OF. Regulations. 1914. With the Jersey Militia Law, 1905. 1*s.* 3*d.* (11*d.*)

KING'S REGULATIONS AND ORDERS FOR THE ARMY. 1912. (Reprinted, with Amendments published in Army Orders up to Aug. 1, 1914). 1*s.* (1*s.*)

KIT PLATES:—

Artillery. Royal—
1. Horse and Field. Kit in Barrack Room. 1912. 2*d.* (2*d.*)
2. Ditto. Kit laid out for Inspection. 1908. 1*d.* (1*d.*)
6. Garrison. Kit laid out for Inspection. 1909. 2*d.* (2*d.*)
10. Ditto. Kit in Barrack Room. 1909. 2*d.* (2*d.*)

Cavalry. 1891. 1*d.* (1*d.*)

(As to prices in brackets, see top of page 2.)

Kit Plates—*continued.*

Engineers. Royal—

1. Dismounted. Detail of Shelf and Bedding, with Marching Order ready to put on. Detail of Shelf and Bedding, with Drill Order ready to put on. 1914. 1*d.* (1*d.*)
2. Dismounted. Full Kit laid out for Inspection in Barrack Room. 1914. 1*d.* (1*d.*)
4. Mounted N.C.O. or Driver and Field Troop Sapper. Full Kit laid out for Inspection in Barrack Room. 1910. 1*d.* (1*d.*)
5. Mounted. Detail of Shelf and Bedding. 1910. 1*d.* (1*d.*)
6. Driver, with pair of Horses. Field Kit laid out for Inspection on Parade, including Articles carried in Valise on Baggage Wagon. 1899. 1*d* (1*d.*)

Infantry—

1. Kit in Barrack Room. 1905. 2*d.* (2*d.*)
2. Kit laid out for Inspection. 1905. 2*d.* (2*d.*) (*Out of print*)

Highland. 1884. 1*d.* (1*d.*)

Medical Corps. Royal Army. Kit in Barrack Room. 1912. 2*d.* (2*d.*)

Ordnance Corps. Army. For guidance at Marching Order and Kit Inspections 2*d.* (2*d.*)

LARGE FORMATIONS. The Operations of. (Conduite des Grandes Unités). Translated from the Field Service Regulations of the French Army, dated Oct. 28, 1913. 6*d.* (5*d.*)

LAW. Military. Manual of. 1914. 2*s.* (1*s.* 9*d.*)

LAW FOR THE RESERVE FORCES AND MILITIA. Manual of. 1886. 1*s.* 6*d.* (1*s.* 2*d.*)

MACHINE-GUN. Tests of Elementary Training. 1*d.* (1*d.*)

MACHINE GUNS AND SMALL ARMS, ·303-inch. Nomenclature of Parts, Stripping, Assembling, Action, Jams, Missfires, Failures, and Inspection of. Revised Edition. 1915. 3*d.* (3*d.*)

MAGAZINES AND CARE OF WAR MATÉRIEL. Regulations for. 1913. 9*d.* (9*d.*); Amendments, July 1914, June 1915. Each 1*d.* (1*d.*): Appendix VI., Jan. 1916. 1*d.* (1*d.*): Amendments, Jan 1916, comprising Sec. XXI. and Appendix VII. 1*d.* (1*d.*)

MAP READING AND FIELD SKETCHING Manual. 1912. (Reprinted, with Additions, 1914). 1*s.* (11*d.*) (*And see* Schools, Army.)

MECHANISM AS APPLIED TO ARTILLERY. Notes on. Second edition. 1902. 1*s.* (11*d.*)

MEDICAL CORPS. Royal Army (*and see* Territorial Force):—

Admission to. Regulations for. Jan. 1912. 1*d.* (1*d.*)
Standing Orders. 1914. 1*s.* (10*d.*)
Training. 1911. 9*d.* (9*d.*)

MEDICAL DEPARTMENT. Army. Index to Appendices of Reports from 1859 to 1896. 3*d.* (3*d.*)

MEDICAL SERVICE. Army:—

Regulations. 1906. (Reprinted, with Amendments up to Sept. 30, 1914). 4*d.* (5*d.*)
Ditto. Revised Appendix No. 51. Scale of Medical and Surgical Equipment for Units in the Field. 1*d.* (1*d.*)

MEDICAL SERVICE. Strategical and Tactical Employment of the, as carried out in an Army Corps; with a series of Problems. Translated from the Austrian. 4*s.* 6*d.* (3*s.* 4*d.*)

MEDICAL SERVICES. Army. Advisory Board for. The Treatment of Venereal Disease and Scabies. First Report. 1904. 1*s.* 6*d.* (1*s.* 3*d.*): Second Report. 1905. 2*s.* (1*s.* 6*d.*); Third Report. 1905. 1*s.* (10*d.*): Final Report. 1906. 6*d.* (5*d.*)

MEDICAL SERVICES OF FOREIGN ARMIES. Handbook of. Part I. FRANCE 6*d.* (5*d.*) (*Under revision*): Part II. GERMANY. 6*d.* (5*d.*): Part III. AUSTRIA-HUNGARY. 6*d.* (6*d.*): Part IV. RUSSIA. 6*d.* (5*d.*): Part V. ITALY. 6*d.* (5*d.*): Part VI. THE NETHERLANDS AND BELGIUM. 1911. 6*d.* (5*d.*)

MEKOMETER HANDBOOK. 1911. 6*d.* (6*d.*)

MILITARY LANDS ACTS, 1892 to 1903. Byelaws. (*See* Artillery and Rifle Ranges Act, &c.).

MOUNTED TROOPS (DIVISIONAL) TRAINING. Provisional. June 1915. 1*d.* (1*d.*)

(**As to prices in brackets, see top of page 2.**)

MUSKETRY REGULATIONS:—
- Part I. 1909. (Reprinted, with Amendments, 1914). 6*d.* (7*d.*)
  - Ditto. Amendments, Nov. 1915. 1*d.* (1*d.*)
- Part II. Rifle Ranges and Musketry Appliances. 1910. (Reprinted, with Amendments to Oct. 31, 1914). 4*d.* (4*d.*)

NIGHT OPERATIONS. Elementary Training in. 1911. 1*d.* (1*d.*)

NUMBER OF TROOPS TO THE YARD in the Principal Battles since 1850 Memo. on. With opinions of Modern Authorities on limits of extension at the present day. 1884. 9*d.* (7*d.*)

NURSING SERVICE. Queen Alexandra's Imperial Military. Regulations for Admission to the. 1914. 1*d.* (1*d.*)

OFFICERS TRAINING CORPS:—
- Regulations. 1912. 2*d.* (2*d.*) *(Under revision)*
  - Ditto. (Inns of Court). 1*d.* (1*d.*) *(Revision under consideration)*
- Special A.O., March 16, 1908. 1*d.* (1*d.*)
- Junior Division. Instructions for the Annual Camps. 1913. 2*d.* (2*d.*)

OPERATION ORDERS. A Technical Study, by HANS VON KIESLING. Translated from the German. 1*s.* 6*d.* (1*s.* 3*d.*)

OPTICAL MANUAL or Handbook of Instructions for the guidance of Surgeons. Third edition. 1885. 1*s.* 6*d.* (1*s.* 3*d.*)

OPTICS. Notes on. 6*d.* (5*d.*)

ORANGE FREE STATE. Topographical Survey of the, 1905-1911. Report on the. 10*s.* (7*s.*)

ORDNANCE COLLEGE (*and see* Artillery College):—
- Advanced Classes (up to the 33rd.) Reports on. Each 1*s.* (9*d.*)
  - Ditto. 31th. 6*d.* (5*d.*)
- Artificers. Military. Handbook for. 10th Edition. 1915. 9*d* (9*d.*)
- Dynamics. Notes on. Second edition. 3*s.* (2*s.* 5*d.*)
- Officers' Mess (Royal Artillery) Management and First Principles of Book-keeping. 3*d.* (3*d.*)
- Ordnance Courses. Reports on. Each 1*s.* (9*d.*)
- Regulations. 1907. 2*d.* (2*d.*)

ORDNANCE CORPS. Army. Standing Orders. 1912. (Reprinted, with Amendments to June 30, 1914). 6*d.* (6*d.*)

ORDNANCE MANUAL (WAR). 1914. 6*d.* (5*d.*)

ORDNANCE. SERVICE. Treatise on. Seventh edition. 1908. With volume of plates. 7*s.* 6*d.* (5*s.* 6*d.*); Amendments. June 1909, Dec. 1910. Dec. 1912, April 1911. Each 1*d.* (1*d.*); Do. Dec. 1909. Dec. 1911. Each 2*d.* (2*d.*)

ORDNANCE SERVICES. ARMY. Regulations:—
- Part I. 1912. (Reprinted, with Amendments up to July 1, 1915). 6*d.* (7*d.*)
- Part II. Instructions for Laboratories and Laboratory Operations, Examination of Explosives and Ordnance. 1914. 1*s.* (11*d.*)
  - Ditto. Amendments, June, Dec. 1915. Each 1*d.* (1*d.*)

PATHOLOGICAL SPECIMENS in the Museum of the Army Medical Department, Netley. Descriptive Catalogue of. Third Edition. Vol. I. By Sir W. Aitken, M.D. 1892. 5*s.* (3*s.* 8*d.*)

PAY DUTIES of Officers Commanding Squadrons, Batteries, Companies, &c. Instructions. (Revised for the period of the War). I. Home and Colonies. II. In the Field. May 1915. 1*d.* (1*d.*)

PHYSICAL TRAINING. Manual of. (Reprint 1908 with Amendments published in Army Orders to Dec. 1, 1911). 9*d.* (9*d.*)

PLACE-NAMES OCCURRING ON FOREIGN MAPS. Rules for the Transliteration of. 1906. 1*s.* (9*d.*)

PORTABLE SUB-TARGET (Mark I.), and How to Use it. 1911. (Reprinted, with Amendments, 1914). 1*d.* (1*d.*)

POSTAL SERVICES. ARMY. Manual of. War. 1913. (Reprinted, with Amendments, 1915). 3*d.* (3*d.*)

PROJECTION, &c. Linear Perspective. A Text-Book for use of the R.M. Academy. Part I.—Text Part II.—Plates. 1904. 6*s.* (4*s.* 5*d.*)

PUBLICATIONS (RECENT) OF MILITARY INTEREST. List of. Quarterly. Nos. 1 to 8. 2*d.* (2*d.*) each; Nos. 9 to 17. 4*d.* (4*d.*) each. [*Continued by* THE ARMY REVIEW.]

(As to prices in brackets, see top of page 2.)

RAILWAY DISTANCES. Ireland. Handbook of. Third edition. 1884. 7*s.* 6*d.* (5*s.* 3*d.*)

RAILWAY MANUAL (WAR). 1911. (Reprinted, with Amendments, 1914). 6*d.* (5*d.*)

RAILWAYS. MILITARY. RECONNAISSANCE AND SURVEY OF. Notes on, for Officers of R.E. Railway Companies. 1910. 2*s.* 3*d.* (1*s.* 8*d.*)

RANGE-FINDER Handbooks:—
- Infantry. No. 1. (Marindin). 1913. (Reprinted 1915). 3*d.* (3*d.*)
  - Ditto. No. 2. (Barr and Stroud). 31·5-inches base. 1913. 8*d.* (8*d.*)
  - Ditto. Addendum. 1*d.* (1*d.*)
- Watkin. Regulations for Instruction in, and practice with. 1882. 1*s.* (9*d.*)

RANGE FINDING. COAST DEFENCE. Manual of. Part I. 9*d.* (8*d.*)
- Ditto. Amendments. June 30, 1914. 1*d.* (1*d.*)
- Ditto. Addendum. Self-contained-Base Instruments. 1915. 1*d.* (1*d.*)

RANGES, MINIATURE CARTRIDGE. (*Reprinted from* THE ARMY REVIEW, January 1914). 3*d.* (3*d.*)

RANGING. Examples of. (*See* Artillery. Training. Field.)

RANGETAKERS. Instructions for the Training of, with the Range-finder, Artillery. 1*d.* (1*d.*)

RECRUITING FOR THE REGULAR ARMY AND THE SPECIAL RESERVE. Regulations. 1912. (Reprinted, with Amendments to Aug. 31, 1914.) 3*d.* (3*d.*)

REMOUNT MANUAL (WAR). 1913. 2*d.* (2*d.*)

REMOUNT REGULATIONS. 1913. 3*d.* (3*d.*)

REQUISITIONING OF SUPPLIES, TRANSPORT, STORES, ANIMALS, LABOUR, &c., IN THE FIELD. Instructions for the. 1907. 1*d.* (1*d.*)

RESERVE (*and see* Special Reserve: Territorial Force):—
- Army Reserve. Class I. Regulations. 1911. 1*d.* (1*d.*)
  - Ditto. Amendments. June, 1913. 1*d.* (1*d.*)
- National Reserve. Regulations. 1913. 1*d.* (1*d.*)

RIFLE. ROSS MAGAZINE ·303-inch, Mark IIIB. Handbook of the. 1915. 1*d.* (1*d.*)

RIFLE RANGES, TRAINING GROUND, AND MUSKETRY CAMP, PENALLY. (Western Coast Defences). Standing Orders. 1910. 2*d.* (2*d.*)

RIFLES, &c. Cleaning of. Notes on the. 1911. 25 for 6*d.* (7*d.*)

RIFLES, SHORT AND CHARGER-LOADING, MAGAZINE, LEE-ENFIELD. Handbook for Serjeant-Instructors of Special Reserve, Officers Training Corps, and Territorial Force in regard to the Care, Inspection, &c., of. 3*d.* (3*d.*)

RUSSIAN MILITARY AND NAVAL TERMS. Dictionary of. 1906. 3*s.* 6*d.* (2*s.* 6*d.*)

RUSSO-JAPANESE WAR:—
- Medical and Sanitary Reports from Officers attached to the Japanese and Russian Forces in the Field. 1908. 5*s.* (3*s.* 10*d.*)
- Official History. Part I. Causes of the War. Opening Events up to and including the Battle of the Ya-lu. Second edition. 1909. 1*s.* 6*d.* (1*s.* 3*d.*); Part II. From the Battle of the Ya-lu to Liao-yang, exclusive. 1908. 5*s.* (3*s.* 8*d.*); Part III. The Siege of Port Arthur. 1909. 4*s.* 6*d.* (3*s.* 4*d.*); Part IV. Liao-yang. 1910. 4*s.* (3*s.*); Part V. Sha Ho. 1911. 4*s.* 6*d.* (3*s.* 5*d.*).
- Official History (Naval and Military). Vol. I. To Aug. 24, 1904. With case of Maps. 1910. 15*s.* (10*s.* 7*d.*); Vol. II. Liao-yang, the Sha-ho, Port Arthur. With case of Maps. 1912. 15*s.* (10*s.* 10*d.*)
- Reports from British Officers attached to the Japanese and Russian Forces in the Field. In three Vols., with two cases of Maps (*not sold separately*). 21*s.* (15*s.*)

SALISBURY PLAIN. SOUTHERN COMMAND. Standing Orders applicable to all Troops Encamped on Salisbury Plain, and applicable generally to Troops Quartered at Bulford and Tidworth. 1913. (Reprinted, with Amendments, 1915). 3*d.* (3*d.*)

(As to prices in brackets, see top of page 2.)

"SAM-BROWNE" BELT, SCABBARD, AND SWORD KNOT Specifi-tion and Drawings. 1899. 1*d.* (1*d.*)

SCHOOLS. Army:—

Annual Reports on. 1911-12; 1912-13. Each 1*s.* (9*d.*)
Map Reading. Notes on. 1915. 3*d.* (3*d.*)
(*And see* Map Reading and Field Sketching).
Military and other Terms, and Words which occur in Orders. Lists of. 1914. 2*d.* (2*d.*)
Physiology. Elementary. Handbook. 1901. 1*d.* (1*d.*)
Regulations. 1911. 4*d.* (4*d.*)
School Hygiene. Handbook of. For Teachers. 6*d.* (6*d.*)
Singing in. Regns. for Teaching. 1911. 1*d.* (1*d.*)
Standing Orders for Inspectors, Examiners, and Teachers. 1910. 6*d.* (5*d.*)
Type Exercises of Extracts from Regimental Orders for use of Candidates for Third-class Certificates of Education. 1912. 3*d.* (3*d.*)

SCOUTS. Training and Use of. Lecture by Col. F. C. Carter. 1905. 2*d.* (2*d.*)

SCREWS. Standard Leading. Provision of, for Screw-cutting Lathes. Report of Committee. 1905. 1*s.* (10*d.*)

SEVASTOPOL. Siege of. 1854–55. 3 vols., with Case of Maps and Plans. Half Mor., £5 4*s.* Cloth, £4 4*s.*
Or separately:—Vol. I. Engineer Operations. £1 6*s.*; Vol. II. Ditto. With Case of Maps and Plans. £2 10*s.*; Vol. III. Artillery Operations. 10*s.*

SEWAGE. Practical Treatment of. The latest development of. 1903. 6*d.* (5*d.*)

SHOEBURYNESS GARRISON. Standing Orders. 1913. 1*s.* 6*d.* (1*s.* 1*d.*)

SIEGE OPERATIONS in the Campaign against France, 1870-71. (*Von Tiedemann.*) Translated. 4*s.* 6*d.* (3*s.* 3*d.*)

SIGNALLING. Training Manual. 1915. Provisional. 6*d.* (*In the press*)

SIGNALLING DISC. Directions for use. 1911. 1*d.* (1*d.*)

SIGNAL SERVICE. THE ARMY. 1*d.* (1*d.*)

SIGNAL SERVICE. ARMY. Manual of—**WAR.** Provisional. 1914. 2*d.* (2*d.*)

SMALL ARMS Text-Book. 1909. With Tables. 2*s.* 6*d.* (2*s.* 1*d.*)

SMALL WARS. Their Principles and Practice. Third Edition. 1906. (*Reprinted,* 1909). 4*s.* (3*s.*)

SOMALILAND:—

Military Report on. 1907. Vol. I Geographical, Descriptive, and Historical. 2*s.* (1*s.* 7*d.*)
Operations in, 1901–04. Official History. Vol. I. 3*s.* (2*s.* 4*d.*); Vol. II. 4*s.* (3*s.*)

SOUTH AFRICAN WAR, 1899–1902:—

Medical Arrangements. 7*s.* 6*d.* (5*s.* 6*d.*)
Medical History. An Epidemiological Essay. [Reprinted from "The Journal of the Royal Army Medical Corps."] 3*s.* 9*d.* (2*s.* 9*d.*)
Railways. 4*s.* (3*s.*)
Surgical Cases Noted. 7*s.* 6*d.* (5*s.* 6*d.*)
Telegraph Operations. 10*s.* (7*s.* 1*d.*)
Voluntary Organizations in aid of the Sick and Wounded. Report of the Central British Red Cross Committee on. 1902. 3*s.* (2*s.* 5*d.*)

SPECIAL RESERVE:—

Regulations for Officers of the Special Reserve of Officers, and for the Special Reserve. 1911. 4*d.* (5*d.*)
Scheme for the Provision, Organization and Training of the Special Reserve required to supplement the Regular Army, and the Application of the Scheme to the existing Militia. (Special A.O., Dec. 23, 1907.) 2*d.* (2*d.*)
Scheme for the Provision, Organization, and Training of that portion which will be drawn from the Territorial Force to supplement the Regular Army on Mobilization being ordered. (Special A.O., Nov. 20, 1908). 2*d.* (2*d.*)

STAFF COLLEGE Regulations (Camberley). 1905. Reprinted with Amendments up to Nov. 30, 1910. 1*d.* (1*d.*)

(As to prices in brackets, see top of page 2.)

STAFF. General. Duties of the. (*Von Schellendorff.*) Fourth Edition. 1905. (*Out of print*)

STATIONS OF UNITS OF THE REGULAR FORCES, MILITIA, SPECIAL RESERVE, AND TERRITORIAL FORCE. Quarterly up to No. 45, July 1914. Each 2d. (2d.) (*Publication suspended*)

STATUTES relating to the War Office and to the Army. 1880. 5*s*. (3*s*. 9*d*.)

STATUTORY POWERS of the Secretary of State, Ordnance Branch. 1879. 5*s*. (3*s*. 9*d*.)

STEAM ENGINES AND BOILERS, AND GAS AND OIL ENGINES. Management of. Notes and Memoranda. 1911. 1*d*. (1*d*.)

SUDAN ALMANAC. 1916. Compiled in the Intelligence Department, Cairo. Astronomical [illegible] by the Egyptian Ministry of Public Works, Physical Service. [illegible] 1*s*. (9*d*.)

SUDAN. BRITISH FORCE IN THE. Standing Orders. 1914. 9*d*. (7*d*.)

SUDAN. The Anglo-Egyptian. A Compendium prepared by Officers of the Sudan Government:—

Vol. I. Geographical, Descriptive, and Historical (*with Eighty-two illustrations*). 10*s*. (7*s*. 4*d*.)

Vol. II. Routes. 7*s*. 6*d*. (5*s*. 5*d*.) (*Not containing Chapter VII., Supplement (A).*)

Ditto. In Separate Chapters. 1*s*. (10*d*.) each:—

I. and II., *Nil*. III. North-Eastern Sudan. IV. Eastern Sudan. V. Central Sudan. VI. South-Eastern Sudan. VII. Bahr-el-Ghazal. VIII. Kordofan. IX. North-Western Sudan.

Ditto. Chapter VII. Supplement (A). Bahr-el-Ghazal. Additional Routes. 1*s*. (10*d*.)

SUDAN CAMPAIGN. History of the. Two parts, and Maps. 1890. 15*s*. (10*s*. 11*d*.)

SUPPLY MANUAL (WAR). 1909. 6*d*. (6*d*.)

SUPPLY. RE-ORGANIZED SYSTEMS OF, and of Ammunition Supply of the Expeditionary Force in War, consequent on the introduction of Mechanical Transport. Memorandum explaining the. Feb. 1912. 1*d*. (1*d*.)

SUPPLY, TRANSPORT, AND BARRACK SERVICES. Regulations. 1915. 6*d*. (6*d*.)

SURVEYING. Topographical and Geographical. Text Book of. Second edition. 1913. 7*s*. 6*d*. (5*s*. 6*d*.)

Ditto. 1905. Appendix XI. Tables for the Projection of Graticules for squares of 1° side on scale of 1 : 250.000, and for squares of ½° side on scale of 1 : 125.000 ; with other Tables used in Projection Maps. 4*d*. (4*d*.)

Ditto 1905. Appendix XII. Tables for the Projection of Graticules for maps on the scale of 1 : 1.000.000. 1910. 2*d*. (2*d*.)

TACTICAL RIDES AND TOURS ON THE GROUND. The Preparation and Conduct of. Translated from the German. 1*s*. 3*d*. (1*s*. 1*d*.)

TELEGRAPHY AND TELEPHONY. Army. Instruction in:—

Vol. I. Instruments. (Reprinted, with Corrections, 1914.) 1*s*. 6*d*. (1*s*. 4*d*.)

Vol. II. Lines. 1909. (Reprinted, with Corrections, 1914.) 1*s*. (11*d*.)

Ditto. Revised Chapter I. Field Cables. Provisional. 1*d*. (1*d*.)

TERRITORIAL FORCE (*and see* Equipment):—

Cadet List. A List of the Cadet Units which had received Official Recognition on March 31, 1915. [illegible] (7*d*.)

Cadet Units in the British Isles. Regulations governing the Formation, Organization, and Administration of. 1914. (Reprinted, with Amendments in Army Orders to Dec. 1, 1914.) 1*d*. (1*d*.)

Field Kits. Officers and Men. 1*d*. (1*d*.)

Hospitals, General, of the. Regulations for. 1912. 2*d*. (2*d*.)

Medical Corps. Royal Army. Syllabus of Training. 1914. 1*d*. (1*d*.)

(As to prices in brackets, see top of page 2.)

Territorial Force—*continued.*

Mobilization of a Territorial Infantry Battalion. (*Reprinted from* THE ARMY REVIEW, July 1913.) 3d. (3d.)
Nursing Service. Standing Orders. 1912. (Reprinted, with Amendments, 1914). 1d. (1d.)
Pay Duties during Embodiment. Instructions in. 2d. (d.)
Regulations for the (including the Territorial Force Reserve), and for County Associations. 1912. (Reprinted, with Amendments published in Army Orders to Dec. 1, 1914). 6d. (7d.)
Voluntary Aid:—
Scheme for the Organisation of, in England and Wales. Dec. 1910. (*Out of print*)
Ditto. Ditto. Amendments. 1d. (1d.)
Ditto, in Scotland. Oct. 1911. 2d. (2d.)
Ditto. Ditto. Amendments. 1d. (1d.)
Training. (Extracts from "Medical Corps. Royal Army. Training. 1911.") 6d. (7d.)

TRACTOR TRIALS held by the Experimental Sub-Committee of the Mechanical Transport Committee at Aldershot, Sept. and Oct. 1903. Report on. 6d. (5d.)

TRAINING AND MANŒUVRE REGULATIONS. 1913. 4d. (5d.)

TRANSPORT. MECHANICAL:—
Heavy Pontoon Bridge for use by. Provisional. 1914. 2d. (2d.)
Regulations for the Appointment of Inspectors of. 1d. (1d.)

TRANSPORT. PACK. Notes on. 1d. (1d.)

TRUMPET AND BUGLE SOUNDS for the Army. With Instructions for the Training of Trumpeters and Buglers. 1914. 9d. (8d.)

TYPHOID (ANTI-) COMMITTEE. Report. 1912. 2s. 6d. (1s. 11d.)

TYPHOID (ANTI-) INOCULATION COMMITTEE. Report on Blood Changes following Typhoid Inoculation. 1905. 1s. 6d. (1s. 2d.)

URDU-ENGLISH PRIMER. For the use of Colonial Artillery. 1899. 15s. (10s. 2d.)

VALISE EQUIPMENT. Instructions for Fitting:—
Pattern 1888 with pattern 1894 Pouch opening outwards. 1895. 1d. (1d.)
Bandolier pattern. 1903. 2d. (2d.)

VALPARAISO. The Capture of, in 1891. 1s. (10d.)

VENEREAL DISEASE. *See* Medical Services.

VETERINARY CORPS. Army:—
Regulations for Admission. 1910. 2d. (2d.)
Standing Orders. 1906. 4d. (4d.)

VETERINARY MANUAL (WAR). 1915. 1d. (1d.)

VETERINARY SERVICES Army Regulations. 1906. (Reprinted, with Amendments to Dec. 1, 1914). 3d. (3d.)

VOLUNTARY AID. *See* Territorial Force.

WAR OFFICE LIST, AND ADMINISTRATIVE DIRECTORY FOR THE BRITISH ARMY. 1914. *Sold by Harrison & Sons, 45, Pall Mall.* 5s. *net.* (*Under revision*)

WATER SUPPLY MANUAL. 1s. 6d. (1s. 4d.)

WORKS MANUAL. (WAR). 1913. 4d. (4d.); Appendix I 1d. (1d.)

X-RAY APPARATUS. Hints Regarding the Management and Use of. 3d. (3d.)

YEOMANRY AND MOUNTED RIFLE TRAINING. Parts I. and II. 1912. (Reprinted, with Amendments, 1915). 6d. (6d.)

ZULU WAR OF 1879. Narrative of the Field Operations connected with the. 1881. (*Reprinted* 1907.) 3s. (2s. 4d.)