MILITARY BOOKS

Published by Authority.

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.

To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses:
IMPERIAL HOUSE, KINGSWAY, LONDON, W.C. 2, and 28, ABINGDON STREET, LONDON, S.W. 1;
37, PETER STREET, MANCHESTER; 1, ST. ANDREW'S CRESCENT, CARDIFF;
or 120, GEORGE STREET, EDINBURGH.

(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. 1.)

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

ACCOUNTS. ARMY. *See* FINANCIAL INSTRUCTIONS.

AFRICA. Notes on the Geology of Continent of. 1906. 3s. (2s. 8d.)

ALDERSHOT COMMAND. Standing Orders for 1921. 6s. (4s. 9d.)

ALLOWANCES. ARMY. Regulations. 1914. (*Reprinted* 1918.) 9d. (9d.)
Ditto. Amendments, April, 1921. 1d. (2d.)
See also FIELD ALLOWANCE, PAY OF OFFICERS, *and* SEPARATION ALLOWANCE.

AMHARIC LANGUAGE. Short Manual of the. With Vocabulary. 1910. 5s. (4s.)

AMMUNITION FOR Q.F. 4·5-INCH HOWITZER. Notes on. 4th Edition, 1920. (*With Diagrams.*) 1s. (11d.)

ANIMAL MANAGEMENT. 1908. (*Reprinted* 1918.) 2s. (1s. 9d.)

ANIMAL MANAGEMENT, &c. Catechism of. 1d. (2d.)
See also HORSES.

ANTI-AIRCRAFT DEFENCE (Part I, Ground Units). Manual of. 1922. (Provisional). 1s. (1s.)

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

ARMOURED CAR TRAINING. Training and War (Provisional). 1921. 1s. 6d. (1s. 5d.)

ARMOURERS. Instructions for:—
Care, repair, browning, &c., of Small Arms, Machine Guns, "Parapet" Carriages, and for the care of Bicycles. 1912. (Reprinted, with Amendments, 1916). 2s. 6d. (2s. 1d.)
Addendum, Jan. 1918. Care and repair of Rifles, Magazine, ·303-inch Pattern. 1914. 1d. (2d.)
Addendum, Aug. 1921. 1d. (2d.)

ARMY ENTRANCE REGULATIONS. *See* Entrance.

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

ARMY LIST. The Monthly. Officers on the Active List. (*Publication was suspended during the War*):—
Jan. 1919, and after. Each 5*s.* (4*s.* 3*d.*)
Quarterly Supplement. Officers of the Regular Army Reserve of Officers and Territorial Army Reserve of Officers; Territorial Force Associations; Soldiers' Balances Undisposed of; &c., &c. Dec. 1921, and after. Each 4*s.* (3*s.* 3*d.*)

ARMY LIST. The Quarterly (*not issued in* October, 1914). Each 15*s.* (12*s.* 9*d.*)
Ditto. The Quarterly. Part 2, War Services of Officers of the Army, &c. Jan, 1922. (*Gratis to purchasers of the Quarterly Army List.*) (Postage, 1*s.*)

ARMY MEDICAL CORPS, ROYAL. Regulations for Admission. 1921 2*d.* (3*d.*)

ARMY ORDERS. Monthly. Each 3*d.* (3½*d.*) Covers for. 9*d.* (9*d.*)

ARMY ORDERS. Index for 1921. 6*d.* (7*d.*)

ARMY REVIEW. Quarterly. July 1911 to Oct. 1914. (*Vol. I., Nos.* 1 *and* 2, *out of print.*) 1*s.* (Up to July 1914, 1*s.*; Oct. 1914, 11*d.*) *Subsequent publication suspended.*

ARMY SERVICE CORPS. *See* SERVICE.

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

ARTILLERY AT THE PICARDY MANŒUVRES IN 1910. Translated from the French. 2*s.* 6*d.* (2*s.* 5*d.*)

ARTILLERY. Royal:—
Instructions for Practice. Garrison (Coast Artillery), Seawards. June 1922. 3*d.* (3*d.*)
Rangetakers. *See that item.*
Standing Orders for—
Lieut.-Colonel's Command, R.G.A. (Coast and Siege). 1*d.* (2*d.*)
Training—
Coast. Vol. I. 1921. Provisional. 3*s.* (2*s.* 6*d.*)
Ditto. Vol. II. Provisional. 1920. 1*s.* 6*d.* (1*s.* 5*d.*)
Field. 1914. (*Reprinted* 1918.) 1*s.* (1*s.*)
Ditto. Examples of Ranging. To supplement those given in Sec. 227. 2*d.* (2*d.*)
Garrison—
Vol. I. 1914. 6*d.* (7*d.*)
Vol. II. (Siege). 1911. (Reprinted, with Amendments, 1914.) 9*d.* (10*d.*)
Vol. III. 1911. (Reprinted, with Amendments, 1914). 1*s.* (11*d.*)

ARTILLERY COLLEGE. Reports upon the 14th to 18th Senior Classes. (*Out of print.*) 19th. 1*s.* 6*d.* (1*s.* 3*d.*); 20th and 21st. Each 2*s.* (1*s.* 9*d.*)
Advanced Classes, Reports on. 36th 1*s.* 6*d.* (1*s.* 3*d.*) 37th. 2*s.* (1*s.* 8*d.* 38th. 1*s.* 6*d.* (1*s.* 3*d.*)
See also Ordnance College.

ARTILLERY INSTRUMENTS. Handbook of. 1914. 1*s.* 6*d.* (1*s.* 6*d.*)
Ditto. Amendments. 1*d.* (2*d.*)
Ditto. Addendum to. 2*d.* (3*d.*)
Ditto. Appendix, Dec. 1915 (Periscopes, &c.); and Amendments to p. 111 of the Handbook. *With Plates.* 1*d.* (2*d.*)

ARTILLERY. Light, Medium and Heavy. 1922. Instructions for Practice 3*d.* (4*d.*)

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

ARTILLERY AND RIFLE RANGES ACT, 1885, and MILITARY LANDS ACT, 1892. Byelaws under:—
Aldeburgh, 1896; Ash (Aldershot Camp), 1887; Finborough, 1901; Hythe, 1894; Inchkeith Battery, 1896; Kinghornness, 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.* (2*d.*)
Purfleet, 1911. 1*s.* (10*d.*)
Salisbury Plain, 1900. 4*d.* (4*d.*)

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

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

ARTILLERY TRAINING. Vol. I. 1920. Drill (Provisional). 2*s.* (1*s.* 9*d.*) Vol. II. 1920; Gunnery (Provisional). 1*s.* 6*d.* (1*s.* 5*d.*); Vol. III. 1921. Organization and Employment of Artillery in War. 1*s.* 6*d.* (1*s.* 5*d.*)

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

BALLISTICS. Handbook of (*translated from the 2nd German edition*):—
Vol. I. Exterior Ballistics. 30*s.* (28*s.* 3*d.*)

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.* (1*s.* 1*d.*)

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

BICYCLES. (Pedal.) Military. Handbook on. 1922. 1*d.* (1½*d.*)

BOUNTY TO SOLDIERS. *See* FIELD ALLOWANCE.

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

CADET LIST.
CADET UNITS. } *See* TERRITORIAL FORCE.

CADETS OF THE SENIOR AND JUNIOR DIVISIONS, OFFICERS TRAINING CORPS. Report on the Examination for Certificates "A" and "B" held in Nov. 1920. 1*s.* 6*d.* (1*s.* 4*d.*)

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

CASUALTY LISTS, WAR OFFICE AND AIR MINISTRY WEEKLY, Aug. 7, 1917, to March 4, 1919. Each 3*d.* (4*d.*)

CAVALRY. Technical Operations; Cavalry in an Army; Cavalry in Battle. Translated from the French of Captain Loir, XX Army Corps Staff. With a Preface by General Langlois. With Maps. 3*s.* 6*d.* (3*s.* 2*d.*)

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.* (2*d.*)

CAVALRY TRAINING. Vol. I, 1921. Provisional. 2*s.* (1*s.* 7*d.*) Vol. II, 1920. Provisional. 9*d.* (8*d.*) *See also* ITALIAN CAVALRY.

CEREMONIAL. 1912. (*Reprinted* 1919). 6*d.* (7*d.*)
Ditto. Provisional Amendments, June 1914. (*With Plates and Key.*) (*Reprinted* 1919). 2*d.* (3*d.*)

CHEMISTRY. PRACTICAL. Quantitative and Qualitative. A Course of. 1914. 5*s.* (4*s.* 2*d.*)

CHEMISTS OF THE RESEARCH DEPARTMENT. Rules and Regulations specially relating to. 1918. 1*d.* (2*d.*)

CHIROPODY. Manual of. 2*d.* (4*d.*)

CLOTHING AND NECESSARIES (including Materials). Priced Vocabulary of. 1920. Provisional. 1*s.* (11*d.*)
Ditto. Amendments, Jan., April, Aug., Nov. 1916; Feb., April, Dec. 1917; March, Nov. 1918; Jan., Nov. 1919. Each 1*d.* (1½*d.*); Jan. 1920. 1*d* (2*d.*); Dec. 1920. 2*d.* (2½*d.*); March 1921. 2*d.* (3*d.*); Sept. 1921. 3*d.* (4*d.*); Feb. 1922. 1*d.* (2*d.*)

CLOTHING Regulations:—
Part I. Regular Forces. April 1922. 1*s.* (11½*d.*) Amendments, Aug. 1922. 1*d.* (1½*d.*)
Part II. Special Reserve. 1914. 3*d.* (5*d.*)

COLCHESTER GARRISON. Standing Orders. 1918. 9*d.* (9*d.*)

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

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.*)

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.* (2*d.*)

CONSTITUTION. THE GERMAN. (*Edition without Notes*). 1920. 6*d.* (8*d.*)

COOKING AND DIETARY. Manual of Military. 1918. 6*d.* (7*d.*)

CO-ORDINATION OF VOLUNTARY EFFORT resulting from the formation of the D.G.V.O. Department. A National Scheme of:—
- Appendices III and IV. A Detailed Report of the Work of the Recognized Associations. 1920. 5*s.* (4*s.* 1*d.*)
- (*The Report of the Director-General, with Appendices I and II, was published as* [Cmd. 173] *of Session* 1919. Price 2*d.* (3*d.*))

COST ACCOUNTING SCHEME FOR 1919–20. Provisional Instructions relating to. Part I.—For the guidance of Staff, Regimental and Departmental Officers at Home Stations. 3*d.* (5*d.*)

COURSES OF INSTRUCTION. 1922–23. 9*d.* (9*d.*)
- Ditto. Supplement, April 1922. 1*d.* (1½*d.*)
- Ditto. Amendment, A.O., May 1922 1*d.* (1½*d.*)
- Ditto. Supplement. Army School of Hygiene. Issued with Army Orders for July, 1922. 1*d.* (1½*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. 1917, Provisional. 6*d.* (6*d.*); Amendments, Aug. 1918. 1*d.* (2*d.*)

DEMOBILIZATION. ARMY. Regulations:—
- Part I. With Diagram showing Method of Dispersal; and Map of Dispersal Stations and Areas in the United Kingdom. 1*s.* 6*d.* (1*s.* 6*d.*)
- Part II. With Plan of Hutment Lines showing suggested Appropriation of Buildings for use as a Dispersal Station; and Map of Dispersal Stations and Areas in the United Kingdom. 6*d.* (7*d.*)
- Part III.
  - Ditto. Chap. XXIV. Labour Units. 2*d.* (2½*d.*)
  - Ditto. Chap. XXV., Part 1. Dispersal of Officers of the Army Chaplain's Department. 1*d.* (1½*d.*)
  - Ditto. Chap. XXV., Part 2. Ordnance Services. 2*d.* (2½*d.*)
  - Ditto. Chap. XXVI. Q.M.A.A.C. 2*d.* (2½*d.*)
  - Ditto. Chap. XXVII. Animals. 3*d.* (3½*d.*)
  - Ditto. Chap. XXXII. The Volunteer Force. 2*d.* (2½*d.*)
  - Ditto. Chap. XXXIII. British West Indies Contingents. 2*d.* (2½*d.*)
- Addenda to Chap. V. Special Registration. 1*d.* (1½*d.*)
- Amendments:—
  - Nos. 3 to 25. Each 1*d.* (2*d.*)
  - To Parts I and II. 1*d.* (2*d.*)

DENTAL CORPS. Standing Orders for the Army. 1922. Provisional. 2*d.* (2½*d.*)

DESPATCHES, MILITARY. *See* War of 1914–18.

DISABLED AND DISCHARGED SOLDIERS IN FRANCE. The Training and Treatment of. Report by Sir Henry Norman, Bart., M.P., Liaison Officer of the Ministry of Munitions to the French Ministry of Inventions. 4*d.* (5*d.*)

DISEASES, MEDICAL, IN THE TROPICAL AND SUB-TROPICAL WAR AREAS. Memoranda on. 1919. (*With Plates, Diagrams, Text-figures, and Index*). (*Out of print*)

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

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. 1921. (*Illustrated.*) 5*s.* (4*s.* 2*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.*)
Neighbourhood of Woolwich. Southern Side. 1*s.* 6*d.* (1*s.* 3*d.*)
Woods and Villages. 6 plates. Each 6*d.* (5*d.*)

DRILL BOOK. R.A.S.C. (Issued with A.O. for October, 1920.) 3*d.* (3*d.*)

DYNAMICS. Notes on. 1908. 2nd Edition. 3*s.* (3*s.* 3*d.*)

EDUCATION. IMPERIAL CONFERENCE. Convened June 11 and 12, 1919, by the Chief of the Imperial General Staff. 6*d.* (7*d.*)

EDUCATIONAL TRAINING. Part I. General Principles. 2*d.* (3*d.*)

EGYPT. BRITISH FORCE IN. Standing Orders. 1912. 1*s.* (11*d.*)

EGYPT. CAMPAIGN OF 1882 IN. Military History. With case of Maps. Condensed Edition. 1908. 3*s.* 6*d.* (2*s.* 10*d.*)

EGYPTIAN EXPEDITIONARY FORCE. A brief record of the Advance of the. 1919. 6*s.* (5*s.* 1*d.*)

ELECTRICAL COMMUNICATIONS. FIXED. Instructions as to. 1912. (Reprinted, with Amendments, 1916). 4*d.* (5*d.*)

ELECTRICITY. Notes on. 1920. 3*s.* (2*s.* 6*d.*)

ELECTRIC LIGHT AND POWER WORK OF THE GERMAN ARMY. Notes on. 1920. 1*s.* 6*d.* (1*s.* 4*d.*)

ELECTRIC LIGHT APPARATUS. DEFENCE. Instructions for the Working of. 1915. 1*d.* (2*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.* 6*d.*)

ENERGY EXPENDITURE OF THE INFANTRY RECRUIT IN TRAINING. The. 1920. 3*s.* (2*s.* 6*d.*)

ENGINEER SERVICES Regulations. Peace:—
Part I. 1910. (Reprinted, with Amendments published up to May 1, 1915). 1*s.* (1*s.*)
Ditto. Amendments, July 1922. 1*d.* (1½*d.*)
Part II. 1911. Technical Treatises. (Reprinted, with Amendments, to May 1, 1915). 9*d.* (8*d.*)
Ditto. 1920. Technical Treatises. 4*d.* (5*d.*)

ENGINEER TRAINING. 1922. Provisional. 9*d.* (9*d.*)

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

ENGINEERING. Military:—
Part I. Field Defences. 1908. 1*s.* 6*d.* (1*s.* 6*d.*)
Part II. Attack and Defence of Fortresses. 1910. 9*d.* (11*d.*)
Part III. Bridging. 1921. 3*s.* 6*d.* (2*s.* 9*d.*)
Part IIIa. Military Bridging.—General Principles and Materials. 1913. 1*s.* (11*d.*); Index. 1*d.* (2*d.*)
Part IIIb. Ditto.—Bridges. 1914. (*Reprinted* 1918.) 2*s.* (1*s.* 10*d.*)
Part IV. Mining and Demolitions. 1910. (Reprinted, 1915, with Amendments to 1912 inclusive). 1*s.* (11*d.*)
Part V. Miscellaneous. 1914. 1*s.* (1*s.* 1*d.*)
Part VI. Military Railways. 1898. (*Out of print*)

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

ENTRANCE. ARMY. Regulations:—

R.M. Academy. Admission to, and for First Appointments therefrom to the Royal Artillery and Royal Engineers. 1920. 2*d*. (3*d*.)

R.M. College. Admission to, and for First Appointments therefrom to the Regular Army. Provisional. 1920. 3*d*. (4*d*.)

Military Forces of the Self-governing Dominions and Crown Colonies, Officers of the. 1912. 1*d*. (2*d*.)

Militia and Imperial Yeomanry. Officers of. 1907. 1*d*. (2*d*.)

Royal Army Veterinary Corps. Regulations for Admission to the. 1*d*. (2*d*.)

Special Reserve of Officers, Malta Militia, Bermuda Militia, Channel Islands Militia, and Territorial Force. Officers of the. 1920. 1*d*. (1*d*.)

University Candidates. Provisional. 1920. 1*d*. (2*d*.)

Warrant Officers and N.C.Os. of the Regular Army. Combatant Commissions as Second Lieutenants, 1914. Provisional. (*Under revision*)

Staff College (Camberley). 1*d*. (2*d*.)

See also MEDICAL CORPS.

EQUIPMENT. INFANTRY. Pattern 1908 Web. 1913. 2*d*. (4*d*.)

See also VALISE EQUIPMENT.

EQUIPMENT Regulations:—

Part 1. 1912. (Reprinted, with Amendments published in Army Orders up to Aug. 31, 1914). 1*s*. (1*s*.)

Part 2. Details—

Sect.

I. Infantry (Regular Army). 1913. (Reprinted, with Amendments published in Army Orders up to Dec. 31, 1915). 6*d*. (6*d*.)

I*a*. Mounted Infantry. 1912. 6*d*. (6*d*.)

II. Cavalry (Regular Army). 1914. 3*d*. (5*d*.)

III. Army Service Corps (Regular Army). 1913. (Reprinted, with Amendments published in Army Orders up to Dec. 31, 1915). 6*d*. (6*d*.)

V. Royal Army Medical Corps (Regular Army). 1914. 2*d*. (3*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* (3*d*.)

X*a*. Engineer. General. Fortress, Survey, Railway, and Depôt Units. Peace and War. (Regular Army.) 1914. 2*d*. (4*d*.)

X*b*. Field Troop (Regular Army). 1912. 2*d*. (3*d*.)

X*d*. Divisional Signal Company (Regular Army). 1914. 2*d*. (3*d*.)

X*e*. Signal Company (Wireless) (Regular Army). 1912. 2*d*. (3*d*.)

X*f*. Headquarters Signal Units (Regular Army). 1914. 2*d*. (3*d*.)

X*g*. Signal Company (Cable) (Regular Army). 1912. 2*d*. (3*d*.)

X*h*. Signal Squadron (Regular Army). 1914. 2*d*. (3*d*.)

X*j*. Signal Troop with Cavalry Brigade (Regular Army). 1912. 2*d*. (3*d*.)

X*k*. Signal Troop with a Cavalry Brigade not allotted to a Cavalry Division (Regular Army). 1914. 2*d*. (3*d*.)

X*l*. Signal Company (South Africa) (Regular Army). 1912. 2*d*. (3*d*.)

X*m*. Bridging Train (Regular Army). 1912. 2*d*. (3*d*.)

X*n*. Field Squadron (Regular Army). 1914. 2*d*. (3*d*.)

XI*a*. Horse Artillery. Q.F. 13-pr. (Regular Army.) 1913. 9*d*. (9*d*.)

XI*b*. Field Artillery. Q.F. 18-pr. (Regular Army.) 1914. 9*d*. (9*d*.)

XI*c*. Field Artillery. Q.F. 4·5-in. Howitzer. (Regular Army.) 1913. (Reprinted, with Amendments up to Aug. 1, 1914). 9*d*. (9*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-inch Equipment. Mountain Battery and Ammunition Column. Mule Transport. (Regular Army.) 1914. Provisional. 6*d*. (6*d*.)

XII*a*. Royal Garrison Artillery (Regular Army). 1914. 2*s*. 6*d*. (2*s*. 3*d*.)

XII*b*. Royal Garrison Artillery, Siege Artillery, Movable Armament, and Machine Guns in Armaments. 1913. 1*s*. (1*s*.) Amendments, Aug. 1914. 1*d*. (2*d*.). Aug. 1922. 1*d*. (1½*d*.)

XII*c*. Heavy Artillery. B.L. 60-pr. (Regular Army). 1913. 9*d*. (9*d*.)
Ditto. Amendments, July 1914. 1*d*. (2*d*.)

XIV. Cavalry School, Netheravon (Regular Army). 1914. 2*d*. (3*d*.)

XV. Camel Corps School, Egypt (Regular Army). 1914. 2*d*. (3*d*.)

XVI. Special Reserve. 1913. 4*d*. (5*d*.)

XVII. Officers Training Corps. 1919. 1*d*. (2*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*. 4*d*.)

Part 3. Territorial Force. 1914. 6*d*. (6*d*.)

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

Equipment Regulations—*continued.*

Part 3. Details:—

Sec. IX. Artillery. 1912. *(Out of print)*

Ditto. Amendments, April 1912; Feb. 1914. Each 1*d.* (1*d.*)

Sec. X. Engineer. 1912. 3*d.* (4*d.*)

Amendments to Part 1. Feb. 1916; June, 1921. Each 1*d.* (2*d.*)

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

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

Amendments to Parts 1, 2, and 3. March, July 1913; April, Aug. 1914; Each 2*d.* (3*d.*) Sept. 1920. 2*d.* (2½*d.*)

Amendments to Part 2, Sec. XVII (Officers Training Corps) Feb. 1920. 1*d.* (2*d.*)

Amendments to Parts 1 and 2. Dec. 1920. 3*d.* (3*d.*)

Amendments to Part 1. Oct. 1921. 1*d.* (2*d.*)

EXAMINATION PAPERS (all published papers of which the dates are omitted are *out of print*):—

Qualifying Certificates. Sept. 1905; March 1906; Sept. 1909; March, Sept. 1910; March, Sept. 1911; March 1912. Each 6*d.* (7*d.*)

Entrance: R.M. Academy, Woolwich; R.M. College, Sandhurst; Royal Air Force. Supplementary First Appointments in the Royal Marines, Indian Police Force, Police Forces of Straits Settlements, Federated Malay States, and United Malay States. Cadetships in the Royal Navy (Special Entry). June-July 1921. 3*s.* 6*d.* (2*s.* 11*d.*)

Entrance: R.M. Academy; R.M. College; Indian Army College, Wellington. Nov.–Dec. 1915. 1*s.* (10*d.*)

Entrance: R.M. Academy; R.M. College; Indian Army College, Quetta. Cadetships in the Royal Navy (Special Entry). March 1918. 6*d.* (6*d.*)

Entrance: R.M. Academy; R.M. College; Royal Air Force. Nov. 1919. 2*s.* (1*s.* 7*d.*)

Entrance: R.M. Academy; R.M. College; Royal Air Force; Supplementary First Appointments in the Royal Marines; Cadetships in the Royal Navy (Special Entry). June 1920. 2*s.* (1*s.* 8*d.*)

Entrance: R.M. Academy; R.M. College; Royal Air Force. Nov. 1920. 2*s.* (1*s.* 9*d.*)

Entrance: R.M. Academy, Woolwich; R.M. College, Sandhurst; Royal Air Force. Nov. 1921. 2*s.* (1*s.* 9*d.*)

Entrance: R.M. Academy, Woolwich; R.M. College, Sandhurst; Royal Air Force; Royal Marines; Royal Navy Cadets; Indian Police Force and Ceylon and Far Eastern Police Forces. June and July 1922. 1*s.* 6*d.* (1*s.* 4*d.*)

R.M. Academy, Fourth Class; R.M. College, Fourth, Third, and Second Divisions. July, Dec. 1904. Each 1*s.* (1*s.*) June 1905. 1*s.* (1*s.* 2*d.*)

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

Staff College. Admission. July 1911; June–July 1912; June-July 1913. Each 1*s.* (1*s.* 1*d.*)

Militia, Imperial Yeomanry, and University Candidates. Oct. 1906. 1*s.* (11*d.*)

Officers for Promotion. Dec. 1912; May and Dec. 1913; April 1914. Each 1*s.* (1*s.* 1*d.*) Oct. 1920. 1*s.* 6*d.* (1*s.* 2*d.*) April 1921. 1*s.* (10*d.*) Oct. 1921. 1*s.* 6*d.* (1*s.* 2*d.*) April 1922. 1*s.* 6*d.* (1*s.* 2*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 1909; Nov. 1911; March, Nov. 1912; March 1914. Each 6*d.* (7*d.*); March 1921. 2*s.* 6*d.* (1*s.* 10*d.*); Nov. 1921. 1*s.* 6*d.* (1*s.* 4*d.*); March 1922. 2*s.* (1*s.* 8½*d.*)

Foreign Languages. Modern. June 1919. 1*s.* (1*s.*)

Ditto. Jan. 1920. 3*s.* (2*s.* 5*d.*)

Ditto. June 1920. 2*s.* (1*s.* 9*d.*)

Ditto. Jan. 1921. 3*s.* (2*s.* 5*d.*)

Ditto. June 1921. 5*s.* (4*s.*)

Ditto. Jan. 1922. 1*s.* 6*d.* (1*s.* 3*d.*)

40
W.O.
8618

[*Issued with Army Orders for May*, 1923.

MILITARY ENGINEERING.

(VOL. IV.)

DEMOLITIONS AND MINING.

By Command of the Army Council,

THE WAR OFFICE.
May, 1923.

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.

To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses:
IMPERIAL HOUSE, KINGSWAY, LONDON, W.C.2, and 28, ABINGDON STREET, LONDON, S.W.1;
37, PETER STREET, MANCHESTER; 1, ST. ANDREW'S CRESCENT, CARDIFF;
or 120, GEORGE STREET, EDINBURGH.

1923.

Price 2s. 6d. *Net.*

CONTENTS.

PART I.—DEMOLITIONS.

CHAPTER I.

EXPLOSIVES (THEORY).

CHAPTER II.

EXPLOSIVES (DESCRIPTION).

CHAPTER III.

METHODS OF FIRING.

CHAPTER IV.

TESTING ELECTRIC FIRING CIRCUITS, USE OF CELLS, &c.

CHAPTER V.

DESCRIPTION AND PREPARATION OF CHARGES.

CHAPTER VI.

CALCULATION OF CHARGES.

CHAPTER VII.

DEMOLITIONS IN THE FIELD.

CHAPTER VIII.

LAND MINES AND TRAPS.

CHAPTER IX.

BLASTING.

PART II.—MINING.

CHAPTER X.

MILITARY MINING TACTICS.

CHAPTER XI.

RECONNAISSANCE AND CONTROL OF MINING OPERATIONS.

CHAPTER XII.

METHODS OF CONSTRUCTION.

CHAPTER XIII.

CALCULATION OF CHARGES AND THEIR EFFECTS IN MINE WARFARE.

CHAPTER XIV.

MINE GAS AND MINE RESCUE.

CHAPTER XV.

LISTENING.

CHAPTER XVI.

TUNNELLED DUG-OUTS AND SUB-WAYS.

LIST OF PLATES.

(At end of volume.)

PART I.—DEMOLITIONS.

List of Plates—*continued*.

PART II.—MINING.

List of Plates—*continued.*

MILITARY ENGINEERING.

(VOL. IV.)

DEMOLITIONS AND MINING.

PART I—DEMOLITIONS.

CHAPTER I.

EXPLOSIVES (THEORY).

1. *Definition, &c.*

An explosive is a solid or liquid substance, or mixture of substances, which, on the application of suitable stimulus to a small portion of the mass, is converted in a very short interval of time into other more stable substances, largely or entirely gaseous, which are liberated at a high temperature. An action of this nature is known as an *explosion.*

The relation between explosion and simple combustion is very close. Combustible materials, of which petrol and coal are good examples, consist in the main of substances having an affinity for oxygen. Combustion is produced by the combination of these substances with the oxygen of the air, and is accompanied by the evolution of heat and gas. The action of most explosives, though far more violent, takes place on precisely similar lines, but in their case the action once started is self-contained and independent of outside agency. Hence the supply of oxygen must be present within the explosive itself. All the bulk explosives in common use are composed, therefore, partly of combustible elements, of which hydrogen and carbon are the most important, and partly of substances which furnish a supply of oxygen. It is mainly to the gas and heat evolved by this oxidization that the power of an explosive is due.

The gas thus suddenly formed at a high temperature tends naturally to expand, and in so doing to overcome anything which opposes that expansion. Hence the power of an explosive to do useful work is proportional to the volume and temperature of the gas evolved. Solid products of an explosion are unable to expand and do work, though they absorb their proportion of heat; they merely produce smoke and fouling. Most of the more powerful explosives are converted entirely into gas on explosion; but in gunpowder, a comparatively weak explosive, 57 per cent. of the products of combustion are solids.

Substances rich in oxygen are often referred to as *oxygen carriers* or *suppliers*; those most used are nitrates, chlorates, and perchlorates. The oxygen may be either contained in a separate compound, such as saltpetre (potassium nitrate), which is mixed mechanically with the combustible material, or the two may be combined together in a single compound, as in nitro-glycerine, T.N.T., and many other modern explosives. In the latter case the oxygen does not enter into direct combination with the combustible elements of the compound until a molecular metamorphosis is set up by the stimulus of detonation explained in the following section.

2. *Low and high explosives.*

Explosives may be divided into two general classes, *low* and *high* explosives, according to the process by which they explode.

In low explosives explosion is a rapid form of combustion, in which the substance burns regularly in layers, as these in turn become exposed to the flame, until the whole is consumed. Thus the gas is generated comparatively slowly, and the surroundings are submitted to a more or less steady push or lifting effect. Low explosives are, therefore, eminently suitable as propellants, since the gradual development of pressure in the chamber of a gun permits of the ejection of the projectile with high initial velocity without causing excessive stresses in the weapon.

High explosives function in a far more rapid manner by a process known technically as *detonation*. In detonation, a wave or vibration, set up by shock or sudden heating, runs throughout the whole bulk of the explosive, decomposing each molecule almost instantaneously. The explosive is thus, within its own volume, suddenly converted into gas at enormous temperature and pressure. The effect is that of a sudden blow on the immediate surroundings, the violence of which depends on the velocity of detonation and the pressure produced.

Thus, the widely divergent action of different explosives depends in the main not on their potential energy, but on the rate at which that energy is dissipated. For instance, one lb. of gun-cotton detonated against a steel rail will cut it, owing to the intense local shattering action produced; but no amount of gunpowder can achieve the same result (though the entire rail may be blown a considerable distance away), since its comparatively slow action does not permit of a sufficiently sudden concentration of force at the point desired. On the other hand, a charge of gun-cotton, detonated in the chamber of a gun in substitution of a powder charge, will destroy the breech but fail to expel the shell. These two examples are typical of the difference in the action of the two classes of explosives. Briefly, the tendency of low explosives is to shift, and of high explosives to shatter.

3. *Velocity of detonation.*

Variation in rapidity of action is not, however, confined solely to that between the two main classes of explosives. The velocity of detonation varies considerably within the class of high explosives alone, so that, in a lesser degree, the same difference of action exists between high explosives of varying rapidity of detonation as between high and low explosives.

For, though shattering effect on detonation is inseparable from the action of all high explosives, the expansion of the gases subsequent to detonation produces lifting effect as well: the higher the velocity of detonation the more intense the shattering and the less the lifting effect. Hence the action of a very rapid high explosive is violent but local, and conversely an explosive with a comparatively slow velocity of detonation produces moderate shattering combined with good lifting effect.

The velocity of detonation of the different high explosives varies between 3,000 and 8,000 metres per second. This gives a sufficiently wide range of choice to enable a suitable high explosive to be selected for all classes of demolition work, and such only are normally used in modern warfare. Thus for cutting steel-work intense shattering effect is necessary, and an explosive with a high velocity of detonation (such as gun-cotton or nitro-glycerine) is required; while for mined charges lifting, rather than shattering, action is of primary importance, and an explosive which is slower in action (such as ammonal) is preferable.

4. *Tamping.*

As stated in Sec. 1, the action of the gases formed on explosion is to expand, and in so doing to overcome any resistance offered to that expansion. It follows that the maximum expansion will take place in that direction in which the surrounding medium offers the least resistance (known technically as *the line of least resistance* or *L.L.R.*). Hence, whenever it is desired to utilize the lifting effect of an explosive charge, the maximum useful work will be accomplished when the L.L.R. is through the object to be destroyed or removed.

Tamping is material (usually sandbags filled with earth) placed against a charge to produce this effect.

With high explosive charges tamping has little influence at the instant of detonation. The sudden formation of the gases gives a blow of great intensity in all directions, and, on the exposed sides of the charge, the inertia of the air under the enormous sudden pressnre is in itself sufficient tamping. Where shattering effect only is required, tamping, though it slightly increases the effect, is, therefore, of little importance. Good contact with the objective is the main essential, in order that it may receive the full force of the blow which is extremely local.

In all cases, however, where the lifting effect due to the expansion of the gases subsequent to detonation is to be utilized, tamping is essential. Thus, in the case of mined charges, the gallery leading to the charge must be tamped, as otherwise the main force of the explosion would pass down it. The slower the action of the explosive the more pronounced is its tendency to act along the L.L.R., and, in the exceptional case of a low explosive having to be used for a demolition charge, practically no effect will be produced without careful tamping.

5. *Igniting and detonating agents.*

Explosion in the case of low explosives is set up by simple ignition. The coarser forms of cordite and gunpowder require a powerful flame to start the action; a small *primer* of fine grain powder, or similar easily ignited substance, is used for the purpose.

The majority of high explosives, however, especially those more stable forms which can be used in bulk with safety, will not detonate when ignited, their tendency being to burn. Thus, ammonal, if set alight in small quantities, burns sluggishly with a bluish flame, and even a stick of dynamite will burn for a considerable period before it detonates. Most high explosives, however, if ignited in large quantities, ultimately detonate as soon as the combustion induces a sufficiently high temperature and pressure. A combined shock and intense heat, supplied by the explosion of a small quantity of some more sensitive substance, is the most effective method of initiating detonation. The shock must be sharp and sudden, so as to produce momentary intense pressure.

Fulminate of mercury fulfils these requirements, and is almost universally used for the purpose. It is a grey crystalline powder, formed by the action of nitric acid and alcohol on mercury. It is the most sensitive explosive in practical use, and detonates easily on slight shock or friction. In the open it burns with a sudden flash and report, but when slightly enclosed (as in a thin copper tube) and ignited, the burning of the first few grains produces sufficient pressure to detonate the remainder. It is this property which makes it of such efficacy, in the form of a *detonator*, as a medium for the detonation of bulk high explosives by ignition. Detonators are described in Secs. **17** and **20**.

Fulminate of mercury being such a highly sensitive explosive, its use is only safe in very small quantities. The few grains of fulminate composition contained in a detonator are not sufficient to detonate with certainty wet gun-cotton and certain other of the more stable high explosives: a *primer* of an explosive more sensitive than the bulk explosive, and easily detonated by the small fulminate charge, is, therefore, used. The primer on detonation amplifies the initial shock set up, thus ensuring the detonation of the main charge. The Service primer is of dry gun-cotton and is described in Sec. **17**.

6. *The detonating wave.*

The disruptive wave which sweeps through an explosive on detonation is self-regenerating; that is to say, if detonation is produced at one point, the wave spreads out with great rapidity to each particle lying in its path of action. With most high explosives, however, the force of the detonating wave gradually diminishes the further it gets from the source of origin. This tendency is most pronounced in high explosive mixtures (*see* Sec. **7**), and is of considerable importance in very large or attenuated charges (*see* Sec. **37**). Incomplete detonation may result in a portion of the charge being blown away intact, while in other cases detonation may degenerate into the rapid combustion of the remainder of the charge.

It appears that the detonating wave set up by any one high explosive contains a particular vibration peculiar to itself. For, though the detonation of one high explosive can normally be relied upon to detonate another kind in close contact, experience has shown that each is more sensitive to its own detonating wave than to that set up by another kind.

The comparative insensibility of cordite to detonation is explained by this theory. This substance, normally used as a low explosive, consists of an intimate mixture of nitro-glycerine and nitro-cellulose, both of which constituents in a free state are highly sensitive to detonation. Yet only extremely local detonation can be produced in the mixture, as the wave set up dies out very rapidly. *Interference,* due to the difference in vibration of the two high explosives, destroys the rhythm, and thus damps the detonating wave.

The wave of detonation can be transmitted in a lesser degree through air, earth, water, or other materials, and charges at a distance thus exploded are said to *detonate in sympathy.* A case is on record in which a boat containing several tons of dynamite blew up on the Rhine in 1895, and caused the sympathetic explosion of a quantity of dynamite in another vessel moored some 20 yards away. Water is a specially suitable medium for the transmission of the detonating wave, and this fact is often made use of in the destruction of hostile mines at sea.

7. *High explosive mixtures.*

It is clear that true detonation, from the nature of its action, can only take place in those definite chemical compounds the molecular construction of which is more or less unstable, and which are thus susceptible to sudden decomposition by the shock of the detonating wave. Many of the modern high explosives, however, are mixtures, in which one (or more) of the main constituents is a detonating compound, while the remainder consist of materials of a combustible nature. The former constituent detonates throughout the porous mixture, and in so doing causes the almost instantaneous combustion of the other constituents. The result of this combined action is to reduce the velocity of detonation, while the combustible materials raise considerably the temperature of the gases liberated. A powerful explosive with a good lifting effect, suitable for mined charges, is thus formed. Ammonal and blastine are examples of this type.

8. *Service explosives.*

1. The chief requirements of explosives for use on service are safety and simplicity in use and transport, and stability under climatic conditions. Explosives must be powerful, in order that the space taken up by a charge, and the weight and bulk of the explosive in transport, may be reduced to a minimum. For mine warfare it is of great importance that the products of explosion should be as free as possible from poisonous gases.

Gun-cotton.—This is the Service explosive for demolition purposes where cutting effect is required. It is carried by all engineer field units. Wet gun-cotton is issued in 15-oz. slabs, 6 by 3 by 1⅝ inches in size, provided with a tapered hole for the reception of a gun-cotton primer. The slabs are packed in a sealed copper tinned case enclosed within a wooden box; a case contains 14 slabs. The copper tinned case is fitted with a large screw plug and washer to enable the gun-cotton to be periodically examined when in store, and re-wetted if necessary.

For use of cavalry, each slab is packed separately in a sealed copper tinned case, and is called a field charge; 16 of these charges are contained in a wooden box.

1-lb. slabs of wet gun-cotton have now been introduced, and will be issued in place of 15-oz. slabs so soon as existing stocks of the latter have been expended. The 1-lb. slabs are 6 by 3 by 1½ inches in size, and are packed in boxes containing 14.

Ammonal.—An explosive less rapid than gun-cotton is required for mined charges. Ammonal is the Service explosive for this purpose, but other explosive mixtures of the same class may be supplied in its place. The Service ammonal, loosely filled in tins or other containers, weighs approximately 54 lbs. per cubic foot: it is issued in 25-lb. and 50-lb. tins.

Dynamite (or one of the blasting gelatines).—For blasting rock and similar work, a plastic and highly shattering explosive is generally required. Dynamite or one of the blasting gelatines fulfil these requirements, and are usually available for issue in the field for the purpose. They are supplied normally in 2-oz. cartridges wrapped in parchment paper, and packed in boxes weighing 5 lbs. and 50 lbs. when filled.

One of these three types of explosives, which are described in Chap. II, will satisfy the requirements of all ordinary demolition work to be carried out on active service; viz., gun-cotton for cutting and shattering effect, ammonal for lifting effect (mined charges), and dynamite where a plastic shattering explosive is required, as in blasting rock.

2. On active service, however, explosives of various natures may become available through means other than the normal source of supply. Explosive used locally in mines and quarries may be requisitioned, or that captured from the enemy may be utilized. In this connection the use of high explosive shell should not be overlooked. For many demolitions high explosive in this form is just as suitable as explosive in bulk; this is often a point of considerable importance when economy in bulk explosive is necessary. The tamping provided by the steel envelope is in many cases an advantage, and to the effect directly due to the detonation of the high explosive is added that caused by the flying splinters. The amount of explosive contained in a H.E. shell may be taken at approximately 10 per cent. of the total weight of the shell, but this figure varies considerably with different natures and calibres.

3. The explosives carried by engineer units in the field are as follows:—

(At present under consideration.)

The system of replenishment of explosives in the field is laid down in F.S.R., Vol. II (1920), Sec. **188**.

CHAPTER II.

EXPLOSIVES (DESCRIPTION).

9. *Preliminary remarks.*

Although only two or three kinds of explosives are normally issued in the Service for use in demolition and mining work, any of the explosives used commercially may become available on active service. It is, therefore, important that engineer officers should have a working knowledge of the more common explosives, a brief description of which is given in this chapter.

The following is a summary of the explosives mentioned, those in thick type being the most important of their particular group :—

Nitrate mixtures (Sec. 10).	Ammonium nitrate mixtures (Sec. 11).	Chlorate mixtures (Sec. 12).	Nitro-celluloses (Sec. 13).	Nitro-glycerine explosives (Sec. 14).	Coal-tar explosives (Sec. 15).
Black gunpowder. Blasting powder. Bobbinite.	Alumatol. **Amatol.** **Ammonal.** Bellite. Donarite. Roburite. Perdite. Sabulite. Securite. Westphalite.	Ajax powder. **Blastine.** **Cheddite.** Dynobel. **Permite.** Permonite.	Ballistite. Collodion cotton. **Cordite.** **Gun-cotton.** Tonite.	**Blasting gelatine.** Carbonite. **Dynamite No.1.** **Dynamite No.2.** Gelatine dynamite. **Gelignite.** Lithofractour.	**Picric acid (Melinite).** **Tetryl** or **C.E.** **Tri-nitro-toluene (T.N.T.** or **Trotyl).** Tri-nitro-anisol. Tri-nitro-cresol.

10. *Nitrate mixtures.*

1. Any one of the nitrates can be used as an oxygen supplier for an explosive mixture of the gunpowder class. Potassium nitrate is the best known and most used. Sodium nitrate is the main constituent of some blasting powders, but is very deliquescent. Barium nitrate is also used in some mixtures.

2. **Black gunpowder** has the following composition :—

	Parts.
Saltpetre (potassium nitrate)...	75
Sulphur	10
Charcoal	15

For centuries gunpowder was the only explosive known. It has now been entirely superseded as a propellant by smokeless powders of four to five times the power, while it would only be used in bulk for demolition purposes in the event of no other more suitable explosive being available. It still, however, has a variety of uses as an auxiliary, and thus remains a most important explosive.

Gunpowder is quite stable when kept dry, but is completely spoiled by moisture. It ignites readily, and burns with certainty and great regularity; these properties mainly cause its selection for the many purposes to which it is still put. In demolition work its principal use is as the core of safety fuze, but it may also be used in small charges where certainty of action is of more importance than power. Some of the more important of its other auxiliary uses are :—as an igniting primer to cordite cartridges (cordite, especially when in thick sticks, does not ignite readily, and a powerful flash is required); as a bursting charge for shrapnel; as a time fuze composition in shell fuzes. Gunpowder is still used in quarrying work where great lifting and absence of shattering effect is required.

The ease with which gunpowder can be ignited is a source of danger in storing and transporting. A spark caused by a blow on iron or steel will set it off, and special precautions must therefore be taken.

Blasting powder and **Bobbinite** are varieties of gunpowder, but still slower in action. They are used for blasting in coal mines and quarries.

11. *Ammonium nitrate mixtures.*

1. To this group belong a large number of high explosive mixtures with a low velocity of detonation (4,000 to 5,000 metres per second). Ammonium nitrate is an oxygen supplier, and it liberates this gas with the evolution of heat. It is thus a mild explosive in itself and can be detonated, but in practice it is never used alone. When, however, mixed with a high explosive deficient in oxygen such as tri-nitro-toluene (T.N.T.) a powerful explosive is formed. Most ammonium nitrate explosives consist of such mixtures, while to the more powerful types some combustible material is added, which by its oxidization produces a large amount of heat, thus increasing the power (*see* Sec. 7). They are mostly made in porous form, so that the gases from the detonation of the high explosive constituents can readily penetrate the mass. All are very insensitive to ordinary shock, and are difficult to explode by the application of a flame.

Ammonium nitrate is very deliquescent (*i.e.*, absorbs moisture from the air), and explosives containing it soon become useless when exposed to moist air. All ammonium nitrate explosives are, therefore, packed in hermetically sealed cases or waterproofed cartridges.

2. **Amatol** is a mixture of ammonium nitrate and T.N.T. in varying proportions, thus :—90/10, 80/20, 50/50, 40/60, the numerator expressing the proportion of nitrate. The mixtures with the higher proportion of ammonium nitrate make good lifting explosives, and are suitable for mined charges. Amatol composed of 80 parts ammonium nitrate and 20 parts T.N.T. has been found to give the most satisfactory results in demolition work. 80/20 amatol has a velocity of detonation of 5,000 metres per second. It is manufactured in powder form, and is yellow-brown in colour. Amatols with a high proportion of T.N.T. are used extensively as fillings for H.E. shells.

3. **Ammonal**, in its simplest form, consists of 80/20 amatol, with which a suitable proportion of powdered aluminium has been mixed. An explosive is produced which, owing to the heat given out by the oxidization of the aluminium, is considerably more powerful than amatol, and has at the same time a very low velocity of detonation (4,000 metres per second). It thus produces an excellent lifting effect, and for use in large mined charges stands unrivalled. The fact that ammonal is practically safe against detonation by impact from a rifle bullet, and that comparatively small quantities of poisonous gases are produced on detonation (a point of great importance in mine warfare, *see* Part II, Chap. XIV) are additional points in its favour.

Ammonal is about three times as powerful as black gunpowder. The following is a typical composition :—

	Parts.
Ammonium nitrate	68
T.N.T.	15
Powdered aluminium	17

In appearance ammonal is a grey composite powder. In common with all ammonium nitrate explosives, ammonal readily absorbs moisture, the presence of which greatly reduces its sensitiveness. Ammonal containing more than 8 per cent. of water will not, as a rule, detonate. Ammonal is liable to solidify in large lumps after long storage, in which condition its sensitiveness is reduced owing to the mixture being less porous. Such lumps should be broken up before the explosive is used.

Alumatol is similar in composition and appearance to ammonal, but is less powerful. It contains only 3 per cent. of powdered aluminium.

4. **Sabulite** is an explosive resembling ammonal, but calcium silicide takes the place of aluminium. The composition is as follows :—

	Parts.
Ammonium nitrate	78
T.N.T.	8
Calcium silicide	14

Sabulite is a grey powder in appearance. It is not quite as powerful as ammonal, but is more sensitive, and can be detonated by the impact of a rifle bullet. It is also less satisfactory than ammonal for use in mine warfare, as the products of detonation contain more carbon monoxide.

5. Numerous other ammonium nitrate mixtures of similar composition to those already given are used commercially and are known by fancy names. **Bellite** (83 parts ammonium nitrate, 17 parts di-nitro-toluene), **Roburite, Donarite, Perdite, Securite,** and **Westphalite** all belong to this class, and are used extensively for blasting in mines and quarries.

12. *Chlorate mixtures.*

1. This is another important group of explosive mixtures, in which a chlorate or perchlorate is the oxygen supplier. They are similar in composition and action to those of the ammonium nitrate group.

Plain chlorate mixtures are powerful but very sensitive, and can be exploded readily by percussion, friction, or contact with concentrated sulphuric acid. A composition consisting of potassium chlorate, antimony sulphide, and sulphur is used in percussion caps, friction tubes, and igniters. The sensitiveness of chlorate and perchlorate mixtures is greatly reduced by the addition of oils or fats, and such mixtures can then be used as bulk explosives. They are not, however, so safe to handle as explosives of the ammonium nitrate class, and all can be detonated by percussion or strong friction.

2. **Blastine** has been used extensively for mined charges. The following composition is typical :—

	Parts.
Ammonium perchlorate	60
Sodium nitrate	22
T.N.T.	11
Paraffin wax	7

The sodium nitrate is added to neutralize the hydrochloric acid fumes which would otherwise be formed on detonation.

Blastine is a yellowish-white, soft, granular substance, which can be easily compressed. This plasticity is of advantage in long bore-hole charges. It ignites easily, and burns fiercely with a hot flame. It has the same velocity of detonation as ammonal, and is nearly as powerful. The products of detonation contain highly irritant fumes and considerable quantities of carbon monoxide. Owing to this fact and to its sensitiveness to shock, it is not very suitable for use in mine warfare.

3. **Permite** is an ammonium perchlorate explosive in which increased power is obtained by the oxidation of powdered zinc, just as aluminium is used in the case of ammonal.

A typical permite has the following composition :—

	Parts.
Ammonium perchlorate	82
Powdered zinc	10
Vaseline	5
Asphaltum varnish	3

In appearance it is a grey-brown powder. It is more sensitive to percussion than blastine, to which it is about equal in power ; the rate of detonation is rather higher (about 5,000 metres per second).

4. **Cheddite** is brown in colour, rather similar to dynamite in appearance, but less plastic. It is usually prepared in cartridge form, and is used extensively for blasting in quarries. There are several varieties all similar in character. The following is a typical composition :—

	Parts.
Potassium chlorate	79
Di-nitro-toluene	15
Nitro-naphthalene	1
Castor oil	5

5. Potassium perchlorate, which is less sensitive than ammonium perchlorate and, therefore, safer to handle, is used in many similar mixtures, some of which contain a percentage of nitro-glycerine in addition. **Permonite, Dynobel,** and **Ajax powder** are examples.

13. *The nitro-celluloses.*

1. This group is of great importance for military purposes, both as a propellant and as a high explosive.

Cellulose, when acted upon by a mixture of nitric and sulphuric acids, is converted into a complex series of nitrates of cellulose, of which the higher nitrates are the more powerful explosives. The proportion of higher and lower nitrates formed can be controlled by adjusting the strength and temperature of the acids. Cotton is the best cellulose, but wood pulp is also used. The nitrated cellulose requires prolonged washing and purification to get rid of the surplus acid and to stabilize it.

All nitro-cellulose explosives, however highly compressed, burn so rapidly under the pressures produced in a closed space as ultimately to detonate. This action is due to their porous nature, and before they can be used as propellants they must be gelatinized. The ease or otherwise with which this process can be carried out is closely connected with the manufacture of the derived explosives. When thus treated, nitro-cellulose cannot be detonated by ignition, and burns regularly as a low explosive.

The three most important forms of nitro-cellulose produced are :—

Gun-cotton. The most highly nitrated form of nitro-cellulose, containing 13 per cent. of nitrogen. It is insoluble in alcohol-ether, and for this reason is sometimes known as *insoluble* nitro-cellulose. Gun-cotton is a powerful high explosive.

Highly nitrated "soluble" nitro-cellulose. This form consists in the main of the higher nitrates, but is soluble in alcohol-ether. It contains up to 12·5 per cent. of nitrogen, and is correspondingly weaker than gun-cotton. It is the principal constituent of all modern propellants, which comprise two main classes, nitro-cellulose powders and nitro-glycerine powders.

Collodion cotton. This consists principally of the lower nitrates, and contains only 11 per cent. of nitrogen. In addition to being very soluble in alcohol-ether it is also soluble in nitro-glycerine, and is chiefly used as an auxiliary explosive in the manufacture of blasting gelatine.

2. **Gun-cotton** is the most powerful form of nitro-cellulose. In the dry form* (as in the Service primer) it is highly inflammable, burning with a fierce hot flame, and can easily be detonated by percussion. For use as bulk explosive it is compressed into slabs and damped with 15 to 20 per cent. (by weight) of water. The addition of water renders it safer to handle and store, and increases the explosive effect. Wet gun-cotton is non-inflammable, and so stable under shock as not to be detonated by the impact of a rifle bullet.

Gun-cotton decomposes slowly, the rate of decomposition increasing with the temperature. It should, therefore, be stored in a cool place, and never exposed to the direct rays of the sun. Dry gun-cotton may explode spontaneously under the influence of strong sunlight. With careful storage, however, gun-cotton is a very stable explosive in all climates. Signs of acidity, or the presence of brown fumes, indicate advanced decomposition, when the gun-cotton becomes unsafe. In this state it also has a tendency to flake and crumble.

Gun-cotton is about as powerful as ammonal, but has a much higher velocity of detonation (about 7,300 metres per second), thus producing good shattering effect, while the slab form in which it is provided enables a charge to be easily and quickly fixed. It is thus well adapted for cutting demolitions, such as the destruction of steel-work. This fact, combined with its stability under shock, renders it eminently suitable for ordinary demolition work in the field.

Complete detonation of gun-cotton, if used in large mined charges, is not always certain, and its action is too rapid to produce a good lifting effect. The quantity of carbon monoxide formed on detonation is an additional objection to its use in mine warfare.

Tonite is a mixture of gun-cotton and potassium nitrate. It is used commercially as a blasting explosive.

3. **Nitro-cellulose powders** consist of highly nitrated soluble nitro-cellulose (with the addition of ½ per cent. of preservative) gelatinized by

---

* Gun-cotton is never absolutely dry; it is considered *dry* when it contains under 2 per cent. of moisture.

dissolving it in alcohol-ether. They are about 20 per cent. weaker than cordite and similar nitro-glycerine powders, and are suitable for use in small guns and rifles. In compressed form they can be detonated by fulminate of mercury and a gun-cotton primer, and used as a high explosive, but are less powerful than gun-cotton.

4. **Nitro-glycerine powders** are gelatinized mixtures of nitro-glycerine with some form of nitro-cellulose. A small quantity of some basic substance is added to act as a preservative.

Cordite M.D. is the standard Service propellant, and contains 65 per cent. gun-cotton, 30 per cent. nitro-glycerine, and 5 per cent. vaseline. Acetone is used as the common solvent or gelatinizer. A powerful and reliable propellant is thus produced by the incorporation of two sensitive high explosives. The difficulty of inducing satisfactory detonation in cordite is dealt with in Secs. **6** and **38.**

Ballistite is a similar nitro-glycerine powder, but contains a larger proportion of nitro-glycerine. It is still more powerful than cordite, but, for ordinary purposes, is not such a suitable propellant as the latter. The larger proportion of nitro-glycerine produces gases at higher temperatures than cordite, and these cause excessive erosion of the barrels of guns.

14. *Nitro-glycerine explosives.*

1. **Nitro-glycerine** is a slightly yellowish, oily, transparent liquid, made by the action of a mixture of nitric and sulphuric acids on glycerine. It has a velocity of detonation of 8,000 metres per second, and is the most shattering and the most powerful explosive in practical use. The liquid form, however, is inconvenient, and too sensitive to be handled with safety. It is, therefore, always incorporated with some solid substance, which enables it to be used in a convenient plastic form.

All explosives of this group require careful handling as they are detonated by strong shock, especially the blasting gelatines. They are easily ignited, and, though they burn quietly in small quantities, the ignition of a large mass is fairly certain to end in detonation.

Nitro-glycerine freezes at about 4° C. and forms crystals. In this condition it is very sensitive, but the crystals do not carry the detonating wave well, and with a large charge a great portion may be blown away and escape detonation altogether. This applies to all the nitro-glycerine explosives. All freeze at about 4° C., when they become very sensitive and uncertain in their action. They then require to be thawed before use, which is a serious disadvantage to their employment in cold climates. The method of thawing nitro-glycerine explosives is described in Sec. **39.**

Nitro-glycerine is very poisonous, and causes violent headache through mere contact with the skin: it is, therefore, advisable to wear gloves when handling explosives containing it.

Nitro-glycerine explosives are not so safe to handle or to store as wet gun-cotton, but, being plastic and of great power, they are specially suitable for use in small bore-holes and in narrow and irregular spaces where cutting effect is desired. They may be divided into two classes, dynamites and blasting gelatines.

2. The **dynamites.**—In this case the nitro-glycerine is absorbed in a porous solid. This base may be inert, as in **Dynamite No. 1**, which consists of 75 parts nitro-glycerine and 25 parts of Kieselguhr (a porous earth consisting mostly of silica); or it may be an explosive in itself, as in **Dynamite No. 2** (18 parts nitro-glycerine, 71 parts potassium nitrate, 10 parts charcoal, and 1 part paraffin wax). There are many other mixtures of a similar nature; they are all less powerful and slower in action than Dynamite No. 1. **Lithofractour** and **Carbonite** are examples. All the dynamites are disintegrated by water, which causes the nitro-glycerine to separate. In this state the explosives are highly dangerous to handle.

3. The **blasting gelatines.**—Blasting gelatine consists of about 6 per cent. of collodion cotton dissolved with the aid of heat in nitro-glycerine. A stiff jelly is formed which does not exude nitro-glycerine in contact with water. It is usually stored under water. It is about as powerful as, but much less sensitive than, pure nitro-glycerine, and comparatively safe to handle.

There are many mixtures in use containing blasting gelatine as their base, all milder in action than the latter, but very powerful. These are known generally as blasting gelatines, but are also described under some specific trade name according to their composition. Two of the most common blasting gelatines are described below.

Gelatine dynamite contains 80 per cent. of blasting gelatine, and the remainder is a mixture of potassium nitrate, collodion cotton, and wood meal. It is next in order of power to blasting gelatine.

Gelignite contains 60 per cent. of blasting gelatine, and the remainder as with gelatine dynamite. It is a very powerful shattering explosive.

The blasting gelatines are not perfectly stable, and decompose after long storage.

4. A convenient method of describing dynamites and blasting gelatines is to state the percentage of nitro-glycerine or pure blasting gelatine contained in the explosive. Thus, Dynamite No. 1 may be known as a 75 per cent. dynamite, and Gelignite as a 60 per cent. gelatine. Dynamites and gelatines of practically any required percentage may be obtained commercially.

15. *Coal-tar explosives.*

1. A large number of important high explosives are obtained by the nitration of certain of the coal-tar products. They are mainly used in the filling of high explosive shells, but are also important constituents of the ammonium nitrate and chlorate mixtures, while certain of them may be used alone for demolitions.

2. **Tetra-nitro-methyl-aniline,** or **Tetryl,** known in the Service as **C.E.** (composition exploding), is a very powerful explosive, and has a high velocity of detonation, over 7,000 metres per second. It is pale yellow in colour, and is normally manufactured ground into powder or corned. Tetryl is an excellent initiator of detonation, especially for explosives of the coal-tar group; it is used extensively in shells for this

purpose, and may sometimes be employed in compressed form as a primer, in place of dry gun-cotton, for the detonation of demolition charges.

3. **Tri-nitro-toluene,** or **T.N.T.,** sometimes also known in the Service as **Trotyl,** is a very powerful and rapid explosive. It has a velocity of detonation of about 7,000 metres per second. Besides being one of the main constituents of ammonal and certain other explosive mixtures, it may be used alone for demolition purposes. It has a light yellowish colour, and is manufactured either as a loose powder or in a solidified form. The former is easily detonated by mercury fulminate, but the latter requires in addition either a small priming charge of powdered T.N.T. or a tetryl primer. T.N.T. forms the core of Cordeau Detonant.

4. **Picric acid (Tri-nitro-phenol)** is used for demolition purposes in the French Army under the name of **Melinite.** It is a bright yellow substance, and is manufactured, like T.N.T., as a loose powder or in a solidified form, and may be detonated in a similar manner. Its action is about as rapid as T.N.T., but rather more powerful.

5. **Tri-nitro-cresol** and **Tri-nitro-anisol** are similar in action to picric acid.

There are numerous other coal-tar explosives, all of which are powerful and have a high rate of detonation.

NOTE.—For more detailed information on explosives the following text-books and papers may be referred to :—

"Explosives," by A. Marshall (Churchill, 1917. 2 vols.).

"Explosives," by V. Barnett (Bailliere, Tindall, and Cox, 1919).

"Military Explosives of To-day." Three lectures by Professor J. Young, O.B.E. (*R.E. Journal*, Vol. 28, July-December, 1918).

"Modern Explosives," by Professor J. Young, O.B.E. (*Transactions of the Society of Engineers*, 1919; also reprinted in pamphlet form).

"Short Notes on some Explosives," by Major W. A. J. O'Meara, C.M.G. (*R.E. Journal*, Vol. 23, January-June, 1916).

CHAPTER III.

METHODS OF FIRING.

16. *Preliminary remarks.*

The normal firing of all charges (or groups of charges) of high explosives* is produced primarily by ignition, by means of which a detonating impulse is set up through the medium of some sensitive substance, such as fulminate of mercury. The impulse must further be communicated to this substance after a sufficiently long interval of time, or from such a distance as to provide for the safety of the operator.

* The special case of gunpowder, a low explosive, is described in Chap. V, Sec. 38.

The principal methods of obtaining this are :—

i. By safety fuze (time).
ii. By cordeau detonant (distance).
iii. By electricity (distance).

Special methods of firing used in connection with land mines and traps, in the main modifications of the above methods, are described in Chap. VIII.

17. *Firing by safety fuze.*

1. The Service **Safety fuze No. 11** (Pl. 1, Fig. 1) consists of a column of fine gunpowder enclosed in a tube of braided flax. The flax is covered with gutta-percha protected by an exterior coat of varnished black tape. Safety fuze No. 11 is 0·21 inch in diameter, thus ensuring a good fit when inserted in the Service detonator. Earlier issues of safety fuze (**Safety fuze No. 9 and No. 10**) may also still be met with. They are similar to the safety fuze No. 11, but of larger diameter, and, therefore, require the black tape covering to be removed in order to fit the end into the detonator.

The specification for safety fuze lays down the rate of burning per yard at between 75 and 105 seconds, or about 2 feet per minute. This rate, however, is liable to vary considerably if the fuze is old. In hot climates safety fuze deteriorates very rapidly, and is seldom reliable after the tin has been opened six months. A batch of safety fuze should always be tested before use by timing the burning of a measured length. Safety fuze will burn under water, and has been known to do so at a depth of 90 feet after 24 hours' immersion.

Joints between two pieces of safety fuze should be avoided whenever possible; they are a source of weakness, and may easily be a cause of failure. If, however, a joint is unavoidable, the most satisfactory method is to cut a semi-circular nick (Pl. 1, Fig. 3) in each fuze about one inch from the end. The two pieces are then superimposed and bound together with a few diagonal turns of string (Pl. 1, Fig. 4). A joint exposed to damp may be bound with a few layers of rubber tape and solution after the manner described in Sec. **20** for electric cables. No joint is ever permissible in a length which has to remain a long time in position.

Safety fuze is issued in hermetically sealed tins containing 8, 24, or 50 fathoms.

2. The **No. 8 detonator, Mark VII** (Pl. 1, Fig. 5) is the fulminate container used in the Service when firing by safety fuze. It consists of a solid-drawn copper tube 2·2 inches in length and 0·23 inch in diameter. The lower end is closed, and 1·3 inches of the tube is filled with 2 grammes of fulminate of mercury composition, the rest of the tube being left open to receive the safety fuze. It is painted red, and bears on a small label the number and numeral of the detonator.

Detonators must be handled with care, and never left lying about. If dropped, they are liable to detonate from the shock. No attempt should be made to tamper with the fulminate of mercury. Pressure should never be put on the end containing the fulminate, and to bend it is extremely dangerous. Detonators should be stored separately from other explosives.

The detonators are packed in red tin cylinders containing 25.

No. 8 detonators are also issued already fitted with 2 feet of safety fuze for use by cavalry pioneers. They are packed in tin cylinders containing 6 fuzed detonators.

Commercial caps (Pl. **2**, Fig. 1) are the equivalent in civil life of the Service No. 8 detonator, to which they are similar. They are manufactured in ten standard sizes, Nos. 1 to 10, containing from 0·3 to 3 grammes of fulminate composition. Some manufacturers use the terms *triple, quadruple, quintuple, sextuple*, &c., to denote the strength of a cap, in place of numbers. Thus, a *triple* commercial cap is of the same strength as a No. 3. The No. 8 detonator corresponds in strength to the No. 8 commercial cap.

3. The **Service primer.**—The use of a primer to increase the initial detonating wave set up by the fulminate has already been explained in Sec. **5.**

The Service primer is made of dry gun-cotton (Sec. **13**) compressed into 1-oz. cylinders, slightly tapered and 1·35 inches in diameter at the larger end. A circular hole is provided in the centre of the cylinder for the reception of the detonator. The primer is dipped in acetone to gelatinize and proof the surface against moisture. Care must be taken that this waterproofing is intact if the primer is likely to be exposed to damp for any length of time. Cases of failure have occurred through neglect of this precaution, the dry gun-cotton having absorbed sufficient moisture from the air, or from the wet gun-cotton slab in which it has been placed, to render it insensitive to the detonation of the fulminate.

Service primers are packed in sealed tin cylinders containing 10 primers.

4. **Connecting up primer, detonator, and fuze.**

i. The safety fuze is cut to the length required to allow time to reach a place of safety after lighting. The end to be inserted in the detonator is cut straight across, and the other end on the slant so as to expose a larger surface of the core. If the fuze is not to be lighted at once, it is preferable not to sever the scarf-cut end right through (Pl. **1**, Fig. 2); it can then be closed up to prevent powder falling out until it is lighted.

ii. The straight-cut end of the fuze is then carefully inserted into the open end of the detonator, and pushed gently home until the end of the fuze is in contact with the fulminate composition. The detonator should be held by the open end, and with the closed end pointing away from the body. The open end of the detonator is then gently pinched on to the fuze to make it grip, and so prevent it being withdrawn. A pair of pliers may be used for this purpose, or, failing this tool, a jack-knife (Pl. **2**, Fig. 2). Care should be taken that no pressure is put on the closed end containing the fulminate.

iii. The primer should then be tested to receive the detonator. If the hole in the primer is found to be too small, it must be enlarged by means of a *rectifier* (a tool of hard wood, the size and shape of a detonator, made for the purpose). If this tool is not available, a pencil or any piece of hard wood carefully cut to the correct size may be used, but the use of an iron tool is dangerous. If the hole in the primer is found to be too large, paper should be wrapped round the detonator to make it fit firmly. On no account is force to be used to get the detonator into position; screwing or twisting is particularly dangerous.

5. **Lighting safety fuze.**—The simplest method is to use fusees or, failing these, matches. The match head should be held against the core of powder exposed at the end of the fuze (which has been cut on a slant), and ignited by rubbing the box on it.

Where rapidity in lighting the fuze is of importance, a special igniter may be used. The Service pattern, **Igniter, safety fuze, percussion,** consists of a large and a small brass tube secured together, the former containing a striker, spring, and cap (Pl. **2**, Fig. 3). The smaller tube receives the end of the safety fuze, which should be cut straight across. A pin, to which a string loop is attached, passes through the head of the striker projecting from the larger tube, and holds the spring in compression over the cap. The withdrawal of this pin releases the spring, which drives the striker forward, thus firing the cap and igniting the fuze. The igniters are packed 10 in a tin cylinder.

The igniters are easily damaged by damp, and should be stored in a dry place. They are not, therefore, so reliable as matches or fusees for ordinary work, and these latter are preferable where ample time is available to light the fuze.

If several fuzes have to be lighted in quick succession, a **port-fire** may be employed. It is an article of store, and consists of a stick of slow-burning composition with a wooden handle. It burns at the rate of 1 inch per minute. It can be lit with a match, and extinguished by a sharp blow against the boot.

18. *Firing by cordeau detonant.*

1. **Cordeau detonant** consists of a lead tube, 0·23 inch in diameter, filled with specially prepared T.N.T. It has a detonating velocity of 7,000 metres per second, and is employed as an instantaneous detonating fuze. Its principal uses are :—

i. To fire a number of charges simultaneously, when firing by fuze.
ii. To avoid excessive lengths of safety fuze, which would otherwise be required in certain demolitions (*e.g.*, mined charges).

Cordeau detonant may also be used occasionally in conjunction with electric firing to avoid complicated circuits and connections.

Cordeau detonant is quite safe to handle with ordinary care, but may be detonated by a severe blow. Being pliable, it can be bent in any required direction, but sharp bends and kinks must be avoided, as the continuity of the explosive may be broken and failure result from this cause. For the same reason it should not be subjected to any severe strain along its length.

Cordeau detonant may be used for demolitions under water, the metal covering rendering it waterproof. The core of T.N.T. deteriorates on exposure to air. Before using, therefore, about 6 inches of the open end should be cut off, and it is advisable to cap the end inserted in or fixed to charges with a No. 8 detonator, to which the cordeau detonant is connected up in the same way as safety fuze.

2. To use cordeau detonant it must be detonated; it will not detonate if ignited. The standard method of inducing detonation, using two primers and a No. 8 detonator with safety fuze, is shown on Pl. **3**, Fig. 1. An alternative method is to bind three No. 8 detonators firmly to the cordeau, safety fuze being inserted into one of the three (Pl. **3**, Fig. 2).

Cordeau detonant will not detonate wet gun-cotton without the aid of a dry gun-cotton primer, which, though generally not essential, should also be used when firing important charges of other high explosives. The cordeau may be simply passed through the hole in the primer, but close contact must be ensured by wedging with splinters of wood if necessary. Pl. **18**, Fig. 1, shows a method of firing simultaneously several charges of gun-cotton. In cases where it is not convenient to pass the cordeau through the primer, it may be lashed to it and to No. 8 detonators. Pl. **3**, Figs. 3 and 4, show two alternative methods. Wherever communication of detonation to gun-cotton primers is required, it is advisable to make free use of No. 8 detonators.

3. Junctions in cordeau detonant may be made by means of a junction box filled with ammonal or similar high explosive, into which the ends of the cordeau are led (Pl. **3**, Fig. 5). Each should be capped with a No. 8 detonator. A slab of gun-cotton, to which the ends of the cordeau detonant are tightly bound, may be used for the same purpose; the detonation of the slab by the incoming end of cordeau being effected through the medium of a gun-cotton primer as pointed out in para. 2.

Joints soon become defective owing to the deterioration of the core on exposure. They must, therefore, never be used when the fuze has to remain long in position.

The severe jerk set up in cordeau detonant on detonation tends to displace it. It should, therefore, be firmly secured at intervals throughout its length and, in particular, close to the charge. Lengths of cordeau in contact or close to each other should be separated by a board, as one may cut the other without detonating it, and thus cause failure.

The detonating wave of cordeau detonant has a tendency to die out in lengths of over 100 yards. Hence the intensity of detonation should be revived by introducing every 100 yards either a junction box of ammonal or two gun-cotton primers and a No. 8 detonator as shown on Pl. **3**, Fig. 1, the time fuze in this case being replaced by the incoming length of cordeau detonant.

19. *Causes of failure with safety fuze or cordeau detonant.*

i. **The safety fuze may be defective.** Parts of the fuze composition may have become inert owing to moisture getting through the cover, or by deterioration through age. The composition will burn as far as the faulty part, and then go out. This defect is very liable to lead to accidents, since the flax wrapping round the fuze composition may go on smouldering till it passes the fault, when the composition will begin to burn again. This smouldering is so extremely slow that the impression is produced that the fuze is entirely dead. Practically the only safeguard is to ensure that the safety fuze used is fresh and in good condition.

ii. **The end of the safety fuze may not be inserted far enough into the open end of the detonator.** As a result the flame from the fuze does not reach the fulminate, and fails to ignite it. To ensure that the end of the fuze is against the fulminate, the length of open tube should first be measured by gently poking a thin piece of stick or grass down it, and a corresponding length of safety fuze inserted. On no account, however, must force be used in pushing the safety fuze home.

It often happens, in the case of commercial caps, that a little of the sawdust, in which detonators of this form are usually packed, is left in the copper tube above the fulminate composition. It may be removed by placing the mouth of the cap near the lips and blowing across it.

iii. **The detonator may fail to detonate the primer owing either to bad contact between the detonator and the primer** (*see* **Sec. 17, para. 4**)**, or to a faulty primer.**

iv. **The composition at the exposed end of the fuze becoming inert owing to moisture.** This frequently occurs after long exposure, both with safety fuze and cordeau detonant. If a charge has to be left long in position, the exposed end of the fuze should be long enough to allow of 6 inches being cut off immediately before firing. Similarly, the connection between cordeau detonant and safety fuze should not be made until it is intended to fire.

v. **Defective joints in the safety fuze (Sec. 17) or the cordeau detonant (Sec. 18).**

The methods of dealing with miss-fires are laid down in Sec. **42.**

20. *Firing by electricity.*

1. Charges on service are fired electrically by means of electric detonators (electric fuzes for gunpowder charges)* connected up by insulated cable, the usual source of energy being the Service dynamo exploder.

In the following description it is assumed that the theory of continuous current electricity is understood.

2. The **Detonator, electric, No. 13, Mark III** (Pl. 4, Fig. 1) consists of a copper tube containing 2·8 grammes of fulminate of mercury. This tube is of the same diameter and similar to that of the No. 8 detonator, but is enlarged at its upper end to receive an ebonite plug. Two short copper leads, insulated with a rubber covering outside the detonator, are passed through the ebonite plug ¼ inch apart. The ends of the leads inside the detonator are connected together with a piece of fine iridio-platinum wire just above the fulminate of mercury. The fine wire is wrapped round with a piece of fleecy gun-cotton to facilitate the ignition of the fulminate.

On a current of sufficient strength (not less than 0·8 ampere) being passed through the copper leads, the fine wire is raised to a white heat and fuses, thus igniting the fleecy gun-cotton and the fulminate of mercury and causing the latter to detonate. It should be noted, however, that a smaller current (0·35 ampere or over) will cause the wire to glow, and may ignite the fulminate.

---

* In the following description of electric firing and apparatus remarks made concerning electric detonators apply, from an electrical point of view, with equal force to electric fuzes.

The head of the detonator is painted white, and the tube containing the fulminate of mercury red. The detonators are packed in tin cylinders containing 25 detonators and a rectifier. The upper halves of the cylinders are painted white and the lower red.

The remarks made in Sec. **17** with regard to the handling and storage of No. 8 detonators apply with equal force to No. 13 electric detonators.

The **Fuze, electric, No. 14, Mark III** (Pl. **4**, Fig. 2) is similar electrically to the No. 13 detonator, but in this case a cap is formed in the base of the ebonite plug for the reception of mealed powder which surrounds the iridio-platinum wire. As with the No. 13 detonator, the latter is wrapped in a small piece of fleecy gun-cotton to facilitate ignition. The base of the fuze is closed with a metal cap, and the whole is painted white.

The No. 14 electric fuze is used for igniting gunpowder charges, and is useless for detonating high explosives.

The electrical constants of the No. 13 detonator and No. 14 fuze are as follows :—

Material of bridge wire	Iridio-platinum.
Weight of bridge wire, per yard	·45 grains.
Length of bridge wire	·25 in.
Diameter of bridge wire	·0014 in.
Resistance—cold (*i.e.*, at about 60° Fahr.) ...	1·05 ohms.
,, —when just hot enough to start ignition	1·3 ,,
,, —at fusing point	2·6 ,,
Smallest current that can fire	·35 ampere.
,, ,, ,, ,, fuse	·8 ,,
,, firing current to be used in calculation	·8 ,,
Largest safe testing current when testing charges	·12 ,,
Testing for over-sensitiveness—	
Current to be used	·32 ,,
Duration of contact	4 seconds.
Resistance when current is passing	1·3 ohms.
Testing for under-sensitiveness—	
Current to be used	·45 ampere.
Duration of contact	4 seconds.
Resistance when current is passing	1·47 ohms.

It will be observed that the resistance of the bridge of iridio-platinum wire does not remain constant, but increases with the rise in temperature until the fusing point is reached, at which it is 2·6 ohms. In all calculations of firing circuits this fact must be taken into account.

Commercial electric detonators and fuzes may occasionally have to be used. They are constructed on similar lines to the Service pattern described above but are generally of rather rougher manufacture. A high tension type of electric detonator is also used in civil life. A spark-gap takes the place of a wire bridge. (*See* also Sec. **27**, para. 2.)

3. Insulated cables.—The cable specially designed for demolitions in the field, and normally available on service, is the **Cable, electric, E1,**

Mark II (Pl. 5, Fig. 1). It consists of one tinned steel and six tinned copper strands made into a single core covered with pure vulcanized india-rubber, and an exterior covering of braided hemp treated with preservative compound. It is issued in various lengths wound on wooden drums.

Any insulated cable, however, may be used provided that its conductivity resistance is not too great, and that the insulation is adequate. Certain of the cables used by the Signal Corps may be employed. Of these the **Wire, electric, S11, Mark III** (Pl. 5, Fig. 2), is specially suitable. Its covering is similar to the E1, Mark II, cable, with the addition of a layer of primed tape.

The constants of E1, Mark II and S11, Mark III, are as follows :—

Designation.	No. of strands in conductor.	Conductivity resistance per 100 yards.	Weight per 100 yards.
		Ohms.	Lbs.
E1, Mark II	6 tinned copper .... 1 steel	1·31	7·4
S11, Mark III....	3 tinned copper	1·37	7·4

Descriptions of other cables supplied in the Service will be found in the Priced Vocabulary of Stores, Part II, 1921.

Where it is desirable to afford special protection to the conductors, as, for instance, in important mined charges which are to be left in position for a long period, armoured cables may be used. Limited quantities of such cables may usually be obtained on active service from the Signal Corps.

Circuits.—Under normal conditions the circuit should be insulated throughout, cable being used for both the *out* and the *return* conductor (Pl. 5, Fig. 3). In emergency, however, an uninsulated conductor may be used for the return wire provided that the insulation of the *out* cable is perfectly sound (Pl. 5, Fig. 4).

Similarly, where old inferior cable has to be used, one main and the connections between the detonators should be composed entirely, if possible, of good cable; the bad leaky pieces being concentrated in the other main. A bad leak in one main will not affect the circuit provided the rest is well insulated.

On account of the high resistance of ordinary earths, earth returns (Pl. 5, Fig. 5) are not as a rule reliable, and are particularly unsuitable for use with an exploder. If shortage of cable, however, makes the use of an earth return necessary, every effort must be made to reduce its resistance to a minimum. The earth pipe employed in the field telegraph equipment makes a good earth, as also does a pointed iron pipe driven well into moist ground and filled with water. Salt water makes a good earth.

Though in any case a somewhat remote contingency, a firing circuit containing earths is more liable to be exploded by atmospheric discharges of electricity than one which is insulated throughout.

Jointing insulated cables.—The jointing of insulated cables is a most important operation, since a badly made joint may be the cause of failure. It should be carried out as follows. :—Strip off 2 inches of the insulation of each cable, open out the stranded ,wires and clean each thoroughly by scraping with the back of a knife ; take great care not to nick the wires in doing this. Cross the ends of the cables thus cleaned at right angles, as shown on Pl. **6**, Fig. 1, and bend them round each other, as shown on Pl. **6**, Figs. 2 and 3, making three or four complete close turns with each end. Cut off the spare ends, and pinch them close in with a pair of pliers (Pl. **6**, Fig. 4). Now cut off about 6 inches of india-rubber tape, and warm it by rubbing it between the hands. Then bind the rubber tape round the joint, as shown on Pl. **6**, Fig. 5 ; the tape should be stretched as it is applied. When the joint has been covered with one layer of tape, the rubber should be smeared with rubber solution, and the tape wrapped on in successive layers until used up, each layer being smeared with solution. No solution should be allowed to reach the bare wires of the cables. Pl. **6**, Fig. 6, shows the commencement of a three-way joint.

Defects in the insulation of cables may be dealt with in a similar manner. Rubber tape and solution form part of the contents of the *Box, testing and jointing,* carried by engineer field units, and described in Sec. **24**.

Where there is no danger of leakage of current occurring at the joint, and the circuit is to be used at once, the covering of the joint with rubber tape as described above may be omitted.

Additional insulation and protection to a joint can be quickly and effectively given by passing a piece of ⅜-inch india-rubber tubing over the end of one of the wires previously to making the joint, afterwards slipping the tubing over the completed joint and tying the ends tightly to the insulation of the wire or cable on each side with twine or fine wire. A piece of india-rubber tubing so secured is always a very good addition, and is specially useful when a joint is going into deep water, or is intended to last for many weeks. In a moderately dry situation, the rubber tubing may be used without the tape and solution in an emergency.

If neither india-rubber tape nor tubing is available, a fairly good insulating covering may be formed by slitting the insulation of a spare piece of wire longitudinally, removing it, applying two such pieces of sufficient length to the joint so as to overlap one another, and then binding them firmly together and to the covering of the jointed wire with twine or even fine wire from a strand of the spare cable.

It should always be remembered that the joint is the weak part of the circuit. A joint should, therefore, never be made at any point, such as the mouth of the bag containing the charge, where the wire is especially liable to be bent in handling.

4. The Service exploder, vocabularized as **Exploder, dynamo, electric quantity, Mark V** (Pl. **7**), consists essentially of a small series wound dynamo, of which *FF* are the field magnets, with pole pieces *PP* and the armature *M* revolving between them. The field magnets and armature are wound with insulated wire, and the armature is provided with a two part commutator, and caused to revolve by means of a pinion which engages with the rack *R*, but is provided with a free wheel arrangement

which ensures that the armature is only rotated on the downward stroke. The two field magnet coils are normally connected in series through the contact *K* (*see* diagram of connections).

The cycle of operation is as follows. The handle is first pulled up as far as it will go. On pushing down the handle the armature is caused to revolve, and thereby, owing to the residual magnetism in the field magnets, generates a current which still further excites them, until at the bottom of the stroke the maximum E.M.F. is developed. The contact at *K* is now broken by the end of the rack depressing the short-circuiting spring *S*, and the current flows through the external circuit *via* the terminals *TT*. It should be noted that the maximum effect has to be produced at the moment of breaking contact at *K*, and that the rack should be made to descend as swiftly and smoothly as possible.

The exploder is contained in a wooden box, 13 by 8 by 6 inches, painted white, and fitted with a lid that can be locked. A stout leather strap is attached, to enable the box to be slung over the shoulder. Its weight is about 25 lbs.

The power of an exploder is measured in terms of the number of ohms resistance through which it will fuse one detonator. The method of ascertaining this figure, and other tests for the Service exploder, are described in Sec. **26.** The Mark V exploder is designed to fuse through a resistance of 100 ohms. The lower marks of Service exploder, which may be occasionally met with, are similar but less powerful. The Mark IV is designed to fuse through 80 ohms, and the Mark I through 60 ohms.

Various other types of exploder are in use. In the German army an exploder operated by clockwork instead of by hand is employed. By this means the personal factor, present in the Service exploder, is eliminated. It is about as powerful as the latter, but, owing to its electrical construction, it can only be safely used for firing single charges. Exploders designed on the same principle are also used commercially.

Pl. **11**, Fig. 1, shows a method by which two Service exploders may be coupled together in series, where a single exploder is not sufficiently powerful. The two exploders are fired together by a common handle. Both armatures, and all the field windings, are joined in series through one only of the contacts K, so that the common circuit is broken in only one place at the end of the downward stroke of the handle. In order to avoid the loss of energy expended in the spark that would otherwise be formed on break at the contact K, a condenser C is added. Such a combination of two Mark V Service exploders has been found to fuse through a resistance of 180 ohms.

For electrical reasons, the explanation of which is outside the scope of this volume, electric detonators should be connected up in series when they are to be fired by an exploder.

5. **Connecting up and firing.**—Before the circuit is connected up the detonators and cables to be used must be tested (*see* Chap. IV). Further, the resistance of the circuit must be calculated (Sec. **29**) in order to ascertain that the exploder is sufficiently powerful to fire the detonators of the circuit.

These preliminaries having been satisfactorily completed, the following are the steps to be taken :—

i. The detonators, previously tested (*see* Sec. **27**), are placed in the charge, and connected up in series with short lengths of cable. The precautions laid down in Sec. **17**, para. 4 (iii) as to fitting the detonators into the primers must be observed.

ii. The cables, previously tested (*see* Sec. **28**), are laid out from the charge to the selected firing point. The ends of the cables at the firing point should be placed in charge of a N.C.O., and the exploder box kept locked.

iii. The cable ends at the charge are now connected up to the two ends of the circuit containing the detonators.

iv. The whole circuit is now tested (*see* Sec. **29**).

v. The exploder box is unlocked, the handle raised, and the ends of the cables made fast to the exploder terminals. The connections should not be made until *after* the handle has been pulled up.

vi. To fire the charge the handle is pushed down swiftly and smoothly.

21. *Causes of failure with electrical firing.*

The following are the chief causes of failure when firing by electricity.

i. **Broken leads.**—The existence of a break in one of the cables of a firing circuit would normally be detected by testing prior to firing (*see* Secs. **28** and **29**).

The break, however, may occur after the circuit has been connected up and tested. The cables should not be subjected to undue strain at any part of the circuit, especially at joints. Special attention must be paid to this point where cables pass through tamping or round corners. Leads exposed to shell or rifle fire should, if possible, be buried : 2 feet of earth is adequate protection against bullets and small shell splinters, and 7 feet against shell fire.

ii. **A defective joint or partly broken cable in a circuit,** causing a high resistance, and thus preventing the flow of sufficient current to fire the detonators. The necessity of exercising care in making joints cannot be overestimated. The methods of detecting a defect of this nature are described in Sec. **29**.

iii. **Bad insulation of cable or joints causing a short circuit.**—It should be noted that this type of fault can only occur when there is a leakage in both the *out* and *return* leads. The method of detecting a short circuit is described in Sec. **29**.

iv. **Faulty exploder** (Sec. **26**).

v. **Defective detonator.**—The bridge of iridio-platinum wire may be broken. This, however, would be detected at once by the *continuity* test (Sec. **25**). Detonators may, although intact, be a cause of failure through being over or under-sensitive. This defect is discussed in detail in Sec. **27**.

vi. **Failure of the detonator to detonate the primer.**

22. *Comparison of the relative merits of the methods of firing.*

1. The choice of the means of firing a charge depends on many factors. The time available for preparation and firing, the degree of exposure to hostile fire, the length of time that the charge is likely to remain in position, and the apparatus available must all be considered.

Safety fuze, on account of the simplicity and portability of the firing arrangements, and the absence of special apparatus, is generally preferable for hasty demolitions,* and is practically exclusively used for mobile charges. For the same reasons, it is the normal method employed for firing a series of small and scattered charges, as, for instance, in the destruction of railway lines. The absence of long lengths, liable to be cut by shell fire, makes it valuable for use in exposed situations. In spite of the drawbacks of deterioration through moisture and the impossibility of periodical testing, its employment, either alone or in conjunction with cordeau detonant, will be necessary in the large majority of deferred demolitions, since, under the conditions likely to prevail at the time of firing, apparatus for electric firing will only be available for a few of the most important charges.

Cordeau detonant may be employed with advantage in place of safety fuze in mined charges, both for deliberate and deferred demolitions, and generally where an undue length of safety fuze must otherwise be used. It is the only substitute for electricity for the simultaneous firing of multiple charges.

Electricity normally provides the best and surest means of firing important deliberate or deferred demolitions, but the vulnerability of the leads is a serious disadvantage in situations exposed to shell fire. It possesses the advantages of enabling a charge to be fired from any selected spot, however distant, and at the precise instant desired. Though the material and apparatus employed are more complicated and liable to defects, the possibility of testing from a distance up to the time of firing does away with any uncertainty as to the condition of the entire circuit. It is specially suitable for the simultaneous firing of multiple charges.

2. Whatever method of firing is adopted, every important charge should be provided with two distinct sets of ignition. In many cases both electricity and fuze may be advantageously employed, keeping the latter as a stand-by in case of the breakdown of the electric firing arrangements.

CHAPTER IV.

TESTING ELECTRIC FIRING CIRCUITS, USE OF CELLS, &c.

23. *Nature of electrical tests.*

Testing in electric firing is of first importance, but, for ordinary work with reliable materials and exploder, need not be of an elaborate nature. It is normally sufficient to submit the detonators, cables, and finally the

* Definitions of the terms *hasty*, *deliberate*, and *deferred* demolitions, are given in Sec. 52, para. 3.

completed circuit to the continuity test described in Sec. **25**. This test, however, must be regarded as essential and, if the apparatus is not to hand or the time not available to carry it out, it is, as a rule, preferable to resort to firing by safety fuze. On the other hand, for very important charges, or when there is reason to doubt the reliability of the materials, tests of a more detailed and quantitative nature must be performed.

These tests may be divided into :—

i. Testing the exploder (Sec. **26**).

ii. Testing the detonators (Sec. **27**).

iii. Testing the cables and earths, in cases where an earth return is used (Sec. **28**).

iv. Testing the completed circuit when all is ready for firing (Sec. **29**).

24. *The testing and jointing box.*

1. The **Box, testing and jointing,** is an article of store which is carried by all engineer field units.

It is a tin box in a leather cover, measuring 14 by 8 by 5½ ins. outside, and holds all materials, instruments, and tools for testing and jointing electric firing circuits. Its weight is 12 lbs. 3 ozs.

The contents are as follows :—

For testing—

1 box of resistance coils (100 ohms).
1 "Q" and "I" detector.
1 cell, electric, dry, "E."
2 reels (metal) with X48 0·0016-in. iridio-platinum wire (4 dwts.).
1 chamois leather.
1 box of plate powder.

For jointing (*see* Sec. **20**)—

1 pair 5-in. side-cutting pliers.
2 tubes of india-rubber solution.
4 cylinders of india-rubber tape.
½ lb. of cotton waste.

☛ 2. The **box of resistance coils** (Pls. **9** and **10**), vocabularized as **Coils, resistance, 100 ohms, Mark V,** can be used either as a variable resistance (*e.g.*, in the testing of an exploder) or to form a Wheatstone bridge. The coils are made of thicker wire than ordinary resistance coils, in order that they may not be damaged by the comparatively large currents they are called upon to carry. The resistances, which are inserted in the circuit by withdrawing the plugs, are graduated from ·05 ohm to 40 ohms, and so arranged that any multiple of ·05 ohm up to 100 ohms can be obtained. Two additional 10-ohm coils and a contact key are provided, so that the box may be used as a Wheatstone bridge. If required, these two coils can also be used to form part of the variable resistance in other tests. The box is also provided with a pair of clips, ½ in. apart, for holding the iridio-platinum wire in the fusion test (Sec. **25**, para. 4), and three pillars for the reception of reels of iridio-platinum wire.

When the plugs are inserted, they should be given a slight twist to ensure that a good contact is made. Cleanliness of the plugs and contacts is also of the first importance, especially when measuring small resistances. The chamois leather and plate powder contained in the testing and jointing box are provided with this object.

Earlier Marks of **Coils, resistance, 100 ohms,** may be met with; they differ from the Mark V in the following respects :—

Mark IV.—Firing clips of different design.

Mark III.—Firing clips of different design. Different material used for the resistance coils. The two additional 10-ohm coils can only be used in the Wheatstone bridge, as they are made of fine wire, which would be damaged by heavy currents such as might be passed through them in the fusion test. No pillars are provided for the reception of spare reels of iridio-platinum wire.

Marks I and II.—As in Mark III, but in addition, a wandering plug is used for the resistances under 1 ohm, which are made up of 20 coils, each of $\frac{1}{20}$ ohm.

3. The **"Q" and "I" detector** (Pl. 8, Fig. 1), vocabularized as **Detector, quantity and intensity,** is similar in action to a galvanometer, the passage of a current being indicated by the deflection of the needle on the dial. It has two coils and three terminals. Each coil is connected with one of the outer terminals and with the centre terminal (Pl. 8, Fig. 2), the space between the terminals of one coil being marked with a "Q," signifying quantity, and of the other coil with an "I," signifying intensity. The "Q" coil consists of a few turns of thick wire with a resistance of 0·2 ohm; the "I" coil consists of numerous turns of thin wire with a resistance of 100 ohms. To detect a current in a circuit having a low resistance, the "Q" coil should be used; where the resistance is high, the "I" coil. For testing in electric firing, the "I" coil is normally the more suitable.

An improvised detector may be made with a box compass. Several turns of cable are taken round the middle of the box, which is placed so that the magnetized needle and the coils are in the magnetic meridian. On a current being passed through the cable, the needle will be deflected. Such an improvisation is an efficient substitute for the "Q" and "I" detector in the continuity test, but it is not sufficiently sensitive for use with the Wheatstone bridge.

4. The **test cell** (Pl. 8, Fig. 3), vocabularized as **Cell, electric, dry, E,** is a special form of dry Leclanché cell, provided with a resistance coil (Pl. 8, Fig. 4) which brings the total internal resistance up to about 12 ohms, thus ensuring that it will under no circumstances send out sufficient current to fire a detonator. Its E.M.F. is 1·5 volts.

To ascertain that a test cell is safe to use, it should be connected up through a key to a detonator placed in a safety box (an iron box constructed to contain the detonator and localize the effect on explosion) or under a sod of earth, so that if it fires it may do no harm. When the key is depressed for at least 4 seconds, the detonator should not fire.

The use for testing purposes of a cell which furnishes a larger current than a test cell is highly dangerous. If no test cell is available, any type of Leclanché cell with 12 ohms resistance added may be used instead, the safety of the combination beiug tested as described above.

5. The **Iridio-platinum wire** is of exactly the same composition and diameter as that used in the construction of the Service fuzes and detonators. Its diameter is 0·0016 inch, and the weight per yard 0·45 grain. It is issued on metal reels containing about 2 dwts., *i.e.*, 48 grains.

This wire is known in the Service as **Wire, electric, X48 iridio-platinum**. It is expensive material, and economy should, therefore, be exercised in its use.

25. *Description of the principal tests.*

1. The following are the principal tests which may be carried out with the testing and jointing box :—

i. Continuity test.
ii. Wheatstone bridge test.
iii. Fusion test.

2. The **continuity test** provides a means of ascertaining that no break exists in a detonator, length of cable, or completed firing circuit. It consists in sending through the conductor to be tested a current not large enough to fire a detonator, but sufficient to deflect the needle of a detector placed in the circuit. The test cell and " Q " and " I " detector are connected up in series to the conductor to be tested (Pl. **9**, Fig. 1). In testing detonators and firing circuits containing them the " I " coil should invariably be used. On the circuit being closed, the detector should give a deflection, thus showing that the circuit is complete. By this test the *continuity* of a detonator, series of detonators, lengths of cable, or a completed firing circuit may be verified, but it should be noted that only a complete disconnection or break will be detected. A deflection will still be given by the detector when a short circuit, partial break, or bad joint exists (but *see* Sec. **29**, para. 3).

3. The **Wheatstone bridge test** provides a means of measuring the electrical resistance of a detonator, length of cable, or completed firing circuit. It consists in connecting up the box of resistance coils, " Q " and " I " detector, and test cell to form a Wheatstone bridge, as shown on Pl. **9**, Figs. 2 and 3. The conductor, the resistance of which is to be measured, is then balanced on the bridge in the usual manner, the variable resistance being adjusted until the detector gives no deflection when the contact key is depressed. When thus balanced, the resistance of the conductor will be equal to the variable resistance inserted.

The " Q " and " I " detector, however, is by no means a sensitive instrument. It will, thus, usually be necessary to ascertain the limits between which no deflection is obtained. The resistance under test can then be taken as equal to the resistance midway between these two points.

4. The **fusion test** provides a means of measuring the power of the firing apparatus, normally the Service exploder. It consists in determining the maximum resistance through which the firing apparatus will *fuse* with certainty the bridge of a No. 13 detonator. The box of resistance coils and lengths of iridio-platinum wire are required for the test. The iridio-platinum wire is placed between the clips provided for the purpose on the box of resistance coils. As the jaws of the clips are ½ inch apart,

the bridge thus formed is identical with that in a No. 13 detonator. The connections for this test are as shown on Pl. **10**, Fig. 1. The firing apparatus is first tested against a low resistance, and this resistance is gradually increased until the wire fails to fuse. The maximum resistance through which it will fuse the wire is thus ascertained.

26. *Testing the Service exploder.*

1. The power of a Service exploder should be ascertained by the fusion test on receipt from store, and a record made of the result. Subsequent tests should be made whenever there is reason to suspect a decrease in power. It is unnecessary, however, to carry out the fusion test every time the exploder is used for ordinary demolition work.

A certain amount of practice and manual dexterity is required to get the best results out of an exploder, but with a skilful operator an exploder may sometimes be made to fuse through a resistance in excess of the maximum resistance for which it was designed.

In order to allow a good margin of safety, an exploder should not be required to fire detonators through a circuit the total resistance of which is more than 80 per cent. of the figure obtained for the exploder by the fusion test. Thus, an exploder which has been found by testing to fuse through a maximum resistance of 105 ohms can be relied on to fire detonators with certainty in all circuits the total resistance of which does not exceed 84 ohms.

If no iridio-platinum wire is available for the fusion test, an exploder may be considered sufficiently powerful if it is able to fire a detonator through a resistance at least 90 per cent. greater than the estimated resistance of the firing circuit at fusing point.

A very rough test to ascertain that the exploder is in working order, when the apparatus for the fusion test is not available, is to connect up a detonator to an exploder and fire it. The detonator should be placed in a safety box or under a sod of earth, so that it may do no harm when fired.

2. The following are the principal causes of defect in an exploder, and the methods of remedy :—

- i. **Bad contact of brushes on the commutator of dynamo.**—The brushes should be adjusted to bear evenly on the commutator, and both brushes and commutator should be clean.
- ii. **Commutator segments short-circuited by fragments of detached copper.**—The spaces between the segments should be kept clear of metallic dust.
- iii. **Loose or broken connections.**—These should be made good, but, if the fault is in the windings of the electro-magnet or armature, the machine must be returned to store for repair.
- iv. **Dirty contact at K** (Pl. **7**).—The contact should be cleaned by passing a piece of clean paper between the contacts; on no account should an abrasive substance be used for the purpose.
- v. **Defective break of the contact at K at the bottom of the stroke.**—The break should be very sharp, and the contacts should then be separated sufficiently to prevent an arc being

formed across them. The contact spring S should be adjusted, and it may sometimes be advisable to remove the rubber pad under the short contact piece.

vi. **Want of residual magnetism.**—The rack R (Pl. 7) should be forced down to the full extent in order to break the contact at K. The terminals of the exploder should then be connected to a battery of three or four cells for a few minutes. The field magnets will thus be re-magnetized. Care should be taken that the rack is forced down before the circuit is completed, or the battery will be short-circuited.

vii. **Defective insulation of field or armature windings.**—In this case the machine must be returned to store for repair.

To locate the fault in a defective exploder, the side of the exploder box should be removed by unscrewing the screws holding it in position, thus throwing the mechanism and connections open to inspection. The terminals should then be short-circuited, and the handle raised and depressed as in the act of firing. There should be a distinct opposition to the down stroke, and the armature should pull up when it is completed. If this is not the case, a fault in the internal circuit of the exploder is indicated. The connections should be traced out, and a visual examination made for any of the defects described in (i) to (iv) above. Suspected breaks in the windings may be verified by the continuity test. If these measures fail to locate the fault, the resistance between the exploder terminals should be measured on the Wheatstone bridge. This resistance should be nil, except when the handle is pressed hard down. It should then be 6 to 9 ohms (2 to 5 ohms for the armature and 2 ohms for each magnet coil).

If the internal circuit of the exploder is found to be in order, the contact spring S should be examined for the defects stated in (v) above. A spark should be seen between the contact places at K at the moment of break.

A general loss of power is symptomatic of loss of residual magnetism, and, if no defect is detected in the mechanism or connections of the exploder, it may be attributed to this cause. The remedy described in (vi) should be applied.

It is, as a rule, only possible to trace the cause of failure to defective insulation of field or armature windings by eliminating other sources of defect. The tests to determine the insulation resistance of windings are too elaborate for use in the field, and their description is outside the scope of this volume.

27. *Testing detonators.*

1. Detonators when being tested should be placed in a safety box, so that, should a current sufficient to fire inadvertently be sent through them, no harm will result.

For ordinary work it is sufficient to ascertain that the detonator is intact by subjecting it to the continuity test. In carrying out this test, the " I " coil of the detector should invariably be used (Sec. **25**, para. 2).

The possibility, however, of a detonator being over or under-sensitive cannot be overlooked in important demolitions, where several detonators are connected up in series. An over-sensitive detonator may fire and break the circuit before sufficient heat has been generated in the remaining detonators to fire them. As a result, only the over-sensitive detonator will explode. Similarly, an under-sensitive detonator may not be raised to ignition point before the remaining detonators in the circuit have been fired. For very important charges, therefore, the resistance of each detonator should be measured by the Wheatstone bridge test, and detonators varying 10 per cent. from the correct resistance (1·05 ohms) should be rejected. This test will eliminate with a fair degree of certainty detonators in which the bridges are considerably over or under-sensitive.

The sensitiveness of a detonator, however, is not only dependent on the resistance of the bridge, but also on the temperature at which the surrounding composition ignites and the nature of the bridge contacts. The following test has, therefore, been laid down for a batch of No. 13 detonators. They should not fire in four seconds with a current of 0·32 ampere, but should fire within the same period with a current of 0·45 ampere. All the detonators of a batch may be submitted to the first test, and a few to the second. If, in the latter test, they fail to fire, the whole batch should be rejected. The above test, however, must be regarded as a laboratory one, and it would seldom be possible or necessary to carry it out in the field.

It will be observed that, in the case of a number of detonators in series, if the current is of such strength that it requires several seconds for sufficient heat to be generated in the bridges of the detonators, the most sensitive detonator will fire first, and, in so doing, will probably cause the circuit to be broken at that point, thereby preventing the firing of the remainder of the series. To avoid this, it is necessary that the current passing in the circuit shall be considerably greater than that required to fire only. It is for this reason principally that the current to be used in calculations is that required to fuse the bridge wire; if the actual current is greater than this, no harm is done, and the chance of an under-sensitive fuze failing to fire is still further reduced. Experience has shown that, when the current is not less than the fusing current, firing takes place practically instantaneously in all the detonators of the series, and small variations in the sensitiveness of the detonators have no effect.

2. Great care is taken in the manufacture of No. 13 detonators to attain uniformity of behaviour; nevertheless, small variations in sensitiveness do occur. The composition becomes less sensitive with time, and there are unavoidable minute differences in the bridge itself. Provided, however, that the minimum fusing current (·8 ampere) is the least current used for firing, the No. 13 detonator is very reliable.

Where several detonators are to be fired in series in important charges, it is desirable that all should be from the same box or batch, in order to minimize the chance of variation in sensitiveness. Under no circumstances should electric detonators of types other than the No. 13 detonator (*e.g.*, commercial electric detonators) be used in the same circuit with No. 13 detonators. High tension electric detonators (Sec. **20**, para. 2) cannot be tested for continuity; they must be fired in parallel when more than one is used in a circuit.

Tests for the No. 14 electric fuze are identical to those for the No. 13 electric detonator.

28. *Testing cables and earths.*

For ordinary work with reliable cable the continuity test is normally sufficient. In all cases, however, cable should be subjected to a careful (though perhaps necessarily rapid) visual examination whilst being paid out, with a view to discovering sharp kinks, bare places, and sometimes partial fractures of the conductor and bad joints. Doubtful-looking joints should be cut out and remade. Rough electrical testing often fails to show up such *faults*. On the other hand, careful electrical testing will generally detect defects which are not visible to the eye. For very important work the resistance of the cables should be determined by balancing them on the Wheatstone bridge. The result obtained should be compared with the resistance determined by calculation on the basis of the specified resistance per 100 yards ; in the case of E1, Mark II cable, 1·31 ohms.

The position of a bad leak in a cable may be ascertained by connecting it up as shown on Pl. 10, Fig. 2, and passing it through a tank containing water.

The resistance of an earth return, in the rare cases in which it is necessary to use one in a firing circuit, may be measured by the fusion test as follows. First ascertain through what resistance the firing apparatus will fuse the standard iridio-platinum bridge on short circuit (the ordinary fusion test). Say this is found to be W ohms. Then carry out the fusion test as before, but include the earth return in the circuit. Say the figure then arrived at is W_1 ohms. Then the resistance of the earth return to be included in the calculations will be $W - W_1$ ohms.

A clean metal plate, 4 inches by 8 inches, immersed in the sea, or water of equivalent salinity, has a resistance of about 1 ohm, but in ordinary earth it may have a resistance of 40 ohms or more.

29. *Testing the complete firing circuit.*

1. Before testing the firing circuit it is in all cases necessary to ascertain that its resistance at fusing point is not beyond the power of the firing apparatus. This is calculated from the specified resistance of each detonator at fusing point (2·6 ohms per No. 13 detonator) and of the cable (1·31 ohms per 100 yards for E1, Mark II cable).

If the total resistance thus estimated does not exceed 80 per cent. of the figure obtained in testing the firing apparatus, the latter can be relied on to fire the detonators in the circuit. If the total resistance of the circuit exceeds this limit, it must be reduced by using cables of lower resistance, or doubling them, or by using a smaller number of detonators.

Example.—It is required to fire 15 charges simultaneously in a circuit with total length of E1, Mark II cable of 2,000 yards. It is proposed to use two detonators per charge. The exploder has been tested and found to fuse through a resistance of 90 ohms.

Hence, the exploder can be relied on to fire detonators in a circuit the total resistance of which does not exceed $90 \times \frac{80}{100}$ ohms $= 72$ ohms.

Resistance of cables ... ... $= \frac{1 \cdot 31 \times 2{,}000}{100}$

$= 26 \cdot 2$ ohms.

Resistance of detonators ... ... $= 2 \cdot 6 \times 15 \times 2$

$= 78$ ohms.

∴ Total resistance ... ... $= 104 \cdot 2$ ohms, which is too great for the exploder. One detonator per charge may be, however, considered sufficient, when the resistance can be reduced accordingly. It then will be 15 × 2·6 ohms (detonators) + 26·2 ohms (cable) = 65·2 ohms, which is well within the power of the exploder.

2. For the actual testing of the firing circuit in all ordinary work, the continuity test is sufficient. A break in the circuit may be located by testing various portions of the firing circuit separately for continuity.

For demolitions of special importance, however, the Wheatstone bridge test should be used, and the *cold* resistance of the firing circuit measured by this means. This result should be compared with the theoretical *cold* resistance of the firing circuit obtained by calculation on the lines described in para. 1. It should be borne in mind that for this calculation the *cold* resistance of the detonators must be taken (1·05 ohms per No. 13 detonator).

A considerable excess of the measured resistance over the calculated resistance probably indicates a bad joint or partial break. The reverse indicates a short-circuit in some portion of the circuit. If a steady reading for the measured resistance is difficult to obtain, there is probably a loose connection somewhere.

To locate a fault other than a break may require much time and considerable electrical skill. The resistance of each portion of the circuit should be ascertained separately and compared with the calculated resistance for that portion. When spare cable is available, the quickest remedy is to substitute fresh cables for the faulty ones.

3. The circuit of an important demolition, the firing of which is likely to be delayed for some days, should be tested for continuity daily *with the same test cell and detector*. A diminution of the deflection will then indicate an increase of the resistance of the circuit, pointing to a faulty joint or partial break. Similarly, an increased deflection will mean a reduced resistance and the probability of a short-circuit having been formed somewhere between the firing point and the charge.

It is pointed out, however, that only comparatively large variations of resistance will be indicated by the "Q" and "I" detector.

30. *Other sources of electric energy.*

1. While the standard electric firing apparatus is the Service exploder, other sources of electric energy may be utilized.

In emergency the magneto of a motor car or cycle may be used for firing. The leads to one of the sparking plugs should be disconnected and jointed to one end of the circuit, the other end of the circuit being connected to the frame of the car or cycle. Even if the bridge of one of the detonators in the firing circuit be broken, the magneto may sometimes be used with success, since the high voltage current may jump the gap, and the spark so formed fire the detonator.

For firing circuits of exceptional size and importance, the current may be furnished by a dynamo, or from power mains, if facilities for their use exist. In such cases it is, as a rule, advisable to obtain the services of an expert electrician.

2. **Firing batteries** of electric cells are, however, the most important substitute for an exploder.

The **inert cell,** owing to its portability, is a most suitable pattern for the purpose. Chemically its action is practically the same as the Leclanché cell. Any of the four sizes supplied in the Service, and used chiefly for portable telephone and field telegraph sets, may be employed to make up a firing battery. They are vocabularized as **Cells, electric, inert, A, O, P, and S.** Their sizes and electrical constants are as follows :—

Designation.	Dimensions.		E.M.F. (volts).	Internal resistance (ohms).	Weight.	
	Height overall.	Sides.				
	Inches.	Inches.			lbs.	ozs.
A	$8\frac{3}{4}$	$5\frac{1}{2} \times 2\frac{3}{4}$	1·53	0·10	6	$0\frac{1}{2}$
O	$6\frac{1}{2}$	$2\frac{13}{16} \times 2\frac{13}{16}$	1·53	0·22	2	12
P, Mark I	$5\frac{15}{16}$	$2\frac{1}{4} \times 2\frac{1}{4}$	1·53	0 22	1	11
S	$4\frac{1}{2}$	$1\frac{1}{2} \times 1\frac{1}{2}$	1·53	0·30	0	8

The section shown on Pl. **11**, Fig. **2**, is typical of all four sizes. Such cells when issued are absolutely inert (the excitant being composed of a dry powder), and will remain so until water has been added. They can be stored in a dry state for a considerable period without deteriorating. They should be filled with water (charged), in accordance with the instructions printed on them, about 10 hours before they are required for use, when they can be treated as ordinary *dry* cells. When charged the label on the cell should be dated. The cells should be kept as dry as possible, and placed upright on a dry surface. Particular care must be taken not to allow any liquid or *creeping* near the terminals. The corresponding patterns of ordinary dry cell, if new and in good condition, may also be used for firing batteries.

The **secondary cell or accumulator** offers great advantages in that its E.M.F. is high (2 volts when charged) and its internal resistance is so small as to be negligible. It will frequently be available in the form of portable 2-cell (4-volt), 3-cell (6-volt), and 6-cell (12-volt) accumulators.

The **batteries of the Service electric hand torch** may be used for firing in emergency. They consist of three small dry Leclanché cells connected up in series. Each, when new, has an E.M.F. of 1·5 volts and an internal resistance of 0·4 ohm. Two such 3-cell batteries connected up in series are sufficient to fire 2 detonators (in series) through 250 yards of El, Mark II cable.

3. Given the E.M.F. and internal resistance of the cells to be used, the number required to make up a firing battery for any given circuit may be determined by calculation (Ohm's law, *i.e.*, current $= \frac{\text{Total E.M.F.}}{\text{Total resistance}}$); the problem presented is that of sending a current of at least 0·9 ampere through all detonators in the circuit.

A rough rule to determine the number of Leclanché cells for a firing circuit with all detonators in series is to allow two cells for every detonator and one cell for every ohm of resistance in the cables.

The required number of cells having been calculated, the firing battery should be connected up, and its power verified by the fusion test (Sec. **25**). If this is not possible, 25 per cent. should be added to the calculated number of cells.

4. **Comparison of exploder and firing battery.**—It will be observed that the firing battery differs in principle from the exploder in that the electrical energy is latent within the apparatus. Hence, the closing of the circuit is all that is necessary to fire. The use of cells is, therefore, invaluable for electro-contact mines (Chap. VIII), and for all work where the application from an external source of the energy for firing is impracticable. Further, the fact that the current supplied by a firing battery is continuous renders it suitable for firing detonators in divided circuit (Sec. **31**).

For ordinary work in the field, however, cells are not so suitable as an exploder. A firing battery of sufficient power for general demolition work is very bulky and heavy; moreover, the electrical energy is derived from chemical action, and all cells, once charged, deteriorate rapidly even when not used.

The dynamo electric exploder, on the other hand, is merely a contrivance for converting mechanical energy, furnished by the operator, into electrical energy. The durability, portability, and simplicity of such a machine renders it in many respects superior to other firing apparatus for general demolition work under service conditions.

31. *Grouping of detonators.*

When an exploder is employed to furnish the firing current, it is, as already stated, essential that the detonators be connected up in series. In firing with cells, however, since the current is continuous, the objections to the use of divided circuits do not arise, and such a course may be adopted, provided that the circuits are balanced and that a current of at least 0·8 ampere flows through each.

Pl. **12**, Figs. 1 and 2, give typical examples of divided circuits. The main advantage of such groupings is that the premature explosion of one charge does not cause the failure of the remainder, as may happen if all the detonators are in series. With two detonators in parallel in each charge, as shown in Fig. 2, should one of the detonators fail the charge will still be fired by the other. The Service electric detonator is, however, so reliable that it is seldom necessary to make use of these precautions against failure. With divided circuits the calculations are more involved, the connections more complicated, and the location of faults more difficult than when all detonators are in series. Hence, whatever the firing apparatus used, the standard method of connecting up in series should only be departed from in exceptional circumstances.

CHAPTER V.

DESCRIPTION AND PREPARATION OF CHARGES.

32. *Classification of charges.*

As explained in Sec. **4**, the action of all high explosives is twofold; firstly, an intense local shattering effect at the instant of detonation, and, secondly, a lifting action due to the subsequent expansion of the gases formed. It follows that economy will result when both these effects are utilized. But the preparation of a seating for the charge, and the tamping necessary to ensure that the expanding gases operate in the desired direction, usually require much time and labour. In some demolitions the shape of the objective will permit of the charge being fired within an enclosed air-space, and, thus, a considerable proportion of the lifting effect of explosive may be utilized without the labour involved in providing solid tamping, but it is often preferable to rely mainly on the shattering effect, and to place the charge with little or no tamping in close contact with the object to be destroyed.

Charges may, therefore, be divided into three main classes :—

Cutting charges.—The explosive is placed superficially, and acts chiefly through shattering action at the instant of detonation.

Mined charges.—The explosive is buried within a suitable medium, which, forming efficient tamping, enables the main effect to be attained through lifting action due to the expansion of the gases.

Concussion charges.—This is a modified form of mined charge, in which an enclosed air-space replaces solid tamping, and the lifting action of the explosive takes effect through the pressure of the air on the containing walls.

There is no marked line of division between these classes, and compromises between any two of them will often occur in practice. For example, the more a cutting charge is tamped the nearer will it resemble a mined charge.

The relative suitability of various explosives to produce shattering and lifting effect has already been discussed in Chaps. I and II.

33. *Cutting charges.*

The main advantage of cutting charges is the rapidity with which they can be placed in position. Hence, they are well adapted for hasty demolitions in the field, where little time is available to prepare a seating for the explosive. Hard substances are very susceptible to the sudden blow produced on detonation; thus, for steel-work and similar hard materials this class of charge is almost invariably used.

Where cutting effect is to be attained, the following points should be observed in fixing the charge :—

i. All portions of the charge must be in close contact with each other.

ii. The charge should cover the whole surface to be cut, and be in close contact with it.

iii. The charge as a whole must be firmly fixed to the object to be cut.

Any tamping that may be applied will increase the effect, but its use is of secondary importance and may be dispensed with in the majority of demolitions carried out with charges of this class.

Since good contact with the objective is so essential, explosives manufactured in slabs, such as gun-cotton, have a great advantage over those in powder form, in that the accurate fixing of the charge can be effected without the use of a container.

Gun-cotton charges for demolishing walls, arches, &c., may often be made up conveniently by nailing or lashing the slabs to a board which can be firmly fixed against the object to be destroyed; a hole is drilled in the board opposite the primer to enable the detonator to be inserted when the charge is in position (Pl. **18**, Fig. 2).

Powder explosives, such as ammonal, may be placed in sandbags or waterproof bags. In certain cases a tube of strong canvas may be used, the flexibility of the charge being its chief merit. Specially made metal containers are often very suitable: a length of iron water-pipe may sometimes be employed, while for rail or girder demolitions bully beef or tobacco tins may be used in emergency.

Timber packing and mud or clay are useful to secure the close contact of charges in the destruction of girders, &c. (*see* Pl. **21**). In the deliberate preparation of girder bridges for subsequent demolition, cement seatings may be employed; this permits the charges being kept under cover till the demolition is imminent.

In making up charges care must be taken to prevent any strain, to which the fuze or cables may be subjected in handling, being transferred to the detonator, since this might cause displacement and consequent failure, or the premature firing of the detonator. If any tamping is used, the detonator must also be protected against pressure from this source.

In the case of charges not requiring a container, the safety fuze or cables should be securely fixed to the charge 3 or 4 inches from the detonator. Where a bag container is used, a small piece of stick should be securely lashed at right angles to the fuze or cables inside the bag (Pl. **13**, Fig. 1), and these should be doubled back outside the bag and lashed firmly to it (Pl. **13**, Fig. 2).

A length of safety fuze leading to an exposed charge should be lightly fixed or weighted, so that when lighted it will not curl up and set fire to the charge prematurely (*see* Pl. **27**, Fig. 1). Special care should be taken in the case of gunpowder and cordite, which, being easily ignited, are very liable to be fired prematurely in this manner.

34. *Mined charges.*

Explosive is most efficiently employed in the form of a mined charge, since its full effect is then developed. Mined charges may either be buried in the ground or in the medium, such as masonry or rock, which it is intended to destroy. A great advantage of charges of this nature is their almost complete protection from chance detonation by hostile shell fire. They can seldom, however, be employed in hasty demolitions owing to the length of time required for preparation.

When lifting effect is to be attained, the following points should be observed in placing the charge :—

i. The charge should be placed so that the desired direction of action coincides as nearly as possible with the L.L.R. (Sec. **4**).

ii. Careful tamping.

The two principal methods of laying mined charges are :—

i. By mining operations in which a shaft, gallery, and chamber for the charge are excavated.

ii. By drilling bore-holes.

By the first method a large concentrated charge can be laid in the position desired, while by the second method, except where very small charges are used, the explosive will be extended along a considerable length of the bore-hole.

Method i. Mining.—The destruction of roads, railways, bridge abutments, masonry foundations, &c., by cratering effect is, as a rule, best accomplished by a suitably placed concentrated charge.

A vertical shaft is sunk at the side of the road, railway, or other objective, if possible at a point just outside the calculated radius of the crater to be formed. From the bottom of this shaft a gallery is driven to the position selected for the charge or charges (Pl. **25**, Figs. 1 and 2). At an embankment or escarpment the gallery may often be run straight in, and the shaft dispensed with. In some cases the cellar of a roadside house may provide a convenient point from which to drive a gallery. In the case of bridge abutments it is generally advisable to avoid cutting through masonry by starting the gallery behind the wing walls, &c. (*see* Pl. **25**, Fig. 2). The chamber for the charge should be constructed off the main gallery and at right angles to it, in order to increase the effect of the tamping. The level of the chamber floor should be slightly above that of the gallery, which should slope down from the chamber to facilitate drainage. In wet soils it may be necessary to form a sump at the foot of the shaft. Drains should be cut round the top of the shaft to prevent the entrance of surface water.

In loading, the precautions laid down in the previous section for fixing detonators for cutting charges must be taken. The firing cables or cordeau detonant should be taken out along the roof of the gallery, preferably by fastening them with string to nails driven into the timbers at intervals of 2 to 3 feet. If staples are used, care must be taken, when knocking them in, that the covering of the leads or cordeau is not damaged. The charge and firing arrangements having been placed in position, the gallery should be tamped solid with sandbags for a distance equal to three-quarters the diameter of crater to be formed, or up to the foot of the shaft.

The methods of constructing shafts, galleries, and chambers are described in detail in Part II, but it may be pointed out here that the time and labour required are considerable. In fairly easy soil with skilled men working in continuous shifts, an average progress of not more than 6 feet per diem for the shaft and 12 feet per diem for the gallery are good figures to work to, and it is seldom safe to reckon on laying a mined charge of any size in under 5 to 7 days. In most soils a considerable quantity of timber will be necessary in the construction of the shaft, gallery, and chamber. The weight of explosive required for the charge will seldom be less than a hundred pounds, and may run into several thousand pounds. Thus, the use of concentrated mined charges, though most effective, must of necessity be confined to situations where they can be deliberately prepared.

Method ii. Bore-holes.—Bore-holes provide a means for laying mine charges with the minimum of excavation and subsequent tamping. They are used extensively in blasting work, the theory and practice of which is described in Chap. IX, but the extended nature of the charge is an objection to their general use for ordinary demolitions. With long bore-holes the difficulty of controlling operations at the far end of the bore, and of obtaining complete detonation throughout its length, are further disadvantages that have to be surmounted.

This method is, therefore, most suitable where an extended mined charge is required, as, for instance, in demolishing a length of revetment wall or in forming an improvised trench by cratering the ground. It may also be adopted where lack of time, labour, or materials, or where unfavourable soil will not permit of the mining operations necessary to lay a concentrated charge being undertaken. In some cases conditions approaching concentration of the charge may be attained by placing a series of bore-holes side by side (*see* Pl. **26**, Fig. 1). The size of bore-hole used in ordinary demolition work may vary from about 3 to 10 inches. For small mined charges H.E. shells, owing to their cylindrical form, are often very suitable, but for general work an explosive in powder form, such as ammonal, will be used. It should be made up in metal cylinders, of slightly smaller diameter than that of the bore-hole, so constructed that they can easily be rendered waterproof. Pl. **14** gives a typical pattern. For long bores with heavy charges the bore-hole itself should be lined with a metal tube in addition. Stove piping, strong enough to resist bending or breaking, is often very suitable for this purpose.

The following table gives the approximate weight of ammonal per foot run for various diameters of cylinder, taking the weight of 1 cubic foot of tightly packed ammonal as 82·5 lbs. These figures should be reduced slightly to allow for voids when it is not possible to pack the ammonal tightly in the cylinders :—

Internal diameter in inches.	Weight per foot run in lbs.	Internal diameter in inches.	Weight per foot run in lbs.
2	1·8	6½	19·0
2½	2·8	7	22·0
3	4·0	7½	25·4
3½	5·5	8	28·8
4	7·2	8½	32·5
4½	9·1	9	36·5
5	11·2	9½	40·6
5½	13 6	10	45·0
6	16 2	—	—

35. *Concussion charges.*

The use of charges of this class will naturally be restricted to those demolitions in which a structural shell enclosing an air-space is to be destroyed. They are principally employed in the destruction of buildings.

Concussion charges, in common with cutting charges, have the merit of being easily placed in position, while they combine with local shattering action the lifting effect due to the air pressure. An explosive with a low velocity of detonation should be used. The shattering action will be utilized to best purpose by placing the charge so that it will cut an important part of the structure, as, for instance, a main supporting pillar in a building. It is important that all apertures through which the confined air can escape be closed. The most ideal conditions for a concussion charge are where the structural shell is of uniform strength throughout. Such objectives are seldom met with in practice, and it should be noted that where one or more of the containing walls is disproportionately weak the lifting action will tend to act in this direction only (*i.e.*, the L.L.R.), and the remainder of the structure may be left almost intact. Thus, a concussion charge used in a building with stout masonry walls and corrugated iron roof will blow off the latter, and do little damage to the remainder of the structure.

36. *Boring machines.*

The boring machines described below are suitable for making bore-holes in soft and medium soils. The machinery used to drill holes of small diameter for blasting in rock and other hard materials and its employment are described in Chap. IX.

The **Earth auger** is a very handy and useful tool for making short bore-holes in clay, sand, earth, and other soft soils. Its normal function is to excavate holes for telegraph poles, fencing, &c.; several patterns, boring holes from 3 to 10 inches in diameter, are on the market. They are all similar in principle. A typical example is given on Pl. **15**.

It consists of two iron scoops, set slightly eccentrically, and connected together at their upper ends by a distance-piece. One of the scoops is fixed and the other, which is slightly shorter, is so hinged to the distance-piece that it can be moved outwards through about 45°. To the centre of the distance-piece an iron rod 2 feet 6 inches long is fixed, the head of which is fitted with a screwed collar to receive a further length of rod with a " T " handle screwed on at its upper end.

The tool, on being rotated clockwise about its vertical axis, screws into the earth, and the scoops auger out the hole. When the scoops are full of earth, the tool is withdrawn, the hinged scoop turned on its pivot, and the earth scraped out. The procedure is then repeated. Lengthening rods (*see* Pl. **15**), usually 2 feet 6 inches long, are screwed on as the hole is deepened.

The most suitable patterns for general use in laying charges have an adjustable distance-piece, by means of which a range in diameter of about 2½ inches is obtained. The two scoops are set to the diameter desired by unscrewing the wing nut which clamps together the two arms composing the distance-piece.

The length of hole that can be bored depends upon its diameter. Earth augers not exceeding 6 inches in diameter will bore holes up to 25 feet vertically and rather less horizontally. In very soft ground 6-inch holes up to 30 feet deep may be bored. In loose or running soils it will be necessary to line the bore-holes with metal pipes as the work proceeds. In dry or hard clay the addition of a little water will often assist progress. Earth augers cannot be used in stony soils.

Care must be taken not to put too great a strain on the tool, which should be rotated with a slow and even motion. The torque on the rods in a long hole is very severe, and they may easily be twisted or sheared at the joints. Continuing to work the tool after the scoops are full of earth is a frequent cause of damage.

Among its many uses, the earth auger is a handy implement for the driving of ventilation bore-holes in the roofs of dug-outs and sub-ways (Sec. **123**, para. 4).

Thrust-borers may be used for driving long horizontal bore-holes in soft ground. They operate on the same principle as that by which a hole is made when a stick is thrust into clay; iron piping, fitted with a pointed pilot-head at the forward end, is forced through the soil by pressure applied from the rear.

Machines working on this system, driving 3-inch pipes taking a charge of 3 lbs. of ammonal per foot run enclosed in 2¾-inch tin cylinders, were used in the War of 1914-19. Under favourable conditions they were successfully employed in the front line for blowing short lengths of trench to communicate with the enemy trench system during an attack, and for the destruction of trenches and wire entanglements in minor operations. Bore-holes up to 300 feet in length were driven in soft soil free from stones, but 100 feet was about the maximum distance at which holes could be driven with any degree of certainty and accuracy. Owing to the lesser density of the upper soil, the pilot-head tended to turn upwards to the surface, and, in addition, it was easily deflected by stones and inequalities in the ground. An improved pattern of machine, *The Mangnall-Irving Thrust-borer* (Pl. **16**, Fig. 1) is manufactured by the Hydraulic Engineering Company, of Chester, in which these difficulties have to a large extent been overcome. It will drive a 150-foot bore-hole in clay with considerable accuracy, and can be relied on for holes up to 300 feet under favourable conditions. The apparatus is unsuitable for use in soils, such as running sand, the particles of which have not sufficient cohesion to preserve the shape of the bore-hole intact after the pilot-head has passed on. It is designed primarily for laying cables or pipes without digging trenches, but is well adapted for use in demolition work. A short description of the apparatus is given below.

The pilot-head (Pl. **16**, Fig. 2) is 10 feet long, and of special shape to counteract the rising tendency already referred to. At its rear end is fitted an enlarging head, on the diameter of which the size of hole depends; this is normally 4 inches. The pipes are in 4-foot lengths, and of considerably smaller diameter than that of the enlarging head (2½ inches for a 4-inch hole); thus, there is little friction created in pushing them along the bore. They are joined together by muff couplings through which iron pins are passed. The thrust is applied by means of a hydraulic jack, the pump of which is worked by a small petrol engine. The jack is shaped like a gun, and consists of a steel cylinder, down the bore of which the ram works, the latter having a stroke of rather over 4 feet. The jack rests in a steel frame, to which it is pivoted by two trunnions at its rear end. To operate the machine, the apparatus is placed in position in a pit dug to suitable dimensions and of sufficient depth to enable the hole to be driven at the required level. To commence boring, the jack is raised to a vertical position by turning it about the trunnions, and the pilot-head is dropped into the cylinder. The jack thus loaded is then lowered to the horizontal position, and the pilot-head forced into the soil, the thrust being taken up by the back wall of the pit. It is most important that the pilot-head be accurately aligned before the thrust is commenced. Adjustments in direction and elevation are effected by means of the siting vane and clinometer, and the adjusting wires shown on Pl. **16**. When the pilot-head has been forced home, the operation is repeated with successive 4-foot lengths of pipe, which are joined to each other by the muff and pin coupling. The desired length of hole having been driven, the piping is withdrawn (without the pilot-head), leaving a hole 4 inches in diameter. This can be loaded with explosive, or, if desired, can be enlarged by the same process to any size up to 8 inches by means of suitable apparatus supplied with the machine. The *Mangnall-Irving Thrust-borer* will drive 150 feet in half an hour, but against this figure must be set the time taken to prepare the seating for the jack, place it in position, and effect any minor adjustments necessary, so that about 4 hours will, as a rule, be required to carry out the whole operation. A disadvantage to the use of this machine for demolition work is that conditions may frequently render it impossible to salve the pilot-head.

Other patterns of boring machines.—Of the numerous rotary boring machines used in civil and mining engineering practice a few of the lightest and most mobile may be of use on service for laying charges. Of these the *Wombat Borer* (Pl. **17**) is a good example. It was used with success in the War of 1914-19, especially in soils such as chalk, too hard for thrust-borers or earth augers. Apart from demolition work, it was frequently used in hard soils for making ventilation bores in the roofs of dug-outs and sub-ways (Sec. **123**, para. 4).

The rotation of the boring rods is actuated through bevel gearing by crank handles on each side of the machine. The gear-box is held between two columns, fixed to a wooden sledge or bed-plate, and supported by back stays. The length of each column can be adjusted by means of a screw (*see* Pl. **17**), so that the machine can be fixed between the roof and floor if used in a gallery. The machine, the total weight of which is 360 lbs., dismantles into eight *man-loads* (less pump, hose, cutters, and rods); the heaviest part can be carried by two men.

To operate the machine, two men work on each handle. The forward travel of the boring rods is controlled by a friction clutch operated by the wheel in front of the machine, by which means the *feed* of the bit is adjusted to suit the nature of the soil encountered. The rods are 1¼ inches in diameter and in 5-foot lengths; they are hollow, and water is pumped through them to the cutting edge by a small hand pump. In hard chalk a 6-inch Calyx cylindrical bit with a 3-foot or 6-foot core barrel (Pl. **17**, Fig. 1) is employed, and in softer soils a spiral auger with detachable bit (Pl. **17**, Fig. 2).

The plant will drill a hole of 6½ inches diameter up to 200 feet in length at an average speed of 3 to 4 feet per hour in chalk, or 4 to 6 feet per hour in clay. About 16 gallons of water are used per hour.

37. *Detonation of charges.*

1. One point of detonation is sufficient to produce complete detonation in a charge of ordinary size or length composed of any of the bulk explosives in common use, but in large concentrated or long extended charges the tendency of the detonating wave to die out has to be considered.

2. **Concentrated charges.**—A detonator with primer, buried in a concentrated charge, may be taken as capable of inducing complete detonation in all explosive within a radius of 4 feet. On this basis one point of detonation per 12,000 lbs. of explosive is sufficient, but in practice a larger number than that theoretically necessary should be provided, as follows :—

Size of charge in lbs.	No. of points of detonation.
Under 5,000	1
5,000 to 10,000	2
10,000 to 20,000	4
Over 20,000	4 + 1*

* For every additional 10,000 lbs.

At the same time it should be realized that a single primer and detonator will generally be sufficient *to fire* the whole of even the largest charge of high explosive (except cordite). This course may be adopted on emergency, but there is great risk of the incomplete detonation of a large portion of the charge : the use of several points of detonation is essential to ensure the maximum effect being obtained.

As a further means of ensuring complete detonation more *active* or larger priming charges may be used ; the initial impulse of the detonating wave is thereby increased. Thus, the gun-cotton primer may be surrounded with a ring of No. 8 detonators held in a wooden frame, or a charge of explosive of high detonating velocity (say 5 to 10 lbs. blasting gelatine) may be added. Such precautions are only taken, as a rule, in very important mined charges.

3. **Extended charges** present a problem similar to that of large concentrated charges. The distance over which one point of detonation can be relied on to produce complete detonation will be largely increased if the charge is enclosed throughout its length, as, for example, in a metal tube or in a bore-hole. This has the effect of causing the main force of the explosive wave to act along the length of the charge. Thus, an extended charge, which is not enclosed, will require one point of detonation per 10 feet run to ensure complete detonation, but if enclosed this figure may be increased to 50 feet or more without appreciable diminution in explosive effect at the farther extremity. This fact is of considerable practical importance with bore-hole charges, in which detonation can generally only be initiated at the loading end. Special measures, however, must

be taken to promote complete detonation at the extremity of bore-hole charges over 50 feet in length. The most effective method is to use an increased priming charge, so as to give a powerful initial detonating impulse. A priming charge of 16 gun-cotton primers has been used with success in a 3-inch bore 300 feet long, but a pound of dynamite or blasting gelatine should give more certain results. Further stimulus to the detonating wave may be given by the insertion of primers and detonators as *refreshers* at every 6 to 8 feet along the bore. Alternatively, a length of cordeau detonant may be run along the inside of the bore, but this method offers considerable practical difficulties with regard to the loading. Uniform detonation throughout a long bore-hole charge (over 150 feet), even when the above precautions are taken, cannot be relied on with absolute certainty, and a more or less marked diminution of explosive effect towards the end of the bore is often noticeable.

4. **Sympathetic detonation.**—The possibility of firing a series of charges by *sympathetic detonation* (Sec. 6) in order to avoid long and vulnerable circuits has been frequently suggested. Ammonal has been detonated by sympathy over distances of several feet, but the results of experiments are not sufficiently reliable for practical use. Ammonium nitrate mixtures appear to be more sensitive to this influence than the majority of high explosives. Wet gun-cotton is noticeably unresponsive, 2 inches being about the maximum interval at which one slab will detonate another.

38. *Notes on the detonation of bulk explosives.*

Gun-cotton.—A primer must invariably be used for charges of wet gun-cotton to amplify the initial shock set up by the detonator. It should fit tightly in the hole provided for it in the gun-cotton slab.

Cordeau detonant will not detonate wet gun-cotton without the aid of a primer, with which it must be in close contact. A simple method of connecting up gun-cotton slabs for firing by cordeau detonant is shown on Pl. **18**, Fig. 1.

Ammonal may be fired by three methods of detonation :—

i. A detonator and primer buried in the charge.
ii. A slab of gun-cotton fixed in close contact with the charge.
iii. Two or three turns of cordeau detonant bound round a tin of ammonal.

Method (i) is normally the most suitable. Ammonal, however, reacts chemically with copper, and will gradually eat away the tube of a detonator, rendering its withdrawal after any length of time a dangerous operation. Hence, when it is not intended to fire the charge at once, the detonator should be protected from actual contact with the ammonal by enclosing it together with the primer in a small close-fitting waterproof bag.

In an emergency a detonator without a primer may be used. The detonation of the ammonal is, however, not so complete, and failure may result if it is damp.

Dynamite and blasting gelatine.—No primer is required for the detonation of explosives of the dynamite class; a detonator or commercial cap is sufficient. The paper covering is unfolded at one end, and a hole made in the end of the cartridge with a rectifier. The detonator is then inserted in the hole, and the end of the cartridge paper tied firmly round its base to hold it in position (Pl. 19, Fig. 2). While it is important that the whole of that portion containing the fulminate should be buried in the explosive, care must be taken, when firing by safety fuze, that the detonator is not pushed so far into the cartridge that the safety fuze may set fire to the latter before firing the detonator. Apart from the loss of power caused by such action, the combustion of nitro-glycerine in a confined space produces carbon monoxide in dangerous quantities. About one-third of the copper tube of the detonator should be exposed outside the explosive.

Cordite.—The difficulty of inducing satisfactory detonation in cordite has been explained in Sec. 6, but it may be used in emergency for demolition charges when no other more suitable explosive is available. The cutting effect of a cordite charge which detonates completely is even greater than that of gun-cotton.

The sticks of cordite must be bound together as tightly as possible, and for all but very small charges several points of detonation should be provided, each containing a gun-cotton primer and detonator. One point of detonation for every 2 lbs. of cordite and no portion of the charge to be more than 12 inches from a point of detonation is a good rule to follow. Even under these conditions complete detonation cannot always be relied on.

High explosive shell, when used as demolition charges, should be prepared for firing as follows. The fuze or plug should be unscrewed; this requires great care, especially in the case of fuzed shell. Spanners, specially made for the purpose, which enable a good leverage to be obtained, should be used. Hitting the fuze with a hammer or wooden mallet to loosen it is dangerous. The *gaine* should be removed with the fuze, and a fuzed detonator and primer, buried well in the explosive, substituted. An alternative but less reliable method of firing is to detonate a slab of gun-cotton fixed against the shell. The detonation of one of a group of shells placed in close contact is sufficient to fire the whole charge.

Other high explosives.—Special instructions regarding use will, as a rule, be obtainable for the various other natures of high explosives that may become available on active service. Some types are normally fired by a special primer (*e.g.*, melinite and T.N.T.), but in nearly every case the gun-cotton primer is an efficient substitute, and the principles which have been laid down above will apply.

Gunpowder.—To ignite gunpowder, it is only necessary to insert the end of the safety fuze, or, for electric firing, to bury a No. 14 fuze in the bag or box containing the charge. The use of a fulminate detonator is liable to scatter the powder without igniting it. Where, however, the powder is placed in a container sufficiently strong to overcome this effect, a fulminate detonator with primer may be used with advantage, since it will hasten the transmission of the flame throughout the charge, and thus produce a modified form of detonation by increasing the velocity of explosion.

39. *Notes on the handling of Service explosives.*

Gun-cotton.—Dry gun-cotton, owing to its inflammable nature, must be handled with special care. Primers of which the surface has become frayed, resulting in the accumulation of fine gun-cotton dust, are especially easily ignited. Dry gun-cotton must never be cut, as the friction is liable to cause ignition.

Wet gun-cotton slabs may be cut provided suitable precautions are taken. A tenon saw is the best tool to use. The slab should be gripped firmly between two wooden clamps (Pl. **18**, Fig. 3) close to the cut to prevent it from flaking. A sufficient supply of water must be kept at hand; the saw and the cut surfaces should be frequently wetted during the operation, and, after each slab is cut, water should be sluiced over the adjacent ground and the cutting apparatus. As the chips accumulate they should be gathered up and destroyed.

Ammonal should be exposed as little as possible to the air, so that its sensitiveness may not be impaired by the absorption of moisture from this source. Except where special precautions are taken to keep out water (*see* Sec. **41**), large charges are best made up in the hermetically sealed tins in which the explosive is issued. The detonating wave will pass through the thin walls of the tins provided that they are placed in close contact with each other.

Dynamite.—Nitro-glycerine explosives, owing to their increased sensitiveness when frozen, must in this state be handled with special care.

Thawing frozen dynamite or blasting gelatine is a dangerous operation, unless precautions are taken to ensure that no portion of the explosive is heated to a high temperature during the process. Any of these nitro-glycerine preparations when heated up to a temperature approaching their explosive point (about 360° Fahr.) become extremely sensitive to the least shock or blow, and once that point is reached they do not simply ignite, but explode with great violence.

They should never be warmed on or before stoves and fireplaces, nor exposed to the direct rays of a tropical sun, but thawed in an empty water-tight tin placed in a vessel of hot water (heated separately to a temperature that can be borne by the naked wrist, *i.e.*, about 130° Fahr.), or in a proper *warming pan* (Pl. **19**, Fig. 1), a special utensil which cannot be placed on a fire without being destroyed.

Though it is impossible to get complete detonation with frozen dynamite, considerable effect can be obtained. During the Thibet Expedition, 1903-04, extensive road-making operations were in progress at a temperature of about zero Fahrenheit. Approximately two hundred pounds of dynamite were expended during each day in blasting, and it was found quite impossible with the few warming pans available to soften more than about one-tenth of this quantity. The frozen dynamite was, therefore, used as the blasting agent, with one thawed cartridge as a primer to explode the whole charge. Two frozen cartridges were first inserted in the bore-hole, followed by a thawed cartridge with detonator. The frozen cartridges could not be pressed down to fill the holes. It was found that the above charge had roughly the same effect as two thawed cartridges properly pressed in and tamped.

40. *Multiple charges, portable charges, &c.*

Multiple charges.—In all demolitions the number of charges should be kept to the minimum compatible with economy in explosive and the attainment of the desired effect. Numerous small charges necessitate complicated firing circuits, thereby increasing the time taken in preparation and the chances of failure. Moreover, where charges are exposed to shell or rifle fire, it is important that exposed lengths of electric cable or cordeau detonant should be as short as possible, in order to reduce to a minimum the chance of their being cut. So vulnerable indeed is electric cable to shell fire that, in the destruction of girders of bridges and similar work, the use of safety fuze is often preferable.

Portable charges.—Conditions may often render it impracticable to make up a charge on the site, as, for instance, during a raid into the enemy lines. Where detailed information of the objective is available, the form of the portable charge may be adapted accordingly: the *Bangalore Torpedo* (Sec. **59**), used for cutting a passage through barbed wire entanglements, is a good example of a charge of this description. Portable charges should, if possible, be split up into portions that can easily be carried by one man (20 to 30 lbs.). Charges made up in box form are very suitable for general work; they should be fitted with a stout handle, and provided with two or more separate means of ignition by safety fuze. The Service igniter, being quicker to operate than matches, is a suitable means of lighting the fuze, but matches should be carried in addition in case the igniter fails. Pl. **20** illustrates a method for adapting the standard 25-lb. tin of ammonal as a portable charge by fitting a container in which the portable igniter set can be placed when required. A group of several 25-lb. tins, each carried by one man, may sometimes be required for one demolition. They would then be placed in position in contact with each other, two or three of the tins being provided with an igniter set, the firing of one of which would set off the whole charge.

The charge for a deferred demolition (Sec. **52**) will often have to be made up in portable form, since in exposed situations it will frequently be undesirable to leave the explosive in position, if it is unlikely to be required for some considerable period. A seating is prepared for the charge, and the latter, having been fitted to the objective, is then dismantled and kept under cover in the vicinity, so that to place it in position is the work of a few minutes.

41. *Protection of charges against moisture.*

The efficiency of nearly all explosives is adversely affected by exposure to damp; even wet gun-cotton will fail to detonate if exposed to moisture for a long period. Hence, charges under water or in damp situations frequently require special protection. For this purpose waterproof bags, vocabularized as **Bags, gun-cotton,** are provided; they are issued in sizes to contain 25 and 5 lbs. of explosive. The 25-lb. bag (Pl. **13**, Fig. 3) is carried by engineer field units, and is the size most commonly used. It consists of a waterproof bag with a wide mouth provided with a wooden clamp for sealing it. The clamp has two grooves cut in it to permit electric leads or safety fuze being passed into the bag.

As an alternative, earthenware or metal vessels may be used, the lids being sealed with pitch or other suitable material. Petrol tins, the mouths of which are sealed with pitch, make good waterproof containers for explosives in powder form.

Great care must be taken in the case of charges fired under water that the insulation of the electric leads, safety fuze, or cordeau detonant is perfect.

Charges exposed to the weather should be protected against damp and sun. General protection of a charge can be obtained by enveloping it in oiled silk or linen; alternatively, a board or a piece of tarpaulin cover can be used. To prevent damp reaching the detonator and primer, they should be completely enclosed in oiled silk and securely tied before insertion into the slab. (Pl. **3**, Fig. 3.)

If instantaneous detonating fuze is used, it should be lashed at right angles to the No. 8 detonator outside the oiled silk, with a foot spare at the end.

If the charge is to be fired electrically, a No. 13 detonator, also enclosed in oiled silk, should be similarly lashed at right angles to the No. 8 detonator.

Similar precautions must be taken with mined charges which are left in position for any length of time, for even in dry soils moisture will be formed by condensation in the chamber and gallery. The tins in which ammonal is issued afford sufficient protection in most cases, but in wet situations stouter containers such as petrol tins should be used. The priming charges should be placed in waterproof bags or sealed vessels.

Safety fuze rapidly deteriorates on exposure to damp, especially at joints (*see* Sec. **19**); if possible, it should not be fixed till it is desired to fire the charge. In the case of large mined charges which are to be fired by cordeau detonant, the best arrangement is to lead the cordeau beyond the tamping to the foot of the shaft, but to delay connecting it up to the detonator, safety fuze, and gun-cotton primers, which should be kept in a sealed tin close at hand, until the time of firing.

42. *Miss-fires.*

The chief causes of failure through faulty firing arrangements have been discussed in Secs. **19** and **21**. Miss-fires, however, may also occur through defective primers or bulk explosive. Dampness is, as a rule, the cause.

All miss-fires are dangerous and a frequent source of accident, while failure in the presence of the enemy may jeopardize the success of an operation. The chance of a miss-fire occurring may be minimized by using reliable materials, by exercising great care in making up and fixing charges, and, in the case of electrical firing, by careful testing, while the provision of more than one means of firing the charge (*see* Sec. **22**) will, as a rule, render the chances of ultimate failure negligible. With important charges that are to be fired at a stated time in the presence of the enemy, it is usually advisable to fire two or more safety fuzes inserted in the charge (or the alternative circuits in the case of electric firing) simultaneously, so that, if one fuze be faulty, the work will be done by the others.

Miss-fires with safety fuze are, as a rule, more dangerous than with electric firing, since the removal of the tamping and admission of fresh air often cause a smouldering fuze (*see* Sec. 19, para. i) to start burning again and the explosion to take place. In any case the longest possible time should be allowed to elapse after a miss-fire before the charge is approached. As a general rule, under peace-time conditions, at least 30 minutes should be given. The charge should only be withdrawn or touched when it is absolutely necessary to do so. A charge that has miss-fired, if accessible, should preferably be rendered harmless by placing and detonating a fresh charge close to it; this is normally safer than attempting to meddle with the old one.

When there is no alternative but to withdraw the charge, care must be taken that in removing the tamping no strain is put on the detonators by pulling or jerking the leads or fuze connected to them. Safety fuze, which is suspected to be smouldering, should be well wetted with water as soon as it is exposed. Iron or steel tools should not be used for taking out tamping near the charge.

43. *Precautions to be observed when firing charges.*

1. When a demolition is to be carried out under fire, every precaution should be taken against a possible failure through casualties. Spare men should be detailed to replace casualties amongst those carrying stores, and every man with the party should have the means of lighting the charge, and should know exactly what is to be done and the means available.

2. In carrying out demolitions under peace-time conditions, the person who orders the charge to be fired is responsible that the surplus explosives, detonators, &c., have been removed to a place of safety, and that sentries have been posted to prevent people unaware of the place and time of the explosion from coming within the danger area.

In this connection it should be noted that in carrying out the destruction of metallic substances (guns, girders, rails, &c.) the fragments are liable to be blown 1,000 yards or more away. Experimental demolitions of this nature should, therefore, if possible, be carried out in a pit or behind a wall of sandbags. In blasting hard rock, splinters may be thrown long distances.

In the case of large mined charges, 300 yards may be taken as a safe distance from the explosion, when this takes place under normal conditions in soft soil. If, however, the surface soil is hard or frozen, or there is a high wind, the range to which the debris will be hurled may be increased by as much as 50 per cent.

CHAPTER VI.

CALCULATION OF CHARGES.

44. *General principles.*

It is rarely necessary for the charge required to effect a given demolition to be calculated with greater accuracy than to the nearest pound (or slab of gun-cotton) or, in the case of charges of several hundred pounds, to the nearest tin of explosive (*e.g.*, 25-lb. tin of ammonal). While waste of explosive by the employment of excessive charges should never be countenanced, especially where the supply is limited, yet, on the other hand, to run the risk of failure to carry out a complete demolition in order to effect the saving of a few pounds of explosive is seldom justified. The calculation of charges to such a mathematical exactitude that there is no margin of safety should never be attempted even under the most ideal conditions. Small irregularities, which cannot be foreseen, may easily occur in the strength of material or explosive, security of fixing, &c. For this reason the formulæ given in the following sections include a factor of safety to meet such contingencies. Charges should seldom be reduced below the figure arrived at by calculation. The tendency in all demolition work should be, if anything, to overestimate rather than underestimate the charge required for any given operation. This principle still obtains even when the supplies of explosive are limited and the strictest economy is called for. Inadequate charges effecting incomplete demolitions are false economy.

Conditions, for which no allowance is made in the formulæ, necessitating a variation in the charge required for a given demolition, will often arise in actual practice. In such a case a too rigid adherence to the standard formulæ must be avoided; these often can only be taken as a guide. Demolitions may frequently have to be undertaken for which no formula is directly applicable. The officer in charge must be prepared to use his own judgment, based on experience and the data given for demolitions in any way analogous to the operation in hand, and to err when in doubt on the side of overestimating the charge required.

45. *Summary of formulæ.*

The following tables give a summary of the formulæ used for the calculation of charges; they are explained in subsequent sections of this chapter.

Table of formulæ for cutting charges.

The formulæ give the weight of gun-cotton or explosives of equivalent shattering power (such as dynamite No. 1 or gelignite) required. If ammonal is used the charges must be doubled.

Economy in explosive will be effected in the case of objects of rectangular section (masonry piers, baulks of timber, &c.) by placing the charge along the longer side, as the weight of explosive necessary varies directly as the length, but as the square of the thickness to be cut.

In the formulæ used :—

B = length to be demolished in feet.
T = thickness to be demolished in feet.
t = thickness to be demolished in inches.

Other symbols used are explained in the column of remarks of the table.

Object attacked.	Charge in lbs.	Remarks.	Section in which details are given.
CUTTING CHARGES FOR IRON AND STEEL-WORK.			
Iron and steel plates, girders, &c.	$\frac{3}{2}Bt^2$	Untamped. A slab of gun-cotton will cut a steel plate 1 inch thick.	46
Iron and steel bars	$\frac{2}{3}t^2$	Untamped. t is diameter of bar in inches. A slab of gun-cotton will cut a $1\frac{1}{4}$-inch steel bar.	46
Guns :—			
Charge in breech	d^2	Well tamped. Charges may be halved for howitzers. d is diameter of bore in inches.	46
Charge in muzzle	$\frac{d^2}{2}$		
Steel wire cables	$\frac{c^2}{16}$	Untamped. c is circumference in inches. 4-inch cables and under require one slab of gun-cotton.	46
CUTTING CHARGES FOR MASONRY.			
Walls	$\frac{1}{2}BT^2$	Untamped. Continuous charge. The length of breach B not to be less than the height of wall to be brought down. Walls under 2 feet thick require 2 lbs. gun-cotton per foot run.	47
Piers	$\frac{2}{3}BT^2$	Untamped. Continuous charge....	47
Arches at haunch or crown.	$\frac{3}{4}BT^2$	Untamped. Continuous charge	47
Reinforced concrete	5 to $20BT^2$	Depending on the amount of reinforcement.	47
CUTTING CHARGES FOR TIMBER.			
Cutting charge for hard woods :—			48
Rectangular section, baulks, &c.	$3BT^2$	Untamped. } For soft woods these charges may be halved.	
Circular section, spars, trees, &c.	$3T^3$	Untamped. T is diameter of timber in feet. } For soft woods these charges may be halved.	

Table of explosives for mined charges.

The formulæ (except that for timber) give the weight of ammonal required. They should be multiplied by a corrective factor when other explosives are used as follows :—

Sabulite	1·04
Blastine	1·05
Permite	1·15
Alumatol	1·19
Amatol	1·25
Perdite	1·30

(*e.g.*, the formula for a concentrated mined charge in medium soil using amatol will be $C = 1{\cdot}25\frac{D^3}{100}$).

The formulæ employed for boring and blasting work in rock and masonry, using dynamite or blasting gelatine, are given in Chap. IX, Sec. **74.**

The symbols used are explained in the column of remarks of the table.

Object attacked.	Charge in lbs.	Remarks.	Section in which details are given.
MINED CHARGES IN MASONRY, ROCK, AND EARTH.			
Concentrated charges :—			**49**
Rock and masonry	$\frac{D^3}{50}$ or $\frac{L^3}{6}$ ...	D is diameter of crater in feet. L is L.L.R. in feet.	
Medium and soft soils.	$\frac{D^3}{100}$ or $\frac{L^3}{12}$ ...		
Made ground	$\frac{D^3}{200}$ or $\frac{L^3}{24}$		
Extended charges :—			**50**
Rock and masonry	$\frac{D^2}{50}$ or $\frac{L^2}{6}$ per ft. run		
Medium and soft soils.	$\frac{D^2}{100}$ or $\frac{L^2}{12}$ per ft. run		
Made ground	$\frac{D^2}{200}$ or $\frac{L^2}{24}$ per ft. run		
MINED CHARGES IN TIMBER.			
Auger hole charges for spars, trees, &c.	$\frac{3}{8}T^2$	Using dynamite No. 1, blasting gelatine, or gun cotton primers. T is diameter of timber in feet.	**48**

Table of formulæ for concussion charges.

The formulæ give the weight of gun-cotton required, but ammonal, dynamite, or blasting gelatine may be used without any modification of the formulæ.

The symbols used are explained in the column of remarks of the table.

Object attacked.	Charge in lbs.	Remarks.	Section in which details are given.
		CONCUSSION CHARGES.	
Masonry buildings, &c.	$K\frac{AT^2}{10}$	A is the area of internal floor space in sq. feet. T is the thickness of walls in feet. Values of K are as follows :— Mud walls, inferior masonry 1. Good masonry .... 2. Reinforced concrete 4 to 10.	51
Structures with thin walls.	$m\frac{V}{100}$	V is volume of enclosed air-space in cub. ft. Values of m are as follows :— Weak wooden sheds 1 to 2. Corr. iron structures .... 4 to 8. Stout wooden buildings, log huts, &c. .... 6 to 12. Strong steel casing (*e.g.*, armoured car or tank) 20 to 30.	51

46. *Calculation of charges for iron and steel-work.*

1. The use of gun-cotton only is described in this section, but the methods employed apply to other explosives.

2. **Steel and iron plates and bars.**—The formula $\frac{3}{2}Bt^2$ should be used in calculating the charge for steel and iron plates and for structures made up of these materials (girders, roof trusses, &c.). The charge must extend along the whole breadth of material to be cut; it thus follows that the minimum charge that can be used is one slab for 6 inches of breadth. From the formula it will be found that this amount will cut a plate just over 1 inch in thickness. Hence, for plates not exceeding 1 inch in thickness, one slab of gun-cotton for 6 inches of breadth is the rule. For thicker plates the charge must be calculated from the general formula.

1 lb. of gun-cotton will cut steel and iron bars $1\frac{1}{4}$ inches in diameter and under; for larger bars the formula $\frac{2}{3}t^2$ should be used, where t is the diameter of the bar in inches.

3. **Iron and steel girders.**—There are so many different forms of girders in use that it is impossible to lay down rules for their destruction which will be applicable to all. In calculating charges the engineer must be prepared to use his own judgment combined with an intelligent interpretation of the formula $\frac{3}{2}Bt^2$.

All girders are made up of a top and bottom *flange* or *boom* connected by a *web* consisting of continuous plates in plate girders, or of open cross-bracing in braced girders.

The destruction of the lower or tension flange is the most important, and that of the web the least; but to ensure complete demolition of a girder, it should be cut through both flanges and web.

If the flanges alone are cut, while it is impossible that the girder could carry the loads for which it was originally designed, still, since there is always a large factor of safety in such structures, it is possible that the web may keep it from collapsing. With girder bridges and similar steel structures the destruction of the superstructure is also important, hence the collapse of the girder is essential if the demolition is to be complete. Moreover, the repair of a girder, if still standing, may be easier than its entire replacement, or the structure may be of use to the enemy in its weakened state for the passage of troops or light loads.

In demolishing girders there is, as a rule, difficulty in obtaining proper contact between the charge and the metal owing to the presence of rivet heads. The spaces between the rivet heads are generally filled with clay, or, for deferred demolitions, cement seatings may be prepared for the charges. The depth of the filling must be included in calculating the thickness to be cut.

Plate girders.—The most economical method of destroying an "I" section plate girder (of which a typical example is given on Pl. **21**) is to place charges across the top and bottom flanges and the web, as shown in Fig. 1, the amount of explosive sufficient to cut through the metal in each case being calculated from the formula.

In order to avoid minute and detailed calculations, the maximum width throughout is taken for the flanges, and the minimum for the web. This approximation is sufficiently accurate for all ordinary types of girders, and simplifies considerably the calculations. Thus, in the example given (Pl. **21**, Fig. 1):—

i. Top flange—

Max. thickness $t = \frac{1}{2}$ in. (flange) + $\frac{1}{2}$ in. (angle iron) + $\frac{1}{2}$ in. (rivet head) = $1\frac{1}{2}$ ins.

Breadth $B = \frac{15}{12}$ feet.

$$\therefore \quad \frac{3}{2}Bt^2 = \frac{3}{2} \times \frac{15}{12} \times \left(\frac{3}{2}\right)^2 = 4\cdot 2 \text{ lbs., or 5 15-oz. slabs.}$$

ii. Bottom flange—

Max. thickness = $\frac{1}{2}$ in. (flange) + $\frac{5}{8}$ in. (angle iron) + $\frac{1}{2}$ in. (rivet head) = $1\frac{5}{8}$ ins.

Breadth = $\frac{15}{12}$ feet.

$$\therefore \quad \frac{3}{2}Bt^2 = \frac{3}{2} \times \frac{15}{12} \times \left(\frac{13}{8}\right)^2 = 5 \text{ lbs., or 6 15-oz. slabs.}$$

iii. Web—

Minimum width of web = $\frac{3}{8}$ in.

$\therefore$ 1 slab per 6 ins. will suffice.

Length of web = 33 ins.

$\therefore$ Charge $= \frac{33}{6}$ slabs = 6 15-oz. slabs.

The charges are then fixed as shown. Care must be taken that each charge is in close contact with and tightly fixed to the girder, wood packing and clay being used where necessary.

It often happens, however, that it is not possible to fix the charges in the positions described, owing to the superstructure carried by the girder intervening or for other reasons. Moreover, the above arrangement has the disadvantage of involving the simultaneous firing of three separate charges.

The following is an alternative method. The charges for web and flanges are fixed on one side of the girder, as shown on Pl. **21**, Fig. 2, but, in order to compensate for the fact that the flange charges are not then continuous, they must be doubled. Thus, in the example given 10 slabs will be required for the top flange and 12 slabs for the bottom flange. This method may, therefore, be considered universally applicable for an ordinary plate girder, since one side at least is nearly always accessible. It is, as a rule, preferable to the first method given, except where a rigid economy in explosives is called for.

Plate girders of more elaborate section than the example given above may often be met with. Detailed methods of destruction, which will be applicable to all cases, cannot be given. The guiding rule in every instance is to place explosive calculated from the formula $\frac{3}{2}Bt^2$ in contact with the whole of the surface to be cut.

Braced girders differ greatly in their structure and design. It is impossible to give a general statement which will include all cases. As a rule, a suitable point along the girder should be selected at which to cut through all the members (Pl. **22**, Figs. 1 to 3). Charges for each member (*i.e.*, top and bottom flanges and bracing) should then be calculated from the formula $\frac{3}{2}Bt^2$.

4. **Cast-iron arches** should be cut in two places on the slant, as shown by the lines $x\,x^1$ on Pl. **22**, Fig. 4, to allow of a piece falling right out without jamming. As the web is usually very thick in cast-iron arch girders, it must invariably be cut as well as the flanges.

5. **Guns.**—The most effective point of attack is the breech. If a short length of the muzzle is blown off, it may be possible to use the piece again either as a howitzer or as a gun of shorter range.

The number of lbs. of gun-cotton required to destroy the breech of a modern long-range gun may be determined by squaring the calibre of the gun in inches. Thus, a 36-lb. charge of gun-cotton would be required for a 6-inch gun. The charge may be considerably reduced for older and less powerful weapons. For howitzers it may be halved.

The gun should first be loaded with a shell; if no shell is available, 2 or 3 feet of the bore should be tamped with earth. The demolition charge is then packed close behind the shell or earth tamping, and the remaining space in the chamber filled with earth. The breech is then closed as far as possible, just allowing room for the safety fuze or electric leads. With guns of large calibre it is preferable, if possible, to close the breech completely, and fire the charge through the vent tube.

When the muzzle end of a piece is selected for attack, about half the amount of gun-cotton required for the destruction of the breech will suffice, provided that the charge is well tamped on both sides. The charge should be made up in the form of a cylinder of diameter about an inch smaller than the bore.

If explosive in bulk is not available, an alternative but less reliable method of destruction is to detonate a high explosive shell in the breech after first blocking the bore.

A gun may be rendered temporarily useless without the aid of explosives by carrying off the breech block and sights, or attacking it with a sledge hammer or any heavy instrument at hand. In the latter case, the threads of the breech block should be burred, the breech mechanism strained, and recoil buffers dented.

6. **Rails.**—To cut a first-class steel rail one slab is sufficient, but care must be taken that good contact is obtained. It is essential that the charge be firmly bound to the rail. A good method is shown on Pl. **27**, Fig. 1.

7. **Cables.**—The charge for steel wire cables of 4 inches circumference and over is calculated from the formula $\frac{c^2}{16}$, c being the circumference in inches. For cables under 4 inches in circumference, 1 lb. of explosive is sufficient. Where two or more gun-cotton slabs are required, the charge should be divided into two equal portions placed on opposite sides of the cable so as to produce a shearing action (Pl. **22**, Fig. 5). As much of the surface of the slabs as possible should be in contact with the cable (Pl. **22**, Fig. 5), to which they should be firmly secured.

47. *Calculation of cutting charges for masonry* and reinforced concrete.*

1. Masonry is usually most economically destroyed by blasting operations, the principles of which are described in Chap. IX, but in demolitions in the field, where ease and rapidity of laying the charge are of paramount importance, cutting charges, calculated from the formulæ given in this section, are generally used. Where, however, the thickness of masonry exceeds 5 to 6 feet, the employment of a cutting charge becomes unreliable and very extravagant in explosive. Destruction must either be effected by boring and blasting, or by burying a series of mined charges within the masonry (*see* Sec. **49**). Thick piers often offer exceptional

* The term masonry as used in this section includes brickwork and concrete.

facilities for attack by the latter method from the top. The formulæ for cutting charges for masonry, given in paras. 2, 3, and 4, are suitable for good brick or stone-work set with cement mortar, or for concrete. For inferior masonry (brickwork loosely set in lime mortar, rubble walls without mortar, &c.) the charge may be reduced by an amount not exceeding one-half.

2. **Masonry walls.**—Formula $\frac{1}{2}BT^2$. As with cutting steel-work it is essential that the charge be continuous, hence, when using gun-cotton, a minimum charge of 2 slabs per foot run must be used for walls 2 feet thick and under. In order to ensure that the wall is brought down, and not merely a hole made, the length of breech B must be not less than the height of the wall.

3. **Masonry piers,** owing to the greater thrust upon them, require a larger charge than walls. Formula $\frac{2}{3}BT^2$. The charge should be placed on one side of the pier. If time permits, the effect will be considerably increased by cutting a channel in the pier to receive the charge.

4. **Masonry arches** may be attacked either at the crown or the haunches (Pl. **23**, Fig. 1), the formula $\frac{3}{4}BT^2$ being used in either case. In bridges a traverse trench should be dug (provided that the interruption of traffic is permissible) down to the masonry of the arch, in which the charge, which should be continuous and in close contact with the masonry, should be placed. The trench should be filled in, as this tamping will increase the effect. When time or circumstances do not permit of a trench being dug, the crown may be attacked by fixing the charge to a board and securing the whole firmly to the under side of the arch. In order to ensure close contact of the explosive along the whole width of the arch, the board should be trussed (*see* Pl. **23**, Fig. 2). This method requires considerably more explosive, since the thickness T must be taken as the thickness of masonry plus that of the material above it.

From Pl. **23**, Fig. 3, it will be seen that much greater damage is done by attacking an arch at the haunches than at the crown. In the former case the breach formed would be *fg*, while in the latter it would only be *de*. Such a small gap in the case of a bridge could, as a rule, be rapidly repaired.

5. **Reinforced concrete.**—Very heavy charges are required to cut reinforced concrete. Since the explosive cannot be placed in actual contact with the steel reinforcement, a considerable proportion of the shattering action on which the main effect of a cutting charge depends is absorbed before the metal is reached. The material is far more easily broken up, however, by longitudinal stresses tending to pull the reinforcement from its concrete bed; hence, the tearing and rending action which results from the firing of concussion or suitably placed mined charges (Secs. **51** and **49**) gives much more efficient results. Charges in one of these two forms should be used whenever the construction of the objective and conditions permit.

Nevertheless, when an isolated girder or stanchion is to be demolished, there is often no alternative to the use of a cutting charge. In such a case formula varying from *5 to 20BT*², according to the amount of reinforcement present, should be used. The major portion of the charge should be placed where the reinforcement is heaviest (*e.g.*, on the lower flange in the case of girders). The estimation of a suitable charge is always difficult and often largely a matter of guesswork. Frequently the only means of gauging the amount of reinforcement is to ascertain approximately the load which the member to be destroyed is designed to bear. Reinforced concrete in which the reinforcement consists of a large number of steel bars of small section is usually the most difficult to destroy. Where one or more steel girders, rails, or large bars are used, great economy in explosive may be effected, if time permits, by carrying out the demolition in two operations. A charge BT^2 is first placed in position with the object of cutting and shattering the concrete; the steel will then be exposed, and can be cut by placing charges, calculated from the formula $\frac{3}{2}Bt^2$, in contact with it.

48. *Calculation of charges for timber.*

1. Timber, owing to its tough fibrous nature, requires more explosive to cut it than brickwork, and, as a rule, is more simply destroyed by cutting down or burning.

2. **Cutting charges.**—To cut a rectangular baulk or a wooden stockade by a charge of high explosive placed against it, the formula is $3BT^2$ for hard wood (oak, teak, ash, &c.), and $\frac{3}{2}BT^2$ for soft wood (larch, fir, &c.). For round spars the formula is $3T^3$ and $\frac{3}{2}T^3$ for hard and soft woods respectively. T is the diameter in feet. Gun-cotton is normally the most suitable explosive to use. It is, as a rule, best made up fixed to a board, which is nailed or lashed to the objective (Pl. **18**, Fig. 2).

3. **Auger holes.**—A much more economical method of cutting timber of circular section is by means of auger holes. The hole is bored perpendicularly into the timber with an auger of about 1½ inches diameter. It should be of such a length that the centre of the charge lies in the centre of the timber. Where the length of the charge is not greater than the diameter of the timber, a single hole, bored right through the timber if necessary, will suffice, but for baulks over 18 inches in diameter two or more auger holes will, as a rule, be required (*see* Pl. **24**, Figs. 1 and 2). Dynamite or blasting gelatine is the most satisfactory explosive for this form of demolition, but gun-cotton primers or ammonal may also be used. The charge using dynamite No. 1 or blasting gelatine may be calculated from the formula $\frac{3}{8}T^3$, T being the diameter of timber in feet.

4. **Trees** may be felled by means of auger holes, or by notching the trunk on the side to which the tree is required to fall and placing a gun-cotton charge in the notch. Ropes, on which a strain is maintained, may be attached to the top branches of the tree to ensure that the timber is felled in the desired direction.

5. **Wooden piles,** which are to be cut off under water at their base, are best dealt with in the following manner. The charge is attached to a ring of wire rope or hoop-iron encircling the pile sufficiently loosely to permit the whole to slide down it. A stick, up which the fuze or leads are taken, is attached to the ring, and the charge is pushed down into position at the base of the pile (*see* Pl. **24,** Fig. 3). The charge should be placed against the up-stream side of the pile.

49. *Calculation of concentrated mined charges.*

1. The action of large mined charges is analysed in detail in Part II, Chap. XIII, as in mine warfare calculations to a considerable degree of accuracy are necessary.

For demolitions, however, only the cratering effect of mined charges is normally of practical importance. The same precision in calculation is, therefore, not required, and simpler formulæ may be used. In exceptional cases, where it is important to limit the effect, or where a strict economy in explosives is necessary, the more complicated formulæ given in Chap. XIII may be employed.

2. **Formulæ in terms of diameter of crater.**—If C be the charge of ammonal in lbs., and D the diameter of crater required in feet, then :—

$C = \frac{D^3}{50}$ in rock and masonry.

$C = \frac{D^3}{100}$ in soft and medium soils (clay, chalk, &c.).

$C = \frac{D^3}{200}$ in made ground.

The charge must be laid at a depth of not less than $\frac{D}{6}$ or greater than $\frac{D}{2}$; in general, craters formed by a charge placed at depth equal to $\frac{D}{4}$ form the most satisfactory obstacle.

Where it is desired to form a continuous obstacle by a chain of craters, the charges should be laid at intervals equal to $\frac{2}{3}D$.

3. **Formulæ in terms of L.L.R.**—It may sometimes be more convenient where the formation of a crater is a secondary consideration, as, for instance, in the demolition of masonry walls or piers by mined charges buried within them, to calculate the charge required in terms of the L.L.R.

If C be the charge of ammonal in lbs., and L the L.L.R. in feet, then :—

$C = \frac{L^3}{6}$ in rock and masonry.

$C = \frac{L^3}{12}$ in soft and medium soils.

$C = \frac{L^3}{24}$ in made ground.

The diameter of crater formed by a charge calculated in this manner will be approximately $2L$.

Charges, the craters of which are to connect up, should be spaced at intervals of $\frac{4}{3}L$.

4. **Roads and railways** (Pl. 25, Fig. 1).—To create an efficient obstacle in a road or railway the charge should be calculated to form a crater of such diameter as to remove the whole of the prepared or metalled surface.

A concrete foundation or heavy soling to a road should be allowed for by increasing the charge calculated from the formula by 50 per cent.

The presence of water at a short distance below the surface may limit the depth at which charges can be laid. In such cases, or where the road or railway is exceptionally wide, two or more mined charges may be necessary. Normally, however, one charge laid underneath the centre of the way will suffice.

5. **Demolition of bridge abutments** (Pl. 25, Fig. 2).—The charge should be calculated in the same way as for a road crater, but in this case the diameter of crater required should be taken as the width of the bridge abutments exclusive of the wing walls.

When the abutments are faced with masonry, the charge should be calculated from the formula for masonry ($C = \frac{D^3}{50}$), irrespective of the nature of the soil in which the explosive is actually buried. The charge is then rather in excess of that necessary to bring down the abutment, but the additional explosive will have the desirable effect of thoroughly shaking and fissuring the masonry foundations which are left.

The charge should be placed at a distance from the external face of the abutment equal to between $\frac{D}{2}$ and $\frac{D}{4}$; the depth of the centre of the charge should be about one and a half times the distance of the charge from the face of the abutment, and, in the case of masonry bridges, at least as deep as the springing of the arch.

Example.—The masonry abutment shown on Pl. 25, Fig. 2, which is 30 feet in width, is to be destroyed.

The charge required $= \frac{D^3}{50} = 540$ lbs.

It should be placed at a distance of 8 to 15 feet from the external face of the abutment, at a depth varying between 12 and 23 feet according to the distance from the external face at which the charge is actually placed.

6. **Thick masonry walls and piers** (Pl. 25, Fig. 3).—Charges should be buried in the middle of the wall or pier (*i.e.*, so that they are equidistant from both bounding faces). The weight of ammonal required may be calculated from the formula $C = \frac{L^3}{6}$, L in this case being the distance of the centre of the charge from either face of the wall. The charges should be placed at intervals equal to $\frac{4}{3}L$.

Where it is not possible to place the charge centrally, L should be taken as the distance of the charge to the further face, *i.e.*, OB on Pl. 25,

Fig. 4. The ratio of OB to OA, however, must not be greater than 3 to 2, or the charge as calculated will break surface on one face only.

50. *Calculation of extended mined charges.*

The method of calculating extended charges used in boring and blasting operations is described in Chap. IX. For extended charges laid in horizontal bore-holes made by machines of the types described in Sec. **36**, the approximate formulæ following may be used.

W, the weight of ammonal in lbs. required per foot run of bore-hole, may be expressed either in terms of *D*, the width of gap or trench to be blown in feet, or of *L*, the L.L.R. in feet, as follows :—

$$W = \frac{D^2}{50} = \frac{L^2}{6} \text{ in rock or masonry.}$$

$$W = \frac{D^2}{100} = \frac{L^2}{12} \text{ in soft and medium soils.}$$

$$W = \frac{D^2}{200} = \frac{L^2}{24} \text{ in made ground.}$$

When the *D* formula is used, the bore must be made at a depth between $\frac{D}{6}$ and $\frac{D}{2}$. Charges calculated from the *L* formula will blow a gap of width approximately equal to $2L$.

51. *Calculation of concussion charges.*

Concussion charges, when used for the destruction of masonry buildings, should be calculated on the basis of the area of the floor space and the thickness of the enclosing walls. If *C* be the charge of ammonal or similar lifting explosive in lbs., *A* the total area of internal floor space in square feet, and *T* the thickness of the walls in feet, then the charge required will be given by the formula :—

$$C = K\,\frac{AT^2}{10}$$

where *K* is a variable depending on the material of the walls, the value for various materials being as follows :—

Mud walls, inferior masonry	1
Good masonry	2
Reinforced concrete	4 to 10

Example.—A heavily reinforced concrete machine-gun emplacement with walls 3 feet thick and internal area of floor space 30 square feet is to be destroyed.

K should be taken as 10 and—

$$C = K\,\frac{AT^2}{10} = 10\,\frac{30 \times 3^2}{10} = 270 \text{ lbs.}$$

The most satisfactory results are generally obtained by dividing the charge into four or more equal portions and placing them in the corners of the structure. The whole charge thus subdivided is fired simultaneously.

The above formula is not applicable to wooden or corrugated iron huts or any structures with thin walls. The charge for these should be calculated on the basis of the cubic contents of enclosed space, and will vary according to the strength of the structural shell. If C be the weight of ammonal in lbs., V the volume of the enclosed air-space in cubic feet, and m the constructional variant, then—

$$C = m \frac{V}{100}.$$

The values of m for various structures are as follows :—

Weak wooden sheds	1 to 2
Corrugated iron structures	4 to 8
Stout wooden buildings, log huts, &c.	6 to 12
Strong steel casing (*e.g.*, armoured car or tank)... ...	20 to 30

Example.—A strongly constructed corrugated iron hut, of which the contents are approximately 2,000 cubic feet, is to be destroyed.

m should be taken as 8 and—

$$C = m \frac{V}{100} = 8 \frac{2,000}{100} = 160 \text{ lbs.}$$

As in the former example, the charge should be subdivided and placed in the corners or against the main supporting members of the structure, and all charges fired simultaneously.

CHAPTER VII.

DEMOLITIONS IN THE FIELD.

52. *General principles.*

1. The main objects of demolitions in warfare are :—

i. To delay the advance of an enemy by the destruction of communications over which he must pass, and of material which will fall into his hands (defensive).

ii. To impair an enemy's power of resistance by the destruction of captured communications which cannot be permanently held, or materials that cannot be removed, as, for instance, in a raid (offensive).

2. **Reconnaissance.**—The importance of thorough reconnaissance in all demolition work cannot be overestimated. Individual objectives should invariably, in so far as conditions will permit, be carefully examined before the details of the method of destruction to be employed are decided on. This having been done, the charge should be calculated, and the method of firing selected.

Whenever demolitions are to be carried out on an extensive scale, a comprehensive and well considered scheme must be drawn up, in which due weight is given to both tactical and technical features. Haphazard and promiscuous methods without a clearly defined plan cannot produce good results. In preparing such a scheme the following points are important :—

i. The extent to which demolitions are to be carried out in an operation will be laid down by the General Staff.

ii. The complete demolition of the communications at a few points where there are no alternative routes will delay the enemy far more than a number of demolitions which can be quickly repaired or circumvented.

iii. The possibility of effecting destruction by means other than the use of explosive should not be overlooked. This is especially important where the explosive available is limited. Wooden bridges and stores may be burnt; certain materials rendered unserviceable with water; machinery disabled with crow-bars.

iv. Where the disablement only of machinery, &c., is aimed at, the same essential parts should be removed or destroyed throughout. This will prevent the formation by the enemy of a few complete units from parts of the damaged ones.

v. The sequence in which the destruction of communications is to take place during a retirement must be carefully laid down and co-ordinated. For example, the premature demolition of all railway bridges on a disused section of line may block roads, still in use, over which it passes.

vi. Delay action and contact mines may often be used with advantage in conjunction with, but supplementary to, ordinary demolitions (*see* Chap. VIII).

3. **Deliberate, hasty, and deferred demolitions.**—To effect a complete and economical demolition requires careful reconnaissance, ample time for preparing and laying the charges, and conditions that permit of placing and firing the latter without serious enemy opposition. Where such conditions do not prevail, procedure on these deliberate lines cannot be carried out. It will not then, as a rule, be possible to aim at effecting such complete destruction, a more rapid and more easily executed method of attack having to be adopted in preference to that which will cause the most damage.

The quantity of explosives available may also prove a determining factor as to the method of destruction adopted. The problem presented in all cases is that of effecting the maximum damage to the objective in the time available, and with the means at disposal.

Demolitions may, therefore, be classified broadly under the headings of :—

Deliberate demolitions, for the preparation of which ample time is available, and which can be fired deliberately at a pre-arranged time.

Hasty demolitions, in the preparation of which economy of time is of primary importance; the laying and firing of the charge, for which elaborate stores are not likely to be available, will frequently have to be carried out in the face of the enemy.

Deferred demolitions, for which ample time for preparation is available, but the time of firing is unknown. The charge may have to remain in position for a long period, and then finally be fired under hasty conditions.

The preparation of deferred demolitions will, therefore, be generally similar to that of deliberate demolitions, but the final steps necessary to make the charge ready for firing may, to a greater or lesser degree, be postponed until firing is imminent. The firing arrangements, except for very important charges, will resemble those of hasty demolitions. Demolitions prepared as a precautionary measure against retirement generally come under this heading.

The main points in which these three classes of demolition differ may be illustrated by the following example. The destruction of one or both abutments by mined charges is normally the most important operation in the deliberate demolition of a girder bridge, but time may only permit the destruction of the main girders in the case of a hasty demolition. Again, if the demolition is to be deferred, it will probably be advisable to excavate the seatings for the mined charges and collect all stores on the site, but to postpone connecting up the firing arrangements until the time of firing.

4. **The responsibility for giving the order to fire a charge,** when in the presence of the enemy, must be vested in an officer on the spot. An officer in charge of a demolition party should see that the orders he has received include clear and definite instructions as to when the charge is to be fired. He should ensure that the officer or N.C.O. under him, who will have to take charge in the event of his becoming a casualty, is thoroughly acquainted with what is to be done.

53. *Demolition of bridges.*

1. The deliberate demolition of a masonry or girder bridge, provided an adequate supply of explosive is available, will involve the destruction of one or both abutments, the piers (if any), and the main girders. In single span bridges the destruction of the abutments is generally the most important operation ; since by demolishing these, not only will the bridge be wholly or partially wrecked, but it will also be difficult to obtain footings for the foundations for a new bridge on the same site. In viaducts and bridges of several spans the demolition of the intermediate piers is usually equally as important as that of the abutments. The destruction of the abutments and piers of girder bridges will bring down the main girders, but it is advisable to ensure, by cutting them, that they shall not be of use in the construction of a new bridge.

In suspension bridges the main steel cables should be cut, and the suspension towers and their footings should then be destroyed with mined charges. The cables are best attacked where they pass over the top of the suspension towers, as they are more easily cut at a point at which they are firmly supported, while the top of the tower will be blown off by the same operation.

Light wooden trestle bridges constructed of scantling up to 9 inches by 3 inches may be burnt by using petrol or tar. Heavy wooden bridges with timber of larger dimensions are more easily destroyed with explosives (Sec. **48**).

2. In hasty demolitions only the destruction of the girders, arches, or cables of a bridge can, as a rule, be attempted, but occasionally conditions may permit of more extensive damage being effected by the destruction of one or more piers.

Although time may not permit of the destruction of bridge abutments by heavy mined charges on the lines described in Sec. 49, para. 5, it may still be possiblo to damage them considerably. The firing of a charge of high explosive placed on or against the abutments without any tamping will cause considerable havoc, provided it be large enough. It is, however, difficult, as a rule, to obtain a hole in or behind the abutments whereby damage may be effected by a charge of moderate weight. Bore-hole charges, the cavities being made with an earth auger, can often be quickly put in and are very effective. An alternative method is to blow a hole for the main charge in the abutment with a small initial chambering charge up to 50 lbs. in weight. Although the whole operation is thus performed in two stages, it need not take more than half an hour to carry out if the charges are prepared beforehand.

54. *Demolition of tunnels.*

The best points of attack are places where the tunnel passes through loose or shifting ground. The brick or masonry lining should be destroyed for a length of 15 to 25 yards, if possible by a series of small mined charges placed behind it. Where the use of mined charges is impracticable, a length of the lining may be cut by fixing a continuous charge of gun-cotton, calculated from the formula $\frac{3}{4}BT^2$ (T being taken as the thickness of the lining), against the internal face. It is often sufficient to destroy one side of the arch-ring in this manner: the pressure of the overburden will bring down the roof and fill up a section of the tunnel.

In firm soils and solid rock the destruction of the lining will often have little effect, and heavy mined charges must be used.

A very effective block may be made by laying three mined charges, as shown on Pl. **26**, Fig. 2, but much work is entailed in obtaining a seating for the charges. The use of ventilating shafts, off which a chamber for the charge may be cut, will often save much labour. In such cases tamping can be effected by shovelling down earth from the surface.

If the supply of explosive is limited it is, as a rule, better to create several small blocks in the tunnel than one large one.

When the permanent destruction of a railway tunnel is not desirable, an effective obstruction may be made by causing the derailment or collision of rolling stock within it; any axles left intact after the collision should be broken. The removal of wreckage within the cramped space of a tunnel is a difficult and lengthy proceeding.

55. *Demolition of roads.*

1. Apart from the demolition of important bridges, a road is most effectively blocked by means of mined charges (*see* Sec. **49**, para. 4) at suitable sites, *i.e.*, where the greatest expenditure of labour and time will

be required to re-open communication either by a deviation or by overcoming the obstacle. Such sites, roughly in order of importance, are :—

i. *Bridges*.—Provided that the stream or gap forms a considerable obstacle. At small shallow streams the approaches are frequently more important.

ii. *Escarpments or steep hillsides*.—In such cases the charge should be calculated so as to blow out horizontally as well as vertically.

iii. *Embankments*.—Labour may often be saved by making use of a culvert, but care must be taken to safeguard the explosives against water.

iv. *Causeways over marshy ground*.—Charges laid in bore-holes will generally have to be used, owing to the wet nature of the ground (*see* para. 3).

v. *Cuttings*.—In deep cuttings with steep sides a more troublesome obstacle will usually be formed by blowing in the sides of the cutting than by cratering the road.

vi. *Woods*.—At points where the undergrowth is so thick, or the trees so close together, on both sides of the road, that to cut a deviation through them will entail considerable labour.

vii. *Culverts*.—With less than 4 feet of cover they are rarely worth demolition.

viii. *Cross-roads, road junctions, and level crossings* are mentioned as providing a means of blocking two communications by one operation.

ix. *Towns and villages* sometimes afford good sites, but, even if all side streets are blocked as well, a way round may often be quickly made by demolishing the walls of a few houses, and there is always ample hard material on the spot to fill in the crater.

The difficulties of repair will generally be much increased if the site selected for the demolition is chosen so that the crater formed will fill with water, as it will usually be necessary, under these circumstances, to pump the crater dry before a solid foundation can be prepared for the new roadway.

Schemes for blocking the communications over a length of front should be carefully co-ordinated to ensure that all roads crossing a given line (preferably a natural feature presenting defiles, such as a river or line of hills) in the zone of demolitions are obstructed. This will prevent traffic being temporarily diverted along side roads while the obstacles on the main roads are being dealt with.

Roads giving access to important demolitions should, if possible, be themselves blocked, so as to delay the transport of materials for repair to the site.

2. Road craters are normally deferred demolitions, since communications will usually have to be kept open as long as possible. Their deliberate preparation, which must not interfere with traffic, will entail much time and labour, and considerable quantities of explosive will be required. When conditions only permit of hasty demolitions being carried out, it is seldom possible to do much damage to roads except at bridges and

culverts. It will, however, frequently be possible to arrange obstacles, as, for instance, by felling trees (most effective in a cutting) across the road.

3. Where the ground is wet, or the means for constructing a shaft and gallery are not to hand, a mined charge may sometimes be laid beneath the road in a series of auger holes, charged with high explosive in waterproof tin cylinders, and fired simultaneously. Pl. **26**, Fig. 1, shows a charge of 600 lbs. laid by this method. In boring the holes their direction should be gauged by means of a templet.

56. *Demolition of railways.*

1. Bridges, viaducts, and tunnels are obviously the most vulnerable points. Their destruction has already been discussed in Secs. **53** and **54.** Much damage may also be done by blowing craters by mined charges at suitable points. Such points are generally similar to those laid down for roads, but it should be noted that the blowing of a culvert in a high embankment will sometimes cause a serious inundation, and that to re-open it is always a tedious operation. Delay action mines are specially suitable for employment against railways, and are very effective when used in conjunction with bridge demolitions (*see* Chap. VIII, Sec. **66**).

The complete demolition of a railway will also include the destruction or removal of the permanent way, the water supply (Sec. **62**), and all signals, both electric and visual (Sec. **61**). Stores of fuel should be removed or burnt.

Station buildings, as a rule, are not indispensable to traffic, and therefore not worth destroying; but workshops and repair shops should, if possible, be burnt out, and their fittings and machinery, together with all other technical tools or apparatus, removed or destroyed.

2. **Permanent way.**—The first step in every case is to interrupt the main lines of rails. If explosive is available, the most economical method of effecting wholesale destruction of the rails is to fire a charge at alternate joints. By this means one end of each rail is damaged. If possible, the fishplate bolts should first be knocked off with a sledge hammer or unscrewed, and the fishplate removed, in order to provide a good seating for the charge, which should be placed on the inside of the rail. The charges should be staggered as shown on Pl. **27**, Fig. 4, so that the maximum number of sleepers may be destroyed at the same time.

A length of railway may be thus destroyed at a very rapid rate by making use of trollies loaded with slabs of gun-cotton, primers, prepared lengths of safety fuze inserted into detonators, port-fires, and lengths of wire for binding the slab against the rail. A party of eight men is required of whom two push the trolley, while two sit on the trolley and prepare the charges and binding slips, handing them out to another two, who place them against the rail. The remaining two men follow at 400 yards distance with port-fires, and fire the charges as they pass. With a little preliminary drill a length of line can be destroyed in this manner at the rate of 3½ miles per hour.

In 1917 a raiding force of cavalry and mounted engineers succeeded, after a forced march of 40 miles across the desert, in destroying 12¼ miles of single track line and demolishing 52 masonry bridges in 1½ hours.

The objective was the Auja railway, Southern Palestine, in possession of the Turks. Engineer detachments were organized and trained to destroy $2\frac{1}{2}$ miles of rail in half an hour, working at a steady jog-trot. Special squads destroyed the bridges. Gun-cotton slabs had been previously cut on the bevel to fit the rails accurately; they were carried in biscuit boxes lined with damp blanket material. The safety fuze was cut so that the charge fired 80 yards behind the last man; this gave an incentive to speed. The explosives were supplied from pack animals and limbered G.S. wagons brought to within about 100 yards of the railway. The squads detailed for the destruction of the rails consisted of 15 men organized as follows :—

No. 1.—N.C.O. supervised.
No. 2.—Carried slabs and clips, and placed 1 slab and clip on site.
No. 3.—Fixed slab to rail with clip.
No. 4.—Inserted primer.
No. 5.—Inserted fuzed detonator.
No. 6.—Cut end of fuze.
No. 7.—Lighted fuze.
Nos. 8, 9, 10, and 11 kept Nos. 2, 4, and 5 supplied from pack animals or wagons and replaced casualties.
Nos. 12, 13, 14, and 15.—Horse-holders.

When steel sleepers are used in the construction of the permanent way, a good method of destruction is to place charges under the centre of the sleepers at suitable intervals. Their effect will be to twist the rails, and make them unserviceable.

3. There are numerous methods of destroying the permanent way without explosives. A track laid with double-headed rails in cast-iron chairs can be very rapidly destroyed by knocking out the oak keys and breaking off the outer lip of the chair with a side blow of a sledge hammer. Four men can destroy about $\frac{3}{4}$ mile of first-class track by this method in one hour. The fishplate bolts should be left untouched, as all the nuts will have to be removed before the rails can be separated and fitted into new chairs.

When plenty of men are available and time is short, sections of the track may be torn up and turned bodily over, down an embankment if possible. All the intermediate fastenings should be left intact. The longer the length the harder it will be to replace without complete separation of the parts. To carry out this operation, two men per yard are ample for the heaviest track, of whom one man per two yards should work a crow-bar or lever to aid the lift. There is no need to remove the ballast.

Rails may be rendered useless by placing them on fires made with wooden sleepers, and twisting them when hot. Rails which are only bent can be straightened on the spot, but if twisted they must be re-rolled at the mills before they can be used again.

If time and conditions permit, the track may be taken up and removed bodily in trains. This, however, requires careful organization and large working parties, and would, as a rule, be undertaken by the railway administration.

When the wholesale destruction of the permanent way is not possible, points and crossings, as being the most difficult parts to replace, should first be attacked (Pl. **27**, Figs. 2 and 3). Portions of the track, at curves in preference to straight stretches, should be destroyed or removed at intervals, by one of the methods described above.

The deliberate destruction of sleepers and rails in stacks will require special measures. Sleepers and baulk timber should be destroyed by fire. Draught holes should be dug underneath the stacks, and oil poured over them. Ignition will be best effected with *thermit* or incendiary bombs. Stacks of rails must be destroyed with explosive. This should be fixed to boards, and passed in between alternate layers of rails. Gun-cotton slabs used in conjunction with high explosive shells will form a suitable charge.

4. **Rolling stock.**—The prevention of serviceable rolling stock, especially locomotives, falling into the enemy's hands may often be of more importance than the destruction of the line itself and its accessories.

Locomotives may be put out of action with explosives by blowing in the fire-box or boiler, or attacking other vital parts. A simple method of causing extensive damage, when no explosives are available, is to drop two or three bolts, stones, or other hard substances under ½ inch in diameter down the blast pipe, to which access may be gained by opening the door of the smoke-box in front of the engine. When the engine is set in motion the obstruction will be drawn into the mechanism, and cause damage which will, as a rule, necessitate the removal of the engine to repair works before it is again serviceable.

Carriages and trucks are best destroyed by burning; in addition, the axles and wheels should be also broken. Trains may be derailed, preferably over an embankment or in a tunnel, by turning a rail.

Locomotives may be rendered useless but still repairable by taking off the injector, the connecting rods, piston, or valve; carriages may be similarly disabled by removing the springs, so as to let the body fall on the wheels and axle.

5. **Electric railways and trams.**—The disablement of the power-station from which the electricity is derived is the most important step to take. Prime-movers, generators, switchboards, &c., should be destroyed or put out of action by removing indispensable parts. Demolitions of rolling stock and permanent way should then proceed on the lines laid down for other types of railway.

57. *Demolitions—rivers and canals.*

Steamers, barges, and other craft may be scuttled by firing a charge in them, placed against one of the sides below the water-line. A charge of 20 lbs. of gun-cotton will be ample to hole an iron or steel ship not protected with a double bottom or wing compartments: 5 lbs. will be sufficient for wooden vessels.

The obstruction of canals and navigable rivers will generally be automatically effected by the destruction of the road and railway bridges passing over them, but, in exceptional cases, it may be necessary to block the fairway by sinking vessels, filled with stone or concrete, across it. It is important that the vessels should sink as rapidly as possible, in order not to be displaced by the current, and that they should settle down on an even keel. The hull should be holed at several points on both sides by charges fired simultaneously, but care should be exercised to cause the minimum of damage to the main structure of the vessel, in order that no risk may be run of its being broken up by the explosion.

Damage, of a more or less permanent nature, may be effected by attacking lock gates, weirs, and sluices with mined charges, and by smashing the machinery for working them. In cases where the water level of the canal or river is above that of the surrounding country, the banks may be breached with mined charges, thus reducing the depth of navigable channel and at the same time creating a formidable obstacle by flooding the surrounding country. The subject of **Inundations** is dealt with in M.E., Vol. II.

58. *Demolition of buildings.*

1. Wooden buildings are generally most easily destroyed by fire. If petrol or pitch is not available, gun-cotton primers, which should be ignited (not detonated), may be used to start the conflagration. Masonry buildings may be gutted by fire, but, if they are to be razed to the ground, explosive will be required to deal with the walls that remain standing.

2. When explosives only are used, buildings may be destroyed :—

i. By concussion charges.
ii. By attacking the main supporting walls with cutting charges.
iii. By mined charges placed beneath them.

3. **Houses, huts, &c.,** which are sufficiently small, or are so subdivided into rooms that high air-pressures can easily be created within them, are most economically destroyed by concussion charges. The charges should be calculated from the formula $C = K\frac{AT^2}{10}$ or $C = m\frac{V}{100}$, according to the nature of the structure (*see* Sec. **51**). All doors, windows, chimneys, and other apertures should be closed and blocked up with sandbags or other suitable material. Where this is not possible, the calculated charge must be increased. When the building consists of several rooms in more than one storey, the charge, calculated from the formula $C = K\frac{AT^2}{10}$ for the whole structure, should be divided up into proportions corresponding with the size of each room on the ground floor. The charges thus subdivided are best placed in the corners of the rooms, if possible against the main supporting walls. They should be fired simultaneously.

4. **Lecture halls, theatres, &c.,** and all rooms of large cubic contents should, as a rule, be destroyed by attacking the main supporting walls and pillars in detail with cutting charges. These should, if possible, be placed inside the building, and fired simultaneously in order that the air pressures produced may increase the effect. Buildings in which it is impracticable to produce conditions approaching a confined space, or where the roof or one of the walls is disproportionately weak compared with the remainder of the structure, should also be treated in this way.

5. Buildings may also be destroyed by placing beneath them one or more mined charges of sufficient strength to blow out the foundations. Cellars may often be utilized. The destruction effected is thorough, but the expenditure of explosives is heavy, and considerable time for preparation is required. The employment of this method will, therefore, be confined to deliberate and deferred demolitions.

Towers, such as those constructed on the North-West frontier of India with walls usually 3 to 4 feet thick built on a solid base about 15 feet high, are generally best destroyed by mined charges buried in the latter, which will bring down the whole structure.

59. *Demolitions in trench warfare.*

1. **Earthworks and stockades.**—The size of cutting or mined charges required to breach stockades and earthworks may be calculated from the formulæ given in Chap. VI. The following data, however, may be useful. For a stockade of earth between sleepers, the total thickness of which does not exceed 3 feet, a charge of 4 lbs. of gun-cotton per foot run of breach untamped and fixed against it will suffice. For a stockade formed of heavy steel rails laid touching one another, a similar charge of 7 lbs. per foot run of breach will be required.

2. **Wire entanglements.**—For cutting passages through wire entanglements a form of portable charge known as a **Bangalore Torpedo** may be used. It consists of a pipe filled with explosive, and is closed at its extremities with wooden plugs, through one of which a hole is made for the safety fuze or electric leads. The other plug is rounded off and smoothed so as to slip easily through the barbed wire. The internal diameter of the pipe should be at least 2 inches, preferably $2\frac{1}{2}$ inches, to cut a passage practicable for infantry in single file. The torpedo, which must be of length equal to the width of entanglement to be cut, should be laid in the wire, at a height equal to about half of that of the entanglement. Pl. **28** shows a typical form of Bangalore Torpedo made up in three 10-foot lengths.

3. **Trench shelters** made of corrugated iron and sandbags or similar materials may be destroyed by concussion charges calculated from the formula $C = K\frac{AT^a}{10}$, taking $K = 1$ (*see* Secs. **35** and **51**).

4. **Reinforced concrete pill-boxes, machine-gun emplacements, &c.,** may be destroyed by the same method, K in this case being taken as 10 (*see* Secs. **35** and **51**).

5. **Mined dug-outs** can seldom be completely destroyed by a hasty demolition. A portable charge of 20 lbs., thrown down an incline and exploded at the bottom, will, as a rule, be sufficient to kill or place out of action the occupants of the adjoining chambers, but to break the timbering, and so bring down sufficient earth to seal the entrance to a dug-out effectively, an untamped charge of at least 50 lbs. is required.

In deliberate demolitions, where conditions permit of the charges being buried in the walls, floor, or roof, the following method may be employed. Charges of 30 to 50 lbs. (according to the nature of the soil) are buried 5 to 10 feet in, at intervals of 10 to 20 feet, and fired simultaneously. The use of earth augers and cylindrical containers (brass cartridge cases are very suitable) to facilitate placing the charge will save much labour. It may often be sufficient to fire such mined charges at the foot of each incline to render a dug-out useless.

An alternative method is to remove the timbering either by hand (starting from the extremities and working back to the entrance) or by burning it out. In the latter case a little paraffin or petrol will be required to start a fire, but once properly alight the timber will be completely gutted throughout, provided there is more than one entrance to create a good draught. With the timber removed, a charge of 25 lbs. of explosive will in most cases bring down sufficient roof and sides to make reclamation impossible.

The destruction of dug-outs tunnelled out of solid rock is difficult to effect. The entrances may be closed by heavy mined charges laid on the lines described for the destruction of tunnels (Pl. **26**, Fig. 2). It is seldom possible, however, to effect such a thorough demolition that the workings cannot be reclaimed by the enemy.

6. **Mine shafts.**—In the destruction of hostile mine shafts and inclines during a raid on enemy trenches, the same difficulties are encountered as in the hasty demolition of dug-outs. It is seldom possible to cause serious damage with small portable charges unless they can be buried behind the timbering. A charge of at least 50 lbs. is required to attain any measure of success with untamped explosive. The limited time usually available during a raid will be in most cases far more usefully spent in reconnaissance of the mine system.

In the exceptional case where the mine shaft attacked is known to pass through loose or shifting soil at a certain depth below the surface, it should be wrecked by destroying the lining at this point; the charge is let down on a rope to the correct position.

Mine shafts and inclines should, as a rule, be prepared for demolition, so that they can be destroyed at a few moments notice in the event of a successful hostile attack. Mined charges should be buried in the walls behind the lining, as described for the deliberate demolition of wells and dug-outs. The firing arrangements should be such that the demolition charges can be fired from a position in rear if so desired.

7. **Shells, explosives, &c.**—H.E. shells and bombs may be destroyed as described in Sec. **38.** They should be buried or placed in a deep trench to minimize the risk of flying splinters.

Captured charges of high explosive may often be destroyed by burning, but if the fire gets too fierce, the remaining explosive is liable to detonate. To avoid this, the material, which should be carefully searched for loose detonators scattered through the charge to excite detonation, may be spread out in a thin line, and ignited at the downwind end. A little petrol or paraffin will assi t combustion if the conflagration is sluggish. Some forms of high explosive, especially if damp, will not burn; the charge, in such cases, is best rendered harmless by scattering it over the ground. Waste explosive should not be thrown into ponds or down wells, as it may poison the water.

60. *Demolition of motor transport and tanks.*

1. **Cars and lorries.**—The destruction of the engine of a motor car or lorry presents little difficulty. A few well directed blows in the vital parts (radiator, magneto, crank case, &c.), or a few pounds of explosive detonated on the cylinders, will suffice. The wheels, axles, and girders of the chassis should be broken, the petrol tank pierced, and available petrol poured over the body which should be set alight. Cars can be quickly disabled by the removal of the magneto and carburettor and cutting the tyres.

2. **Tanks.**—The engine of a tank may be rendered useless in a similar manner to that of a car. Two or three pounds of explosive detonated on the engine will render a tank useless to the enemy.

The sides of a tank may be blown out, so that it may offer no protection, by a concussion charge of ammonal calculated from the formula $C = m\frac{V}{100}$, m being taken as 30 (*see* Sec. **51**).

The demolition of derelict tanks causing an obstruction in roads, &c., may often have to be undertaken. The sides should be blown out in the manner described above, and the shell then broken up by means of suitably placed cutting charges, calculated from the formula $\frac{3}{2}Bt^2$, into pieces sufficiently small to be easily removed.

61. *Demolition of telephone and telegraph systems.*

The destruction or removal of apparatus in the event of a retirement, to prevent it falling into the enemy's hands, will, as a rule, be carried out by the Signal Corps, and, in general, it is only during offensive operations, such as a raid into hostile territory, that this work will fall to the lot of engineer demolition parties, to which, if possible, one or more expert linemen and electricians should be attached.

Exchanges and central offices, being the most vulnerable portions of a system, should be attacked if possible. Instruments, batteries, exchange boards, &c., should be removed or smashed, and wires cut and tangled together. All papers and records of messages should be preserved and forwarded to the General Staff.

Aerial lines may be destroyed by bringing down the poles, cutting all the wires or cables at intervals, and twisting them up so as to render them useless. Porcelain insulators should be broken. If explosive is not available, wooden poles may be felled as follows. A rope is first fixed to the top of the pole or thrown over the wires. The pole is then partly cut through with a saw or axe at about 4 feet from the ground. The stay of the pole is then cut by one man of the party with a file or pliers, and the remainder strain on the rope and bring the pole down. Iron poles are best attacked with explosive, but they may be broken with a sledge hammer.

The time available during raids will seldom permit of extensive damage of this description being carried out. Small gaps in the line can be quickly bridged by cable, and even the complete restoration of poles and wires should not take very long to accomplish. Often more delay may be caused by placing skilfully laid *faults* on the line, in the shape of *disconnections, leaks,* and *contacts.* For technical operations of this nature the services of expert linemen are necessary. Even where faults are made, however, it is, as a rule, desirable to cut down portions of the line as well. The faults may then escape detection at first, and a second examination of the line by the restoring party will be necessary. It may sometimes be more advantageous to intercept messages by *tapping* the wires than to effect destruction.

When, in the case of a premeditated retirement, wholesale destruction is to be effected, a good method of preparing the line for demolition is to fix Mills hand grenades, or bombs of similar time fuze pattern, to the poles. One bomb is sufficient to cut most types of poles in use, provided it is tightly bound on. When the demolition is to be carried out, all stays are cut, and the bombs are fired by a man running along and releasing the striker of each in turn, the time fuze allowing him to get clear before the explosion takes place. The poles should be cut about halfway up, as the broken lengths will then be too short for use as poles in the repaired line.

Subterranean lines.—The site of buried cables may often be detected by the marks, generally blocks of wood or stone spaced about 100 yards apart, used to indicate the position of the test boxes. Lengths of the line should be dug up, and the cables cut to pieces. Iron conduits should be cut, bent, or otherwise rendered useless. If possible, the trench should be filled in, and all traces removed.

Subaqueous lines are most easily attacked at the cable landings, if the site is known and accessible. They may also be picked up under water by dragging with a grapnel. As large a piece as possible should be cut out of the cable. This should be cut into smaller pieces, and thrown into deep water.

62. *Demolition of water supplies.*

If the system of supply comprises a pumping station and reservoirs, these are, as a rule, the most vulnerable points of attack. The machinery should be destroyed or disabled.

Reservoirs, if with earth walls, are best destroyed by mined charges placed in the latter.

Water tanks may easily be rendered useless by knocking holes in the bottom and sides with a sledge hammer and cold chisel, or riddling them with rifle bullets. If explosives are used, a charge, calculated on the basis of 1 lb. of high explosive per 100 cubic feet capacity of the tank, fired inside it when full of water, will be sufficient. The water provides good tamping.

Pipe-lines, if unburied, are simple to demolish: junctions and bends are the most suitable points of attack. If wholesale destruction is to be carried out, charges should be placed at alternate joints. Lengths of buried pipe-line may be destroyed by running off the water and firing a charge of explosive within them, or by digging them up and smashing them by hand. In general, however, the labour involved is seldom justified by the damage that can be inflicted.

Wells sunk in shifting or friable soils may be damaged beyond repair by placing suitable charges so as to cut the lining. If time permits, the well should be filled with earth prior to firing the charges.

Wells in hard soil or rock having little or no lining are best dealt with by exploding a mined charge, sufficient to blow a crater 20 to 30 feet in diameter, at a depth of 10 to 15 feet and about 10 feet from the edge of the well. The exact position of the well is thus obliterated by the crater, and it will be difficult to recover. Logs of trees, machinery, agricultural implements, or any bulky articles at hand may with advantage be thrown down the well before blowing the charge. Their removal will be difficult, as they will jam against the sides. In a heavily shelled area it may often be advisable to use a smaller charge at a lesser depth, in order that the crater formed may pass for an ordinary shell-hole.

In some cases, where it is unlikely that the enemy will obtain information of the existence of a well at a certain spot, it is preferable to conceal it by filling it in and disguising the surface, rather than to draw attention to the presence of water-bearing strata beneath the site by an obvious demolition.

Deep bore-holes may be effectually put out of action by firing two or three dynamite cartridges in the lining at a considerable depth below the surface, but above the natural water level. When possible, the rising main and pump rods should be disconnected and dropped to the bottom of the bore-hole.

CHAPTER VIII.

LAND MINES AND TRAPS.

63. *Definition and general description of land mines.*

Land mines are explosive charges laid in the ground with the object of delaying the advance of an enemy by impairing his morale, destroying his personnel and transport, or interrupting his communications after the evacuated terrain has fallen into his hands.

The quantity of explosive required may be calculated from the formulæ already given for mined charges. The depth of a land mine will depend on the purpose for which it is laid, and thus the charge may vary from a few pounds to several hundreds. High explosive shells and trench mortar bombs may often be suitably used in place of bulk high explosive.

The making up and laying of all land mines is a dangerous operation, and should be carried out by experts.

Wherever land mines are to be used on an extensive scale, a considered scheme, which should be drawn up in conjunction with that for ordinary demolitions, must be prepared. Careful records should be kept of the position and nature of all mines laid. It may often be necessary to mark the position of contact mines with notice boards, pegs, or flags, to safeguard our own troops and vehicles ; these marks must be removed before the retirement has been completed.

Concealment is essential to the successful employment of land mines. The surface of the ground disturbed in the course of laying a mine must be restored to resemble as far as possible the surrounding soil, and all marks which might arouse the enemy's suspicions must be removed. It should also be borne in mind that excavations, &c., carried out during the preparation of the mines may be revealed by aeroplane reconnaissance. Precautions should be taken accordingly.

Land mines may be divided into three classes according to the method by which they are set in operation :—

i. Contact.
ii. Observation.
iii. Delay action.

Anti-tank mines.—A type of land mine, either contact or observation in principle, specially designed for the destruction of tanks, also came into prominence during the War of 1914-19. Contact mines were generally used, an essential feature of their construction being that the mechanism was only set in operation by a tank, while troops and transport might pass over them with impunity. The most suitable form of anti-tank mine for use in future wars is now under consideration, and no details can be given at present.

64. *Contact mines.*

A contact mine consists of a charge of explosive buried below the surface of the ground, as a rule, at a depth of a few inches only, and contained in a specially designed box (or a shell) fitted with some form of contact firing arrangement. The latter is so constructed that pressure on the surface, caused by the passage of troops or vehicles, sets it in operation and fires the charge.

Numerous designs of contact firing arrangements may be employed; in most forms they function by percussion or friction, but in some cases may be electrical in action. In the former the release of a striker fires a percussion cap or ignites friction composition. The *igniter, safety fuze, percussion* (Pl. **2**) is useful for this purpose, the contact mechanism being so designed that pressure on the surface withdraws the safety pin of the igniter. Pl. **29**, Fig. 1, shows a contact mine designed on this principle. With shells the special type of fuze shown on Pl. **30** may be used. The safety pin prevents the mushroom-headed striker from being forced home by an accidental blow in store or transport, and must be withdrawn to make the mine ready for firing. The action of the fuze is then as follows. Pressure on the top of the striker forces it down, shears the shearing pin, and causes the former to strike the percussion cap; the explosion of the cap passes down the tube, igniting the relay detonator, which in turn detonates the main charge through the medium of the primer.

Electro-contact mines require a battery of cells. The electrical connections and contact mechanism are so designed that the firing circuit is completed when surface pressure is applied. A design of tread circuit-closer, similar to that of the ordinary bell push, is shown on Pl. **31**, Fig. 1. In some cases it may be convenient to use a common firing battery to serve a group of electro-contact mines, the electrical connections being so arranged that each mine can be fired by the closing of its own contact only (Pl. 31, Fig. 3). With all electro-contact mines there is a danger of a short-circuit occurring, thus cutting out the contact-closer and causing the premature firing of the charge. The firing circuit should be carefully tested for this defect before the final connections are made, and the apparatus should be protected as far as possible, when it is being laid, from flooding due to heavy rains, or from dews.

Pl. 31, Fig. 2, shows an electro-contact mechanism for railway mines; it was used with success in the campaign in Syria, 1915-18, and is described in detail as follows. The deflection of the rail as the engine passes over it is utilized to make the electro-contact of the mechanism. This deflection is usually small (⅛ inch or less), and the object of the apparatus is to multiply this movement so as to obtain a safe and reasonably certain electrical connection. The device is contained in a circular metal box, with screwed lid, about 3 inches in diameter and 1¾ inches deep, and is thus of a size which can be inserted under the rail without likelihood of detection. A plunger A, extensible by an adjustable screw, protrudes from the top of the box, and bears at its lower end on a system of levers, at the end of which is a contact piece B. Immediately above the contact piece are two fixed insulated terminals C, connected by means of a plug D to the two leads of the firing circuit. In placing the apparatus in position, the top of the plunger is just made, by means of the screw adjustment, to touch the under surface of the rail. The contact piece is normally kept clear of the fixed contacts by means of the clock spring E, but when the rail is deflected the stud F on the plunger actuates the levers which multiply the motion about 8 times, and raise the contact piece into contact with the fixed terminals. The firing circuit is thus completed, and the mine fired. When the direction of approach of the train is known it is best to place the charge about 10 to 15 feet on the near side of the circuit-closer; in these circumstances the apparatus will be actuated by the leading wheels of the engine and the mine will explode under the driving wheels or fire-box.

The concealment of contact mines is generally more difficult than that of other types, since it is essential that at least the contact firing arrangements shall be near the surface of the ground, in order that it may be set in operation by the objective. There is much scope for ingenuity in the skilful selection of sites where traffic is likely to pass, and yet where the mines are likely to escape detection. The mines are, as a rule, *sown* in fields or belts, often of considerable extent, and so spaced as to render it practically impossible for a body of troops or for vehicles to pass through the field without exploding at least one of their number. This may be effected by placing two or more lines of mines at about 6-foot intervals in staggered formation (Pl. 32, Fig. 1), or by connecting the mines together by planks of wood concealed beneath the surface (Pl. 29, Figs. 2 and 3). The charge of explosive is usually comparatively small (5 to 20 lbs.). It is, as a rule, difficult to conceal contact mines in the metalled surface of roads. They may sometimes, however, be placed with advantage on the edge of roads where traffic may still pass, and where the surface is, as a rule, more muddy, and thus affords greater facilities for concealment. A ruse often adopted is to place an obstacle across the road, and to lay a minefield on each side of it, where a deviation would normally take place. A crater forms a specially satisfactory obstacle in such cases, as the earth scattered by the explosion serves to obliterate any traces on the surface of the existence of a minefield (Pl. **32**, Fig. 1).

65. *Observation mines.*

Observation mines are land mines which can be fired from a distance when the enemy is seen passing over them. Electric firing is the normal method employed, but for short distances cordeau detonant may be used. The mines may be laid in front of a defended position in ground over which the enemy is likely to advance or where he is likely to mass for attack. Occasionally billets, &c., may be mined with charges of this type, and fired as soon as the enemy is known to be in occupation.

The use of observation mines is limited as compared with contact mines. The great length of cable required, which, as a rule, must be buried to protect it, is a disadvantage. Moreover, observation mines can seldom be operated with success in a fog or smoke cloud. The progress recently made in the development of wireless telegraphy renders it probable that observation mines may be fired by its agency in wars of the future. One of the main disadvantages of mines of this class would thus be removed, and their field of application much increased.

The size and depth of charges will, of course, vary with the purpose for which the mines are laid, but, in general, they will be larger than contact mines and laid at a greater depth. The destructive effect is sometimes increased by using stones as tamping.

A **Fougasse,** a special form of mine embodying this feature, is shown on Pl. **32**, Fig. 2. A low explosive must be used for the charge, the arrangement being an improvised form of mortar. An excavation is made in the form of a frustrum of a cone, and a charge placed in a recess at the bottom. Over this is set a wooden platform 3 inches to 4 inches thick, on which the stones and other missiles are piled. The axis of the cone should be inclined at about 40° to the horizontal, varying a little more or less as the ground in front is ascending or descending. The sides should form an angle of about 12° with the axis. The L.L.R. must be so arranged that, when the excavated earth is piled on the back edge of the fougasse (as shown on tbe plate), the charge will act in the direction of the axis. A fougasse of thc form shown, charged with 80 lbs. of gunpowder, should throw 5 tons of bricks and stones over a surface about 160 yards long by 120 yards wide. Fougasses are difficult to conceal, and, therefore, advantage should be taken of bushes, undergrowth, and broken ground. They may sometimes be fired automatically by a contact device instead of by observation.

66. *Delay action mines.*

In this type of mine some device is employed by means of which the time of explosion may be delayed for a period varying from a few hours to several weeks or even months after the charge has been laid.

This principle is involved in firing by safety fuze, but an inordinate length of this material would be required to produce a delay of even half an hour. A crude form of delay action device, actually used in the War of 1914-1919, consists of a lighted candle with a train of powder at its base : the charge is fired when the candle has burnt down to the powder. The presence of smoke may lead to the detection of delay devices which depend on slow combustion for their action, while, in the case of the candle, the necessity of an adequate supply of air to support combustion is a further disadvantage.

Where great accuracy in the time of delay is not essential, a suitable device may be based on some slow chemical action, such as the dissolving of a disc of celluloid by acetone, or the erosion of a wire by acid. Pl. **33**, Fig. 1, shows a section of a device in which the latter principle is used ; it was employed extensively by the Germans in the War of 1914-1919. The striker is held up against the spring by a fine steel wire. Prior to placing the device in the charge, the copper containing vessel is filled with a corrosive liquid composed of glycerine, copper sulphate, sulphuric acid, and water. This liquid gradually eats away the steel wire until it can no longer restrain the striker : the wire breaks, and the striker flies forward, firing the cap and thus the charge. The period of delay is regulated by varying the proportions of glycerine and water ; to increase the delay more glycerine and less water is introduced.

It is important to note that an electrolytic action is set up between the copper walls of the containing vessel and the steel wire. Under the influence of this action the erosion of the wire takes place with greater uniformity and regularity than would otherwise be the case. Great accuracy of delay cannot be obtained with devices of this type, and they may vary individually by as much as 100 per cent. The rate of erosion of the steel wire is considerably less at low temperatures.

Pl. **33**, Fig. 2, shows the same device applied to high explosive shell. This form is practically identical in size, shape, and external appearance with the ordinary German H.E. shell fuze, and may be screwed into a H.E. shell in place of the latter. One of its chief uses is to explode abandoned shell dumps after they have fallen into the hands of the enemy ; the close resemblance to the ordinary fuze renders detection among a large number of fuzed shells exceedingly difficult. Owing to the ease of fixing, it is also very suitable for use in ordinary delay action mines composed wholly or partly of shells.

Where extreme accuracy of delay is required, some form of clockwork mechanism is most suitable. Devices of this nature are used commercially in connection with automatical control in the lighting of streets and factories. The mechanism of such apparatus is necessarily rather complicated and expensive, and the possibility of the noise from the ticking of the clock (which can be muffled but not completely silenced) leading to detection is a further disadvantage. Thus, such apparatus should only be used for important work where the more simple, noiseless, but less accurate, chemical devices are unsuitable.

The **Venner time switch** (Pl. **34**) is a typical clockwork mechanism of this class, and provides a means for closing the firing circuit at any desired time on any desired day up to seven days from the time of setting. The circuit is electrical, and the apparatus must be used in conjunction with a firing battery of cells. The clock is set by unscrewing the *dial clamping nut,* and revolving the dial till the correct time is read opposite the *time pointer.* The day and time of firing is set by means of the *star wheel* and the *time setting arm* of the revolving dial respectively. The movement of the *bell crank lever* is actuated by a stud bearing against the cam of the star wheel, and kept up to its work by the *contact spring*. Normally the circuit is broken by the end of the lever raising the spring, thus separating the platinum contacts ; at the time set for firing, however, the deep notch in the cam comes opposite the stud on the lever, thus allowing the lever to revolve slightly in a clockwise direction under the action of the spring, which then closes the contacts.

Delay action devices may often be improvised from material on the spot. Thus, a clock may be made to complete an electric firing circuit at a given time on the same principle as the Venner time switch, or water dripping into a vessel may complete a firing circuit when it reaches the level of the electric contacts. A device based on the same principle consists of a mixture of chlorate of potash and sugar surrounding a vessel into which strong sulphuric acid drips ; when the acid overflows, its action on the mixture is so violent that spontaneous ignition results.

Delay action mines may be used with success in buildings, dug-outs, &c., which the enemy is likely to occupy, and in abandoned shell dumps. They are specially suitable for laying in the permanent way of railways, in bridge abutments, and in roads, with a view to causing intermittent interruption of communications after the damage effected by ordinary demolitions has been repaired. Charges of several hundred pounds buried at a suitable depth may often be used.

Mines of this class offer special facilities for concealment, since, unlike contact mines, no mechanism is required near the surface to set them in operation. Unlimited scope is provided for cunning and skill in deceiving the enemy so that he may fail to locate them. The methods employed should be as varied as possible : but any sign on the surface which might lead to detection must be obliterated as far as is practicable (*see* Sec. **68** for methods of detecting mines).

It will frequently be possible to conceal a delay action mine under cover of an ordinary demolition. Thus, the gallery to a charge under a road may be driven from an adjacent house, which is afterwards blown down to hide the marks of the excavation. In this connection, delay action mines, used in conjunction with the destruction of the abutments of bridges by an ordinary demolition, are often particularly effective. The delay action mine should be so placed that it is not damaged by the ordinary demolition charge, but yet so that its explosion will destroy the footings of a temporary bridge erected on the same site.

On railway lines the employment of numerous small delay action mines with varying periods of delay, causing frequent breaks in the permanent way at irregular intervals, will often be more effective than a few large ones, though the latter may be used with advantage at important points. Mines, each consisting of one 6-inch or 8-inch shell, can be rapidly laid and concealed in the following manner, so that detection is a matter of the greatest difficulty. The mines are transported on a railway trolley, and a vertical hole, 3 to 4 feet deep and of correct diameter for the shell, is bored by means of an earth auger. The mine is laid and covered with the surrounding ballast. All surplus earth excavated is placed on the trolley, and removed from the site so that no clue may be given by its presence on the surface.

67. *Traps.*

The name is descriptive of the nature of these devices, which are essentially improvised contact mines placed with the object of making the occupation of abandoned buildings, dug-outs, &c., dangerous. They will usually consist of comparatively small charges, and are seldom very destructive of personnel. They create, however, an atmosphere of uncertainty, which has a considerable moral effect on advancing troops, and may deter them from using much valuable shelter.

The action of traps is based on similar principles to those already described for land contact mines. Designs must be adapted to suit the local features of each particular case, and, in general, the more varied their form the more difficult will be their detection. Cunning and ingenuity must be employed in their construction.

The following are a few typical instances of traps :—a loosened board, so arranged that when stepped on a charge is fired ; an attractive souvenir or trinket, so attached to a concealed charge that it fires the latter on being moved ; a charge placed in a chimney, so that an explosion occurs as soon as a fire is lighted. Charges may be so connected up that they are fired by any of the following actions :—opening a door, window, cupboard, drawer, &c. ; switching on electric light ; lifting a telephone receiver ; playing a piano ; pulling the plug of a water-closet ; cutting or tripping over a wire.

68. *The detection of land mines and traps.*

Mines and traps laid by a skilful enemy are most difficult to detect, and their successful action can only be circumvented by a thorough and conscientious search. During an advance the country must be systematically examined whenever the enemy is suspected to have employed these devices. Specially trained parties of engineers, acting in close co-operation with the infantry, should be used for this purpose ; they should be equipped with probing bars, electric torches, and wire-cutters.

Mines may be detected from the following indications :—

i. Disturbed appearance of surface soil, breaks in the continuity of weeds, irregularities in the timbering of dug-outs, &c.
ii. Small subsidences in the ground ; these are likely to be accentuated in rainy weather.
iii. Presence of spoil, explosive wrappings, boxes, &c.
iv. Footprints in soil foreign to the surface of the ground, *e.g.*, chalk marks where no chalk exists on the surface.
v. Pegs or other marks placed in the ground without any obvious reason.

Where the enemy is using shells for the explosive charge, the deflection of a magnetic needle by the iron shell case may sometimes be a valuable aid to detection, especially in searching walls of buildings and dug-outs. In such cases search parties should be provided with compasses and dip needles.

Search parties should be carefully instructed in the various types of mines and traps that are likely to be encountered. The discovery of any new form should be immediately reported, and a description rendered of its salient features. By this means all troops can be quickly warned, and other search parties placed on the look-out for devices of the same kind.

The removal or rendering harmless of mines and traps is a dangerous operation which should be carried out by experts. Most explosives are rendered inert by moisture. Any charge, therefore, found by the troops should be *drowned*, when it will become reasonably safe, and may be left for removal by experts.

The extraction of the firing arrangement and detonator of many types of mines and traps may be effected in safety provided reasonable precautions are taken. Some mines and traps are so designed, however, that any attempt to dismantle them will set them off ; the whole charge must be carefully removed intact and destroyed in a safe place. The wires of the circuit of electro-contact mines should be cut, and the electric detonator removed. Delay action devices should be removed immediately they are discovered. Particular care must be exercised in removing those of the chemical type, since, if the period of delay has nearly elapsed, the slightest jar may send them off.

Some notes on the disposal of high explosive charges will be found in Sec. **59**, para. 7.

CHAPTER IX.

BLASTING.

69. *General principles.*

Blasting is the operation of dislodging by means of explosives a mass of material from its bed or position.

Vast quantities of explosives are expended every year commercially on blasting operations, which may be undertaken with one of two objects :—

i. To obtain material for some purpose, as in mines and quarries.
ii. To remove material, as in various engineering works such as the construction of tunnels, and road, railway, and canal cuttings, &c.

The principles are the same and the procedure similar in both cases, but, when the dislodged material is to be used, attention must be paid to its condition after blasting, *i.e.*, size of pieces, &c. For instance, dynamite, if used for blasting coal, would shatter the major portion dislodged to fine dust. It is mainly for this reason that gunpowder and similar low explosives (blasting powder, bobbinite, &c.) are used extensively in coal mines and quarries.

Except in obtaining stone for road making, &c. (for details of which *see* M.E., Vol. V), blasting on active service will practically be confined to operation (ii), when the removal is required of rock, masonry, and hard ground which cannot be efficiently dealt with by pick and shovel unaided. For such work a powerful shattering explosive of the dynamite or blasting gelatine class is normally suitable, but occasionally the use of a slower high explosive in cartridge form, such as ammonal, may be more advantageous in dealing with certain natures of soft rock.

Blasting is usually carried out by means of numerous relatively small charges placed in prepared bore-holes of small diameter. The bore-holes may be drilled either by hand or machinery.

70. *Hand drilling.*

1. The principal tools used in hand drilling are boring-bars, scrapers, hammers, sledges, and wedges.

Boring-bars.—These implements are, as a rule, forged out of octagonal cast-steel bars, though occasionally round iron bars with hardened cutting points and heads may be met with.

The cutting portion of the boring-bar is termed a *bit*. A flat chisel-point (Pl. **35**, Fig. 1) is the most common form, but crown drills, of which a few patterns are shown on Pl. **35**, Fig. 2, are sometimes used in soft rock. The angle between the faces of the cutting edge of a chisel-pointed bit varies with the hardness of the rock it is to be used in, but should not exceed 70° (Pl. **35**, Fig. 3). The width of the bit may vary from 1 to 4 inches, and is slightly greater than the diameter of the bar, so as to enable the tool to free itself readily in the bore-hole; thus a boring-bar having a bit 1 inch in width is made from a $\frac{7}{8}$ or $\frac{3}{4}$-inch bar. The cutting edge may be made straight or slightly curved (Pl. **35**, Fig. 3); the straight cutting edge, although working more freely than those of curved form, is somewhat weaker at the corners and liable to fracture in hard rock.

Bits require frequent sharpening, and in hard rock the operation must be carried out roughly once for every foot of hole bored. The services of one or more skilled smiths with a field forge will, therefore, always be required whenever boring operations are to be carried out on a large scale. Care must be taken that the steel is not burnt in forging, and in tempering it should be let down to a bright straw yellow; a rather softer temper should be used in cold weather.

Boring-bars are made in varying lengths to suit holes of different depths; 7 to 8 feet is about the maximum length. The following sizes of chisel-pointed boring-bars, vocabularized as **Bars, boring and jumping**, are supplied in the Service :—

Width of bit in inches	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3	$3\frac{1}{8}$
Length in feet	7*	$5\frac{1}{2}$*	4	3	2	7*	$5\frac{1}{2}$*	$4\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$

* Chisel-pointed both ends.

Scrapers (Pl. **35**, Fig. 5) are required to remove the dust and chippings produced by the drilling. They are vocabularized as **Scrapers, miners**; they are supplied in two sizes, one with a 2-inch scraper at each end, and the other with a 1-inch; they are both 6 feet long.

Hammers, which preferably should be made of cast-steel, vary from $4\frac{1}{2}$ to 9 lbs. in weight. Two patterns of **Hammers, miners, boring** are issued in the Service, 7 lbs. and 5 lbs. in weight, provided with 30-inch helves.

Sledges may vary in weight from 10 to 16 lbs. They should also be made of cast-steel. The Service pattern, **Hammers, miners, sledge** (Pl. **35**, Fig. 4), weighs 14 lbs., and has a 36-inch helve.

Steel wedges are very useful for work in rock that has been loosened and fissured, but not completely broken down, by explosive.

2. **Method of work.**—In mining work single-handed boring is frequently adopted; that is to say, the miner manipulates both the drill and the hammer himself. In work above ground, where there is ample room for free movement, parties of two or three men usually work together, one man manipulating the drill and one or two striking with sledges.

The first step in putting in a bore-hole is to flatten off the surface of the rock at the point to be drilled; a hole is then started carefully in the exact position and direction, and the strength of the blows is gradually increased until the hole is deep enough to guide the drill properly. After each blow the drill is slightly lifted and turned (about one-eighth of a revolution) in order to produce a round hole: this is called *setting* the drill. The dust produced by drilling must be frequently removed from the bore-hole by means of the scraper, so that the effect of the blow may not be impaired by cushioning. Water should be poured into the bore-hole at intervals. By its use the rate of drilling is considerably increased; the cutting edge of the tool is kept cool, the dust being converted into sludge causes less obstruction, and the injurious effect of stone dust on the lungs is obviated. To prevent the water splashing about, straw is wrapped round the drill at the level of the rock surface, or a perforated india-rubber washer is used.

In hard rock light boring-bars, struck by light hammers, give better results than bars of larger diameter, struck by sledges or heavy hammers.

It is seldom practicable (except by churn drilling, described below) to drill bore-holes of over 7 feet by hand, and with those of over 4 or 5 feet it is usually best to drill tapered holes, the diameter of the bit being reduced by about ⅛ inch every 1 or 2 feet bored. In this connection it will be noted that the Service boring-bars provide for boring two holes each 7 feet long, one tapering from 1½ inches to 1 inch and the other from 3⅛ to 2⅝ inches in diameter. Vertical holes up to a maximum depth of 10 feet may be drilled by a method known as *churn drilling*. The boring-bar used is, as a rule, chisel-pointed both ends, as no sledge or hammer is used; the blow given to the rock being obtained by the direct impact of the falling drill, which is raised by two men to a height of about 1 foot and then allowed to drop. To obtain additional weight the shorter bars used for boring by this method may have a bead or swelling on the stock between, but at unequal distances from, the extremities, as shown on Pl. **35**, Fig. 6. The 5½ and 7 feet Service boring-bars are intended for churn drilling, and are chisel-pointed both ends.

3. **The rate of work** depends on the nature of the material to be bored, the size of the bore-hole, and its direction. Work proceeds fastest in holes drilled vertically downwards; it is about half as fast in horizontal holes; if the direction of the hole ascends, the rate of progress is very slow.

The amount of drilling performed is best measured in cylindrical inches, as the figures stated are then independent of the diameter of the bore-hole.

The following table gives the average rate of work for bore-holes vertically downwards in various materials that may be expected from skilled men, one man manipulating the drill, two men striking with sledges.

Material.	Progress per hour in cylindrical inches.
Granite	16 to 24
Whinstone	21
Slate	24
Limestone (hard)	28
Sandstone	32
P.C. concrete	50
Good brickwork	80

In brickwork a 2-inch hole is best, as the smaller sizes become clogged with dust. It should be noted that the depth driven per hour in inches for any given diameter of bore-hole may be obtained by dividing the figures given in the table by the square of the diameter in inches.

4. **Twist drills.**—For tunnelling in soft rock, twist drills, mounted in hand-boring machines wedged between the roof and floor, provide a more rapid method of boring. Of these the *Acme* hand-boring machine (Pl. **36**, Fig. 1), manufactured by the Hardy Patent Pick Company, is a good example. This pattern was used extensively during the War of 1914-19 in the construction of galleries in hard chalk. The machine is designed to take drills varying from 1 to 2 inches in diameter, the larger sizes being for use only in the softer rock.

71. *Machine drilling.*

Power-driven mechanical drills, if available, will invariably replace hand drilling whenever boring and blasting operations on an extensive scale are to be carried out.

There are numerous patterns of percussive rock drills of various sizes and capacity on the market, a detailed description of which is beyond the scope of this book. The action of all, however, is similar, and consists in a rapid reproduction of the cycle of operations carried out in drilling by hand. A succession of hard blows is given to the bit, between each of which the tool is automatically given a partial turn. In the case of the larger drills the turn of the bit is combined with a reciprocating motion, so that the bit is slightly withdrawn from its seating between each blow; but in some of the smaller patterns, known as *hammer* drills, the turn given to the bit is entirely rotary.

A brief description of an example of each of these types will illustrate the manner in which the majority of machine drills work.

The *Ingersoll-Sergeant* (Pl. **37**), a reciprocating drill manufactured by the Ingersoll-Rand Company, consists of a cylinder A in which the piston D is driven, in a manner similar to that of a double-acting steam engine, by compressed air or steam admitted through the main and auxiliary valves B and C. The shank of the drill-bit K is attached to the extension E of the piston by the chuck L, so that the bit moves with the piston. The head of the piston is recessed to receive a rifled bar F, working in a nut G screwed to the piston. The rifled bar actuates at its upper end a pawl and ratchet mechanism (*see* Pl. **37**, Fig. 2), by means of which a partial turn is given to the piston on each return stroke. The feed of the drill is controlled by turning the crank J. The machine is fitted to the tripod or other mounting by means of the spigot M.

The *Butterfly Jack-hammer* drill (Pl. **38**) is similar in action to reciprocating drills with the difference that the shank of the bit is not connected to the piston. The piston B is driven, in a like manner to that of the Ingersoll-Sergeant drill, by compressed air or steam, the supply of which is regulated in this instance by a butterfly valve H. This consists of a single piece of steel having two wings and a central trunnion, which oscillates to and fro according as the pressure becomes greater or less on either wing, one of which controls the inlet and the other the exhaust. As the downward stroke is completed, the end of the piston B strikes the top of the drill-bit L. Thus the drill-bit does not move with the piston, but is given a blow on the completion of each cycle of the latter. This is an essential feature of all hammer drills. The rotation of the drill-bit is effected by the combined action of the pawl and ratchet at D and the rifling on the front end of the piston B working in the rotating sleeve J, the lower part of which holds the drill-bit.

Reciprocating drills require a firm support to take the intense vibration set up, but the lighter patterns of hammer machine normally require no support, other than that furnished by the operator. In the open, reciprocating drills are, as a rule, mounted on tripods (Pl. **39**, Fig. 1), furnished with telescopic legs each carrying a heavy weight to ensure rigidity. For drilling a number of vertical holes in the same plane a mounting, known as a *quarry bar* (Pl. **39**, Fig. 2), is sometimes used ; this consists of a long horizontal steel tube mounted on weighted legs. The drill may be clamped to the tube at any point along it, so that one setting of the mounting will suffice for the drilling of several holes in the same line. When reciprocating drills are used in galleries, they may be fixed to a column wedged between the roof and floor, as shown on Pl. **36**, Fig. 2.

A large variety of shapes are used for the cutting edge of bits : a few representative patterns are shown on Pl. **40**, Fig. 2. The spiral section steel (illustrated in the last two examples given) plays the part of a conveyor, the twist on the steel being made in such a way that it draws the cuttings from the nose of the bit to the mouth of the hole. The plain chisel-pointed bit usually adopted in hand boring is seldom used, as it is liable to jam or break in fissured rock. Many patterns of bit have a hollow centre through which water or a blast of air is forced to cleanse the hole. Water has also the advantages of increasing the efficiency of the tool and allaying the dust, but it is not generally used with the smaller patterns of hammer drills. Too much care cannot be exercised in the tempering of drill-bits ; the degree of hardness required will depend on the quality of the rock and the weight of hammer used. The cutting edge should be made as hard as possible subject to its retaining sufficient toughness to prevent cracking or breaking.

Compressed air is the motive power usually employed, but most mechanical drills are so designed that they can be operated by steam if desired. The main objections to the use of the latter are the loss of power due to condensation—a serious drawback if the drill is to be worked at any distance from the boiler—and the humidity created by the exhaust steam when the drill is used in a confined space. With compressed air there is little loss of power in transmission, while in tunnelling work the exhaust air assists the ventilation considerably. The use of compressed air, however, necessitates the installation of compressor plant, and for this reason it may sometimes be preferable in above-ground operations to drive the drills by steam from a portable boiler. The compressed air or steam is conveyed to the drills by means of iron pipes, which vary in size according to the distance of the drills from the power installation and the working pressure (40 to 125 lbs. per square inch). The machines themselves are connected to the supply pipes by flexible armoured rubber hose piping capable of withstanding the pressure.

The horse-power required varies with the size and the number of machines; rather less power is necessary to drive by steam than compressed air. With the latter a 12 h.p. compressor set is sufficient to drive one small hammer drill, but the horse-power required per drill is proportionately reduced as the number of drills operated by one set is increased, and a 100 h.p. compressor set will drive 15 hammer drills. Air compressor plants of several hundred horse-power may often be installed where prolonged and extensive blasting operations are to be undertaken, but such conditions are seldom likely to arise on active service, where the demand will principally be for light portable sets capable of operating one or more small drills. A 13 h.p. compressor set, driving one Butterfly jack-hammer drill at a working pressure of 60 lbs. per square inch and using bits up to 2-inch, was employed with success in the construction of dug-outs in rock on the Italian front during the War of 1914-19. The whole equipment weighed under one ton, and was easily transported on a G.S. wagon. Pl. 40, Fig. 1, shows a portable compressor set (manufactured by the Ingersoll-Rand Company) designed to drive four jack-hammer drills. It is driven by a 40 h.p. petrol engine. The total weight of the plant, which may be either horse or tractor drawn, is 4,000 lbs. A smaller portable set designed to drive one hammer drill is also made by this firm.

Holes up to 30 feet or more in length may be bored with mechanical drills, but with the lighter machines 10 to 12 feet is about the limit, and it is seldom that holes of a length greater than this are required in ordinary work.

The superior rate of progress of machine as compared with hand drilling may be gauged from the fact that many machines are designed to give a blow to the bit 600 times a minute and few less than 200 times. A rate of advance of 4 inches per minute in hard granite is by no means excessive. Against this must be set the time taken to insert fresh lengths of drill, clean the hole, and, when a new hole is to be commenced, remove the machine and set it up in the new position. Even so machine drilling, especially in the case of holes of large diameter, may often be as much as ten times as fast as hand drilling, and in hard rock an average overall rate of progress of about 5 feet per hour may be expected.

(For instructions on the application and use of compressed air and steam power reference should be made to M.E., Vol. VIII).

72. *Position of bore-holes.*

1. **General principles.**—As the major portion of time and labour in blasting operations is spent on the drilling of holes for the blasts, it is most important that these should be placed so as to obtain the best effect. To determine the position of each bore-hole, it is necessary to consider the effect of the explosion in relation to the other bore-holes and the bounding faces. When several free faces are within the range of one blast, the bore-hole should be so placed that the effect of the charge is about equal in the direction of each face, otherwise nearly the whole of the explosive force may be expended in the direction of the weakest face (the L.L.R.), and a minimum of material will be dislodged. The ratio of the shortest to the longest line of resistance should not exceed 2 : 3 if the maximum effect is to be obtained. Broadly speaking, the greater the number of free faces exposed the larger the amount of material that can be dislodged by a given quantity of explosive, the limit being reached on the one hand in the case of an unattached block, or so-called *freestone*, in which all six faces are free, and on the other in the case of an untouched breast of solid rock, as in a vertical cliff.

In general, a few long bore-holes are more efficient than a larger number of shallow ones. A considerable amount of time is spent in setting up drills, moving tools to a new position, and starting a fresh hole. Moreover, the amount of material detached increases with the cube of the depth of the charge. Thus, within limits, the deeper the holes the smaller will be the number of feet drilled per unit of volume excavated. The most convenient length of hole for practical work in open excavations using machine drills is 8 to 12 feet. It is, as a rule, preferable in tunnelling work to use holes of rather shorter length (5 to 10 feet).

Another point that should be given consideration is the placing of bore-holes so that the dislodgement of material may be assisted by gravity, and thus a minimum of the explosive force is expended in lifting the rock to be broken down. In open excavation work it is generally best to drill the bore-holes vertically downwards, and to place them so that the shortest line of resistance is horizontal and the longest vertical, as then the weight of the rock assists the breaking down.

The possibility of firing the whole series simultaneously is a factor affecting the distance apart at which the bore-holes should be spaced. For example, suitably proportioned shots placed at *A* and *B* on Pl. **41**, Fig. 1, if fired separately, would form the craters *CAD* and *EBF*, but, if fired simultaneously, their combined action would remove the section *GDEH* in addition.

All blasting operations must be carried out on a definite system based on the principles stated above. If holes are drilled in a haphazard manner, the waste of labour and explosive may be enormous.

2. **Open excavations,** such as cuttings through rock, will normally have two free faces, the top and the breast of the rock. The bore-holes should be driven vertically downwards, as shown on Pl. **41**, Fig. 2, the depth of the bore-hole varying from once to three-quarters of the depth of the face AB. The distance of the bore-hole from the face should vary from two-thirds to three-quarters of its length, according to the toughness of the rock and the diameter of the hole. The spacing of the bore-holes will depend on

these factors and on whether the shots are fired separately or simultaneously, and may vary from two-thirds to twice the depth of the bore-hole. The most satisfactory distance can only be determined by trial and error. Breast-holes may sometimes be driven as well to blast out the rock at the base to formation level (*see* Pl. **42**, Fig. 1).

When the depth of the cutting is beyond the capacity of the drilling machines, the face should be divided up into a series of stepped workings known as benches. The depth of the benches will vary according to the depth of holes that can be drilled with the plant available; 10 to 12 feet benches are very suitable for machine drilling, while for hand drilling they should be about half this depth. The width of the benches should be about 10 or 15 feet. Pl. **42**, Fig. 1, gives an example of the arrangement of benches and bore-holes in driving a cutting through homogeneous rock under ideal conditions.

3. **Tunnelling and shaft sinking.**—In tunnelling work there is normally only one free face; the amount of drilling necessary and explosive used per ton of rock are thus considerably greater in comparison to that in open excavations. In very soft friable rock one or two shots fired in the vertical face may loosen the rock sufficiently to enable the pick to complete the work without further aid. The holes for the shots should, if possible, be drilled at an angle between 60° and 45° to the vertical face (Pl. **41**, Fig. 3), but in small headings the boundary walls may only permit of the use of the drill at a slight inclination to the face. In hard rock, on the other hand, a large number of bore-holes must be drilled. The method employed is to drill some of the holes (called the *cut* or *cut holes*) in such a manner that they will remove a core of the rock from the solid face of the heading, thus exposing an additional free face for the remaining bore-holes to work on. The *V* and the *pyramid* cuts, shown on Pl. **42**, Figs. 2 and 3, are the most common forms employed. The breaking-in shots AA are fired together first, and then the remaining bore-holes BB also simultaneously. The spacing of the bore-holes and the number required will, of course, depend on their diameter and the nature of the rock. In very hard rock or large headings it may be necessary to fire more than one series of shots in addition to the breaking-in shots, those nearer the *cut* being fired first.

The method followed in sinking shafts through rock is similar to that adopted in driving headings, but rather heavier charges will be required owing to the additional force required to lift the rock.

4. **Fissured and stratified rocks.**—The presence of natural *backs* and fissures in the rock may play an important part in determining the most advantageous position of the bore-holes. Before commencing drilling a very careful examination of the lie of fissures and the stratification of the rock should be made. Their effect can only be gauged by experience and careful observation.

Rocks having a pronounced stratified formation are often difficult to blast, as the gases produced by the explosion tend to leak away along the junctions of the strata before they can exert their full effect. Generally speaking, a bore-hole should not be drilled across the joints of the strata. If the individual strata are thick, the bore-hole may be driven at right angles to them, but should be wholly in one stratum. As the surfaces of the strata cohere much less strongly than the mass of each one, their junction is nearly equivalent to a free face. Thus, on Pl. **41**, Fig. 4, the bore-hole AB will dislodge the section ABDE, while if the bore-hole be deepened to C a larger charge must be used, but the action of the shot fired will still be practically confined to the section of rock ABDE, and part of the effect of the explosion will be wasted. If the strata are thin, the bore-hole should be driven parallel to them, so that it is entirely in one stratum (Pl. **41**, Fig. 5).

73. *Nature of charges, and loading and tamping.*

1. Extended charges are normally used in blasting operations. They are naturally suitable for this work, since the diameter of the bore-hole is always very small in comparison with its length. Generally speaking, the charge should not occupy more than two-thirds to three-quarters of the length of the bore-hole, but within these limits it is, as a rule, advantageous to fill as long a length as possible with explosive. If the charge to be used is small, this can be effected by using a smaller bore-hole, or by loading with a lower grade of dynamite or blasting gelatine.

Concentrated charges, on the other hand, may be preferable under certain conditions, especially where very deep bore-holes are employed and there are several free faces. The space for the charge is obtained by firing a small chambering charge, usually two or three dynamite cartridges, at the bottom of the hole. It is important that the charge be well tamped. If a large chamber is required, it may be necessary to fire two or three chambering charges in succession, using a slightly larger amount of explosive each time. The bore-hole should be vertical or nearly so, as otherwise it is difficult to fill the chamber with explosive. The use of an explosive less rapid than those of the nitro-glycerine class is, as a rule, preferable for charges of this nature, and loading will be facilitated if it is in powder form. Ammonal or amatol is very suitable.

2. **Loading.**—The normal method of loading bore-holes is as follows. The size of the 2-oz. cartridges, in which dynamite and blasting gelatine are generally issued, is 3½ inches long by ⅞ inch in diameter. For small bore-holes the cartridges should be inserted one at a time, and for the larger ones two or more should be tied together according to the diameter of the hole. Each cartridge or bunch of cartridges should be gently squeezed home with a wooden rammer (Pl. **19**, Fig. 3); an iron implement should never be used for this purpose, and on no account should undue force be exerted. The preparation of the cartridge containing the detonator has already been described in Sec. **37**, para. 3; it should be inserted last, and should be in close contact with the remainder of the charge, but must not be squeezed home. The procedure is similar when other natures of explosive are used.

3. **Tamping.**—Dry sand forms the most suitable tamping; about 8 to 12 inches of this material, which should be placed immediately above the explosive, but not rammed, is sufficient. Failing sand, damp clay or mud, gently rammed home, may be used. Tamping in the case of nitro-glycerine explosives is by no means essential, and many authorities recommend the addition of an extra cartridge (two or three for bore-holes of

large diameter) in its place. Tamping, however, must be used for explosives less rapid than dynamite.

74. *Calculation of blasting charges.*

It is quite impossible to determine by calculation the exact charge necessary, as this will depend on many factors which may vary with each successive blast. The number of free faces and their relative position to the charge, the presence of fissures, &c., whether the charges are fired simultaneously or separately, are all points which have a direct bearing on the explosive effect, as explained in Sec. **72**. The toughness of the rock, the strength of the dynamite or other explosive used, and whether the charge is concentrated at the bottom of the bore-hole or extended along the greater part of its length, are further important factors. A more or less correct estimate of the charge required can only be gauged by general experience and a special knowledge of the peculiarities of the material in which the blasting operations are undertaken.

All that can be done here is to give, as a guide, formulæ for average conditions, which must be modified to suit the circumstances by the process of trial and error. Except where the condition of the dislodged material has to be considered, as in quarrying building stone, it is seldom that any harm will result from the use of a charge rather in excess of that necessary, while, on the other hand, if the charge employed is too small, the time and labour expended in drilling and loading the hole may be entirely wasted. Hence in excavation work, when in doubt as to the correct charge, the tendency should be to overestimate rather than underestimate the exact amount of explosive required

In the case of extended charges the amount of explosive necessary varies directly as the length of the bore-hole, and as the square of the length of the line of least resistance from the bottom of the bore-hole to the face (*i.e.*, AB on Pl. **41**, Fig. 3). Thus, if C be the charge in ounces, and L the length of the L.L.R. in feet, then—

$$C = kvL^2$$

where k is a constant depending on the nature of the rock and the explosive used, and v is a constant depending on the number of free faces.

k will, of course, vary considerably under different conditions, but in hard rock, using 80 or 75 per cent. gelatine or dynamite, it may be taken at the start as equal to 1; the value can be adjusted, if necessary, as experience is gained from the results of the blasts.

When there is only one free face, $v = 1$ should be taken in calculating the charge for the breaking-in shots. For the subsequent enlarging shots working to the cut, $v = \frac{3}{4}$ should be taken. If there are two free faces, as on Pl. **41**, Fig. 2, $v = \frac{1}{2}$, or in other words half the charge required for one free face is sufficient when there are two. Hence, for blasting in hard rock with dynamite No. 1, if no definite value for k has been determined by trial and error, the following simplified formulæ may be used :—

$C = L^2$ (one free face. Breaking-in shots).

$C = \frac{3}{4} L^2$ (one free face. Enlarging shots).

$C = \frac{L^2}{2}$ (two free faces).

Charges may be still further reduced when there are more than two free faces, but the conditions vary so much that it is impossible to give definite values for v.

The size of charge required will also be dependent on the other variants mentioned in Sec. **72**, such as presence of fissures, stratification of rock, &c., but it is impossible to give formulæ which take these factors into account. Modifications in the charge must be made based on experience and trial and error.

It will be noted that one of the ruling factors determining the size of a charge is the length of the bore-hole, although, as a rule, the explosive will only be distributed along a portion of it. It is clear, however, that, if this factor were omitted, the same charge would be required for the bore-hole AC as that for AB (Pl. **41**, Fig. 6). If the charge were correct for AB, it would probably be inadequate in the longer bore-hole, producing only a crater of ECF in the face DF and failing to break through to the face DA.

A larger charge than would otherwise be necessary must be used for material under exceptional pressure, as for instance a pillar of rock or masonry supporting a heavy overburden. A charge half as large again is usually sufficient, but, where the pressure is very great, it may be necessary to double the charge.

For concentrated charges in hard rock, using ammonal, the formulæ $C = \frac{L^3}{6}$ or $C = \frac{D^3}{50}$, where C is the total charge in lbs., L the line of resistance in feet, and D the diameter of crater to be formed in feet (*see* Sec. **49**), may be employed when there is only one free face. The approximate diameter of crater formed when the L^3 formula is the basis of calculation will be $2L$. The corresponding formulæ for an 80 per cent. dynamite or blasting gelatine are $C = \frac{L^3}{10} = \frac{D^3}{80}$.

Where there are two free faces, the charge, which should be calculated from the L^3 formula, may be halved, provided that the ratio between the lines of resistance to the two faces does not exceed 2 : 3. L should be taken as the longer line of resistance. A further reduction in the amount of explosive may be made where the number of free faces exceeds two. Concentrated charges used for blasting rock under heavy pressure must be increased as for extended charges.

75. *Miscellaneous blasting operations.*

1. Blasting may sometimes be of assistance in stony or frozen ground which is too hard to loosen easily with a pick. A series of holes should be made in the ground with a jumping bar, and charged in the ordinary way. The charges may be calculated from the L^3 formula already given, about half the quantity of explosive required for hard rock being sufficient. The distance apart of the holes should not be more than twice their depth. Dynamite or blasting gelatine should not be used in frozen ground if other suitable explosive is available, owing to the liability of nitro-glycerine to freeze.

2. The following method of digging an emergency trench in easy soil under heavy fire may sometimes be employed. A furrow about 12 inches

deep and 4 inches wide, conforming to the shape of the trench in plan, is dug by men lying prone and using scoops or entrenching tools. In this a charge of ammonal of about 3 lbs. per foot run contained in a flexible canvas pipe is laid and fired. A crater trench providing 3 to 4 feet of cover will be formed, under protection of which the remainder of the excavation may be completed.

The levelling of breastworks and similar mounds of earth may sometimes be most economically carried out with the aid of explosives. The charges are laid in bore-holes, spaced at suitable intervals and excavated with earth augers (Sec. **36**).

3. Explosives may sometimes be used to clear a passage through thick ice. In the case of an ice-bound river, operations should be commenced, if possible, at the down-stream end, as the detached ice will then be carried away by the current. A series of bore-holes should be driven through the ice, the interval between each being from three to five times the depth of the ice, so as to break it up into slabs some 20 to 30 feet square. A charge similar to that used for frozen ground will suffice. The effect will be increased if a series of bore-holes is fired simultaneously. A powerful shattering explosive gives the best results, but the liability of nitro-glycerine explosives to freeze in contact with the ice, even if thawed just prior to loading, is a great disadvantage to their employment. Blastine is very suitable; the cartridges should be waterproofed by being dipped in melted paraffin wax.

4. The yield of a well (or bore-hole) may sometimes be increased by firing at its base a few sticks of dynamite, which has the effect of tapping a larger area through fissuring the water-bearing strata. Small charges of explosive may also be employed in some cases to drain a water-logged and impervious stratum overlying porous strata; the fissures produced by the explosion disintegrate the soil, and provide channels by means of which the water may escape.

PART II—MINING.

CHAPTER X.

MILITARY MINING TACTICS.

76. *Historical sketch.**

Military mining belongs to the oldest application of engineering to the art of war; underground attacks during sieges, as well as the complementary operations of defensive mining, were used at least four centuries before the Christian era. It is recorded that long before the use of gunpowder many places were captured by gaining access either through mine galleries or through breaches in the walls made by undermining. Gunpowder was first used in mine warfare in 1487. After this date underground attacks became more common, for mining was a more direct and effective application of explosives than that employed by means of the crude artillery of this early period.

The effectiveness of artillery gradually improved, but, up to the time of the introduction of rifled guns during the American Civil War, it was not powerful enough to breach the masonry fortifications then used, except at comparatively short range. Mining, therefore, continued to be an important weapon of siege operations, and was effectively employed during the Crimean War. At the siege of Sebastopol over five miles of galleries were driven by the opposing armies, and the French alone consumed over 130,000 lbs. of black powder. The scale of these operations far exceeded that of any previous wars.

With the exception of the Crimea, the campaigns of the latter half of the nineteenth century afforded practically no instances of military mining, and it began to be held by many that, with the improvement in artillery, mining had become of little importance. Though some military engineers continued their study of mine attack and defence, this matter in general was given little attention.

Mining, however, was again revived in the Russo-Japanese War. Underground operations played an important part in the siege of Port Arthur, when for the first time modern high explosives were used for mine charges. More significant in this war was the attack and defence of trenches by mines in the Chaho Valley—the first instance of the employment of mining against field fortifications.

The use of mines in the Russo-Japanese War seems to have excited little interest among European staffs. This was, no doubt, largely due to the fact that it was generally held that any European war of the Great Powers would be quickly ended by one short decisive campaign. Few believed that a war with modern weapons and armies could last long enough to make possible the protracted sieges in which underground attacks would be useful. For the same reason, the employment of mining in trench warfare appears to have been given little consideration.

* Numerous extracts from a paper entitled "Military Mining," by Alfred H. Brooks, formerly Lieutenant-Colonel of Engineers, U.S. Army and Chief Geologist of the American Expeditionary Force, are contained in this section.

Hence military mining had come to be regarded as of small importance, and at the outbreak of war in 1914 none of the European armies had received much training in the art. Underground defences were, of course, still used as a part of strong fortifications, and, in their construction, troops like the German fortification engineers received training in underground work. There were, however, hardly any trained miners in European armies, though, in theory at least, the pioneer troops of all countries had had some practice in the art.

The long period of position warfare which obtained on the Western front during the War of 1914-1919, produced conditions which, up till then, had been associated only with fortress warfare. Improvements in weapons during the years preceding the war had conferred advantages on the defence, the consequences of which it was difficult to foresee; the strength of entrenched positions behind wire entanglements had become almost the equivalent of that of permanent fortification of an earlier period. The two great opposing systems of field-works extended almost unbroken from the English Channel to the Swiss border, and, therefore, presented no vulnerable flanks. It soon became evident that decisive results could not be obtained by frontal attacks delivered on the then accepted methods of field warfare. A deadlock had been reached, in which many of the features peculiar to siege warfare were reproduced on a vast scale.

In many places the trenches were but a few hundred feet apart, and the tactical situation was favourable to mine attacks. In these the Germans were the first aggressors. The attack was apparently part of a general plan, for in December, 1914, German mines were exploded in a number of sectors extending from Lorraine to the plains of Flanders. As a result, the Allies were compelled to take underground defensive measures. Soon, mining operations developed on so large a scale that a great force of special troops had to be organized for the purpose. Both the Allied and the Central Powers were obliged to fall back on the skill of men trained in mining during civil life. By the middle of 1916 the British Expeditionary Force alone had some 25,000 troops employed in underground work, and it is probably a conservative estimate that at least 60,000 were employed by the opposing armies on the Western front.

The Germans made their most vigorous attacks in the British sectors. The first of these found the British unprepared, but this condition, as has been shown, was overcome, and by the end of 1915 they were ready in many places to take the aggressive. During 1915 and 1916 mining and countermining continued on an unprecedented scale without notable gains on either side, but early in 1917 the British had in most places gained control of the underground situation. After this, the Germans contented themselves with maintaining their defensive positions.

Some brilliant mine attacks were also made by the French Army, but owing to their inability to spare the large number of men required and to the less favourable geological conditions, underground warfare did not develop on so large a scale on their front. A few instances of mining also occurred on the Italian front and during the Dardanelles campaign.

Aggressive mining by the British finally culminated in the attack on the Messines Ridge, where, on 7th June, 1917, 1,000,000 lbs. of explosives were discharged on a front of 10 miles (*see* Pls. **43** and **44**). This is the greatest mining operation in the history of warfare, and with it underground attacks practically ended, though both sides continued to hold their defensive positions until the close of trench warfare in 1918.

The decline of mining activity in the latter period of position warfare on the Western front may be traced to the gradual change in the conduct of the defence. In the earlier stages of the campaign, conditions conducive to the maintenance of a strongly-held front line obtained, and suitable objectives for mining enterprises were presented. With the continual growth of armament and increase in shell power of both sides, however, the tendency to develop defence in depth became more and more marked. The continuous front line was replaced by weakly-held forward observation posts, supported by strong positions situated well to the rear. By the close of 1917 it had become a recognised principle that the main centres of resistance must be sited beyond the range of hostile trench mortars and, incidentally, that of underground attack. Further, the isolated front line posts did not create those favourable conditions for the execution and concealment of mining operations which had been a feature of the solidly constructed forward trench systems of the earlier phase. Thus, the trend of evolution which position warfare tactics had taken tended more and more to discount the value of mining as a means of assisting the infantry assault.

Though the primary purpose for which mining troops had been organized gradually disappeared, the same conditions which eventually led to an almost complete cessation of mining activity called for skilled underground work in another direction. Underground protection on an ever-increasing scale was required as a counter-measure to the heavy bombardments to which all positions were liable; the bulk of the mining personnel during the position warfare period of 1917-18 were employed in fulfilling the insistent demands for dug-outs, sub-ways, and similar mined works.

In view of the probable increase in the range and power of heavy artillery, and of the offensive power of bombing aircraft, the demand for underground protection in civilized warfare is certain to render necessary the inclusion of a strong mining force as an integral part of modern armies, quite apart from considerations as to the recurrence of mine warfare.

Those who directed the active period of mine warfare generally concede that the results achieved were seldom commensurate with the expenditure of personnel, material, and time, and it is improbable that military mining will ever again be employed so indiscriminately as it was during the War of 1914-1919. The latter stages of position warfare in this campaign clearly demonstrated that, given large resources of artillery and tanks, mining ceased to play a useful part in assisting the assault. It would be unwise, however, when forming conjectures as to the utility of mining in future wars, to draw sweeping conclusions from this fact. It is clear that armies cannot commence a campaign with a store of the vast quantities of war material that were gradually amassed in France and Flanders. Thus, it is not improbable that, whenever position warfare develops in future wars, the conditions at the outset will be of a comparatively primitive nature and similar to those which obtained in the earlier phases of the deadlock on the Western front. Under these circumstances the occurrence of favourable opportunities for underground attack are not unlikely.

Mining, be it remembered, though slow, is simple to carry out, because elaborate apparatus is not required; the pick and shovel are the only essential tools, and all auxiliary plant can readily be improvised. The repeated use of mining from earliest times to the present may largely be ascribed to this independence of the products of the foundry and machine shop, an inherent advantage which still obtains.

The utility of mining for the destruction of strong points favourably located for underground attack and not easily reducible by other means cannot be denied. Compared with artillery, its weak points are the time required for preparation and the very limited extent to which a change in objective can be made. On the other hand, artillery produces results by cumulative effect; the defence may have been able to prepare alternative defences meanwhile, and the damage inflicted cannot be known with certainty. A mine, given that its preparation has not been detected, operates without warning, and completely demolishes at one blow everything within its radius of action, while, apart from the material damage, the moral effect produced by the explosion and earth tremor is a potent factor in disorganizing the defence. Thus, though favourable opportunities for military mining may seldom occur, it is an effective weapon that every army must be prepared to employ, both for the offence and the defence.

77. *General considerations.*

1. The rôle of mining in war is to facilitate the advance of the infantry against fortified positions by the destruction of defences and personnel and by the moral effect on the garrison. Conversely, its employment is necessary in warding off an enemy mining attack.

Mining may be classified as **Offensive mining,** that is, operations against the enemy's surface defences (used in the broadest sense of the word to include personnel, machine guns, dug-outs, &c.), and **Defensive or Countermining,** that is, operations against hostile underground workings. Defensive mining may further be divided into **Protective mining,** undertaken as a precautionary measure at localities exposed to underground attack, and **Mine fighting,** active operations against hostile mining.

Both offensive and defensive mining may sometimes be combined in one operation; the enemy being engaged by some galleries, while others are pushed forward to the objective.

2. The principles of mine warfare are the same as those of surface warfare, and differ only in their application and in the relative values of the factors under the altered conditions. For example, protection from surprise can only be secured below ground by listening. The ear replaces the eye as a means of obtaining information; listening instruments take the place of field glasses. Bad listening ground may be compared to forest or enclosed country, and good listening ground to an open plain. Again, the ratio of time to space is altogether altered, for progress is very much slower; an advance of one foot underground may be taken as roughly equivalent to a mile on the surface.

3. Conditions rendering mining possible will occur only during war of position, and even then suitable material objectives are unlikely to present themselves until the enemy has been driven back on the centres of resistance of his main defensive position. Siege warfare, however, may differ in certain characteristics from other natures of position warfare. In siege warfare ground is of far greater importance, and the objectives are likely to be more material, while, if the investment be complete, limited resources of explosives, timber, &c., may hamper the defence and thus render a break-through more feasible. On the other hand, surprise will be more difficult, since probable objectives will be more clearly defined, and protective systems will generally have been constructed in advance by the defenders. Against field defences the moral effect of a successful mine explosion will frequently be out of all proportion to the material damage done, and the main object of a mining offensive should, therefore, be so to demoralize the enemy as to render a surface attack overwhelming.

4. Again, geological conditions must be favourable. Some soils, water-logged strata for example, cannot be mined with the apparatus available on service, and some only by means which preclude any reasonable hope of effecting surprise. The value of an accurate geological survey is, therefore, apparent.

Success in mining depends almost entirely on surprise and speed of working. These two conditions, though frequently antagonistic in practice, are both primarily based on good organization. Generally speaking, surprise is essential in offensive mining, so much so that it will not usually be worth while to continue an attack if the enterprise is discovered, while in defensive mining speed becomes more and more important as the opposing galleries are located.

The rate at which the spoil (*i.e.*, material excavated) can be evacuated is frequently the determining factor in the progress of the galleries. Very careful organization and supervision are, therefore, necessary, not only in ensuring silent and efficient tramming and hoisting in the mines, but also in regulating the transport to the dumps on the surface.

The concealment of spoil and all surface works connected with mining is always important, and is generally vital to the success of offensive operations.

Good ventilation (Sec. 97) in the mines is essential: not only do men work slowly in a vitiated atmosphere, but, in mine fighting, the galleries must be cleared quickly from *mine gas* (the products of mine explosions, *see* Chap. XIV) in order to permit of a speedy resumption of work. The deadly nature of this gas, of which carbon monoxide is the most important constituent, must be impressed on all ranks. The difficulty of dispersing mine gas in some soils will frequently have a marked influence on mine fighting tactics.

The timbering, drainage, and lighting of underground systems are problems which must be given careful consideration. Details of methods are described in Chap. XII.

The importance of listening in all mining operations has been referred to in para. 2; scientific methods must be employed if the fullest information is to be obtained from this source; it is the principal means of detecting the existence and nature of enemy underground activity (Chap. XV).

5. Besides being a very slow process, mining absorbs a large number of men, not only in the actual tunnelling, but also in the transport of material and the disposal of spoil. Offensive mining should, therefore, never be undertaken except as part of a definite tactical scheme in which the effect of the explosions will be exploited by the infantry. The blowing of isolated mines in order to assist a trench raid, or merely to cause small casualties (but without a permanent advance being intended), is never justifiable in view of the time and labour involved. Further, such enterprises will almost invariably result in the formation of an active mining front, on which the mine fighting assumes dimensions altogether incompatible with the results obtainable. These objections, however, do not apply with equal force to sectors where mine fighting is already in progress, when opportunities may occur for small offensive enterprises without undue labour.

Against an underground attack the only defence of the point threatened is countermining, and the significance of the mere threat of hostile mining is frequently sufficient to make protective measures advisable at localities where such an attack may reasonably be expected. Mine fighting, however, rarely leads to decisive results, and should be avoided when possible, unless for the attainment of some definite object.

It must never be forgotten that mining is a means to an end, and not an end in itself. Underground tactics and strategy, therefore, must be subordinated to surface requirements. Co-operation with the infantry in defensive work is essential, and they in turn must be acquainted with the capabilities and limitations of mining before it can be employed to the fullest advantage.

78. *Offensive mining.*

1. Given the two essential conditions of sufficient time and mineable ground, the chief requisites for a mining offensive are a soft stratum that can be excavated with little noise, and facilities for the concealment of surface works (spoil dumps, shafts, &c.). Other advantages are a short distance to tunnel and adequate objectives. It must, however, be remembered that the more obvious the advantages the more likely is the enemy to have taken protective measures. Physical difficulties, provided they can be overcome, are not always disadvantages.

2. Surprise, the essence of an offensive, depends very largely on the possibility of silent work; the soil must be of a consistency that will permit of reasonable progress without picking or blasting. It may be possible without quiet methods of excavation to surprise a careless or unsuspicious enemy by deep mining (or by confusing and deceiving him with other workings), but the chances of detection are enormously increased. No ground can be mined absolutely silently, and the more that noise is unavoidable the greater the depth at which the offensive galleries must be driven, if they are to escape detection; hence the value of a deep workable stratum. Soft and, therefore, favourable strata will frequently only extend a short distance below the surface; shallow galleries, however, run great risk of discovery (as the sound of work can be heard above ground or from dug-outs), and are liable to destruction by shell fire (*see* Sec. **120**, para. 4).

Further, should the objectives be reached, shallow mines have a comparatively small radius of destruction.

3. The concealment from ground and aerial observation of all surface works that may give a clue to the existence of mining operations is equally important, if surprise is to be attained. Every advantage must be taken of accidents of the ground, and skilful use must be made of camouflage. This concealment, which must cover all stores of timber, spoil dumps, tramming, &c., and must precede the actual commencement of work, demands the most constant attention and careful organization.

4. The galleries will usually be directed straight for the objectives, unless there is less likelihood of detection by the adoption of a more circuitous route. Branches will, as a rule, be driven at the further end of each main gallery, so that two or more mines may be fired off it (Pl. **44**).

The vulnerability of these long isolated galleries to flank attack is obvious. The galleries, however, are not designed for mine fighting; the objective is to be gained by stealth and not by force. The provision of flank protection will only increase the chances of discovery. Should it be necessary to engage the enemy underground, the operation should generally be confined to a separate defensive system.

The disadvantages of shallow galleries have been stated in para. 2. The amount of explosive required, however, to produce good surface effects with mines much over 100 feet deep is ordinarily prohibitive. A depth of 50 to 60 feet is a good figure to aim at. On the other hand, it may sometimes be necessary, physical conditions permitting, for galleries to descend to depths considerably over 100 feet in order to escape detection by an enemy defensive system, and then to rise to a suitable distance from the surface when nearing the objective (Pl. **45**, Fig. 2).

In the selection of objectives, points should be chosen which will cause the greatest dislocation and demoralization of the defence. The plan should be prepared in close co-operation with the General Staff, by whom it must be finally approved.

Precautions must be taken against the enemy gaining information of offensive mining operations through his agents. A policy of secrecy must be adopted with regard to all schemes, which should only be made known to those directly concerned. Personnel should be warned against irresponsible talk.

5. In the preceding paras. offensive mining has been considered in which surprise is a condition of success. It is possible to undermine a position by forcing a way underground by mine fighting (Sec. **80**), but, with the adaptability of modern methods of defence, an objective can rarely be of sufficient value to compensate for the heavy expenditure of personnel, time, and material involved by such tactics. As a means of assisting the assault, mines laid under these conditions are of little value. The enemy must know of their existence, and will, therefore, hold the threatened area lightly and consolidate positions to the flanks and rear. Further, no reliance can be placed on the availability of the mines for use at the time fixed for the attack, for they cannot be held indefinitely against enemy countermining, and must either be exploded as a defensive measure or be destroyed by hostile action underground.

79. *Defensive mining.*

1. The physical conditions favourable to the defensive will obviously be the reverse of those required for offensive mining, that is to say, a shallow mineable section and hard strata which transmit sound well are to be desired.

The concealment of spoil and all surface works must be given careful attention, for, though absolute secrecy is not so vital as in offensive mining, hostile shelling will cause confusion and delay.

The circumstances calling for underground defence will vary from those in which an exposed position is of sufficient importance to warrant protection against underground attack, although no hostile mining has taken place, to the extreme case in which hostile galleries have been driven under the position to be defended. Defensive systems may, therefore, be classified under two headings :—

i. Protective systems, the primary function of which is to give warning of underground attack.

ii. Fighting systems, designed to engage and drive back hostile galleries by mine fighting.

The dividing line between these two classes of defence is by no means clearly defined, and it is obvious that a fighting system must take the place of a protective system should mine fighting subsequently develop.

2. A **protective system** may be compared to the forward elements of surface defence, which are sited for observation rather than resistance. It will consist of a series of mined listening posts, so disposed along the threatened front as to give warning of attack. At the same time, it will often be necessary to fire mines from these underground listening posts in order to check an attack and, thus, gain time for the construction of a fighting system to meet it. It follows that the scheme of active defence must be settled in some detail, and the listening posts sited to work in with it.

The degree of protection provided will depend to a large extent on the nature of the soil. In soft bad listening ground the approach of enemy work may only be heard a short distance away, and will be an indication of immediate danger ; in hard ground the increased range of hearing should give time to intercept an advancing gallery. The necessary work will, therefore, vary from a partially developed fighting system, of the lateral type described in para. 3, to detached listening galleries at intervals along the exposed front. The latter form of defence will usually be of the **herring-bone** type (Pl. **45**, Fig. 1), in which a series of independent galleries are driven more or less in the direction of the enemy, and forked at their extremities in order to cover the maximum of ground for listening and fighting.

The interval between listening posts of protective systems will naturally depend on the range of hearing in the soil in which they are constructed ; it must be such that an enemy gallery cannot be driven between any two posts without being heard from one of them. Where the mineable section is deep and the range of hearing short, it may be necessary to construct listening posts at more than one level.

Galleries should only be pushed out sufficiently far to adequately safeguard surface defences; if unduly advanced, they may come in contact with an opposing protective system, and unnecessary and undesirable mine fighting may develop in consequence.

The flanks of an active mining front should always be covered by protective systems.

3. For **fighting systems**, capable of offering a protracted resistance, the lateral type of defence must be adopted. This consists of two or more entrances connected up by a gallery running parallel to the front defended; from this gallery, which is termed a *lateral*, galleries for fighting and listening purposes are driven (Pl. **46**).

The provision of a lateral underground may be compared to the creation of adequate communications behind the battle front in surface warfare, for it enables concentration of effort at any threatened point along its length. A factor of almost equal importance is the improvement in ventilation which it affords (*see* Sec. **97**).

The lateral should be situated sufficiently far in rear of the mine fighting area to render it safe from damage by the explosion of mines. This distance will naturally vary with the radius of rupture of mines likely to be fired, which in turn depends on the depth of the system. In deep systems it may be necessary to site the lateral behind the front line of the position defended, but, provided it can be protected, the further advanced the lateral the better.

The spacing of the fighting galleries, driven forward from the lateral to form the first line of defence, should be such that all ground between any two adjacent galleries can be covered by maximum camouflets (Sec. **100**) fired from them (Pl, **46**). The problem is three dimensional in character, for the depth at which an opposing system can be driven must be considered in determining a suitable interval. This should never be as much as twice the depth of the system, and, where the section to be covered is deep, may be even less than the depth of the system. **Backing-up galleries**, forming the second line of defence or attack, are pushed out from the lateral in the intervals between the fighting galleries of the first line. The backing-up galleries should be driven just short of the radius of action of charges fired from the first line galleries. Their function is to take up the advance when a mine is fired from the first line, and thus permit of the resumption of work without loss of time.

Pl. **46** shows a plan of a fighting system in which the above features are demonstrated. The exigencies of the situation will seldom permit of the construction of a system on such ideal lines; the position and direction of the galleries must to a large extent be governed by enemy activity and other factors. Nevertheless, the principles laid down must be closely followed. Pl. **92** shows a typical fighting system, which was developed in actual practice during the War of 1914-1919.

The radius of rupture of a mine of given index is a direct function of its depth (*see* Chap. XIII). It is clear, therefore, that the advantage of fighting range will always lie with the deeper system. Fighting galleries should, therefore, be driven considerably below the estimated depth of hostile workings, or, where this is not possible, at the lowest practicable level. Frequently, the construction of fighting systems at two separate levels will be the most effective means of gaining ground. The shallower system will be employed to engage the enemy and clear the ground of his advanced workings, in order to permit of the pushing forward of fighting galleries from the deeper system.

Where a protective system of the herring-bone type has been provided prior to the development of mine fighting, this may preferably be kept separate from the fighting system subsequently constructed at a lower level, and used for listening only or for surprise blows.

Listening, which must cover the whole front, is carried out from both first line and backing-up galleries, and, where the distance at which hostile work can be recognized is short, this may be the ruling factor governing the spacing of the latter. Thus, deep systems in bad listening ground may require a larger number of backing-up galleries than fighting considerations alone would dictate, and under similar conditions systems at more than one level may be required when the whole depth of workable ground cannot be covered by listening from a single system.

4. The **emergency defence**.—The preceding paragraph has dealt with the deliberate preparation of a typical fighting system. The situation may, however, arise where a hostile mining attack is not suspected until the surface defences are found to be already in danger.

The primary object then becomes to dislocate the enemy's plans by compelling him to fire before he is ready. It will be necessary to sink down from the forward defences of the position, and reach the level of the hostile workings as rapidly as possible; shafts should generally be used. If the enemy is already under the defences, the shafts must be sunk down on to his galleries, a proceeding that will almost inevitably involve casualties. Should the enemy refuse to fire, clearing mines must be exploded as soon as the enemy is within effective range. These tactics may often necessitate the destruction of the shafts; fresh ones must be sunk to replace them.

While the enemy is thus held, listening posts should be established along the remainder of the threatened front, and a fighting system, if possible deeper than the hostile galleries, developed in rear. From this system galleries should be pushed forward, and the enemy driven back by mine fighting, the tactics of which are outlined in Sec. **80**.

80. *Mine fighting.*

1. For the reasons given in Sec. **78**, para. 5. mine fighting will be confined practically to defensive mining. Disregarding surface considerations, however, and examining mine fighting solely in the light of its main object, *i.e.*, the defeat of the enemy underground, offensive action must be a predominant feature of the tactics of this form of warfare, if success is to be attained. Not only is it necessary to take the offensive where ground has to be gained and the opponent driven back, but it is impossible to hold an underground position in the face of an aggressive enemy by merely passive methods. The explosion of a mine by the defence may shatter the attack gallery and check the advance, but, if this is not followed up by pushing forward fresh galleries, the enemy will eventually reach

his objective by driving through or round the shattered zone. By making sufficient sacrifice, almost any underground system can be penetrated unless the opponent also assumes the offensive ; while, on the other hand, if the defence be conducted on the right lines, it can be rendered practically impregnable.

2. The immediate aim of the commander directing mine fighting must be so to manœuvre that the firing of a mine by either side will cause more damage to the enemy's operations than his own. Damage may be inflicted in two ways ; by casualties to personnel (caused directly by mine explosions or indirectly by the mine gas produced), and by the destruction of workings. The former is the more important owing to the moral effect produced, and will generally outweigh considerations of material damage, which, however, cannot be wholly disregarded.

The firer, by withdrawing his miners, avoids the possibility of casualties, but he cannot gain a similar immunity from material damage. The explosion of a mine destroys everything within its radius of action, and it is clear, therefore, that a portion of the system from which it is fired will always be destroyed. Hence, to blow before the hostile gallery is within range will not only cause no casualties to the opponent, but will be to his material gain. The tendency to fire too soon, a most common fault, must be guarded against. In exceptional cases, where the situation is uncertain and the enemy is suspected to be lying in wait with completed mines, it may be necessary to fire *clearing blows*. Generally speaking, however, the adoption of hit or miss methods is unsound, and there should be a reasonable certainty that adequate damage will be inflicted before a mine is fired.

3. It is impossible to give precise rules by which the correct moment to blow may be determined. This will depend on so many varying factors, not the least of which are the psychology and habits of the enemy.

The most favourable conditions will obtain when hostile work approaches a completed gallery, of the existence of which there is reason to believe the enemy has no knowledge. In this case a mine should not be fired until the hostile gallery has passed, or, if there be danger of the enemy breaking through, is within a few feet of the head of the gallery which is lying in wait. It will, however, usually be necessary to load and tamp the charge when the enemy is still so far away that he cannot hear the noise caused by this operation. Subsequent listening must be carried out behind the tamping and with the aid of electrical listening apparatus tamped in with the charge (Sec. **114**). By adopting these tactics excellent effects will be obtained, for the enemy gallery, being untamped, will form a line of least resistance along which a large proportion of the force of explosion will pass. Cases have occurred in which over a hundred feet of gallery have been wrecked under these circumstances, and the whole of the workings flooded with gas.

On the other hand, if, when two opposing galleries are approaching each other, the sound of work can be heard mutually by both sides, they may reach a critical distance apart at which it will be to the advantage of either side to blow. The situation must be judged to a nicety, and, if also appreciated correctly by the enemy, a successful issue may be dependent on rapidity of loading and tamping.

4. Not infrequently good results may be obtained by misleading the listeners of a nervous enemy and inducing him to fire short. Work may be stopped, and the noises associated with loading and tamping simulated, after which the miners, with the exception of a listening patrol, are withdrawn. Alternatively, loud methods of work may be adopted to make the gallery sound nearer to the enemy; in some cases the use of boring tools or the firing of a round of blasting shots has produced the desired results. A dummy pick (Pl. **49**, Fig. 1), operated by a string from a distance to simulate ordinary pick-work at the face, may be an effective ruse, but its regular beat and the absence of the accompanying sounds of shovelling will seldom deceive the trained listener.

Against similar enemy tactics the only counter is careful and methodical listening and a correct appreciation of the results thus obtained. Bluff enters largely into the tactics of mine fighting, and the cooler head will have the advantage. When the situation is obscure, it is well to realize that the enemy is probably labouring under similar difficulties. A bold policy will often pay, and big risks must be taken. On the other hand, the moral effect of underground casualties on the miner is out of all proportion to that produced by casualties on the surface. Losses incurred through the unexpected firing of mines will make men nervous, and will destroy their confidence in their officers' knowledge of the situation; these conditions will be deterrent to the speed of working. It will, therefore, often be necessary to cease work and withdraw the majority of personnel when a hostile blow is thought to be imminent. In some cases the enemy may evince a tendency to fire at a definite time of day (*e.g.*, at sunset or sunrise); the hours of shifts may be regulated accordingly.

So long as the enemy can be heard at work (the dummy pick, as already described, can generally be distinguished from honest work) there is little cause for apprehension; it is during the periods following the cessation of work that the closest scrutiny is required. The value of being able to predict an enemy blow by good listening is inestimable. To reduce casualties the minimum number of men should be employed in the danger zone. The worst time to be caught by a hostile blow is when in the act of tamping, owing to the increased number of men usually required for this purpose.

From the foregoing remarks it will be obvious that the time for firing mines to destroy the enemy must be carefully chosen. Every endeavour should be made to inflict underground casualties on the enemy at the same time as his galleries are destroyed; electrical listening intruments may be tamped in with the charge in order to ascertain that the enemy is at work at the moment of firing. For a similar reason, the time of firing mines should be varied as much as possible.

5. Too much stress cannot be laid on the importance of exploiting without delay the zone cleared by the explosion of a mine by pushing forward backing-up galleries. It is evident that this work can be performed in comparative safety during the period immediately following a blow, for no enemy galleries can remain within the shattered area. Quick work is, therefore, essential, and the more rapidly the galleries can be pushed forward the more ground will be gained before the enemy galleries again

become a menace. Difficulty will frequently be encountered in driving through shattered ground; in some soils pockets of mine gas may be a source of much delay, and a more rapid advance will be made by going round the ruptured zone. On the other hand, it may be possible to adopt silent methods of work in shattered ground, where the virgin soil is hard, and thus to effect surprise.

6. The **break-through.**—The listening organization should be so complete that there should be no chance, even in soft soils, of the enemy actually breaking into a gallery of the system. Should this occur, however, he must be vigorously attacked with revolver, bomb, or bayonet, and driven out of the system or captured. His means of entrance should then be sealed by blowing an emergency charge (Sec. **99**, para. 5). All lights carried will form a target in fighting of this nature, and should be extinguished; the enemy, being in a strange gallery, will be at a disadvantage in the dark.

When an enemy system is broken into, opportunity should be taken to gain information of the lie of the hostile galleries; a rough survey of as much of the system as can be explored without detection should be rapidly made with the aid of a compass. Communication should then be broken off by blowing emergency charges; the break should, if possible be made within the enemy's system so that a portion of his defences may be captured.

7. In the description of fighting systems (Sec. **79**, para. 3), the range of the maximum camouflet was taken as a basis of design. The range of such charges will normally be sufficient in deep systems, but larger charges should be used where this is not the case. They will have the disadvantage of forming a crater, which may dislocate the surface scheme of defence by obstructing the field of view, &c.; they may also cause additional work in necessitating the consolidation of crater lips. Further, the firing of a heavy charge may do considerable structural damage to the system from which it is fired. The necessity for causing severe damage to the enemy, however, will usually far outweigh these disadvantages. The employment of inadequate charges will only be to the detriment of the firer, and will raise the morale and confidence of the opponent. These remarks apply especially to shallow systems where the use of heavily overcharged mines will be the rule rather than the exception.

8. **Surface considerations.**—It has been explained in para. 7 that cratering charges will frequently be used; indeed, the development of mine fighting will almost invariably result in the formation of a chain of craters between the opposing lines. The crater lips (Sec. **100**, para. 5), which will often form the forward defences of a position in the mine fighting area, may have to be consolidated. Under these circumstances the most favourable time of day for carrying out this operation may be a ruling factor in fixing the time for firing the mine. In any case the closest touch must be maintained with the garrison, in order that they may have the necessary working party and material ready for consolidation.

As a rule, imminent risk of destruction from a hostile mine will be run on the far lip of the crater, and only the near side lip can be held. Thus, a crater with a high lip on the near and low lip on the far side will, generally, be the most desirable form. The miner, however, can exercise no control over the configuration of crater lips, though their height is governed to a limited extent by the size of charge used (Sec. **102**, para. 2). The removal of the far lip by mines or explosive charges applied from the surface is very difficult to accomplish, though its height may frequently be reduced by these means.

CHAPTER XI.

RECONNAISSANCE AND CONTROL OF MINING OPERATIONS.

81. *Mining schemes.*

1. Mining operations should never be undertaken unless and until a definite scheme has been worked out and approved by those in authority. In preparing schemes the value of reconnaissance cannot be overestimated; all available information with regard to tactical and physical conditions must be collected. It is only after the careful consideration of this information that a definite plan of action can be prepared.

Data must first be obtained under the following headings :—

i. Surface features; a rough survey of the locality including enemy positions will be required (Secs. **82** and **84**).
ii. Geology (Sec. **83**).
iii. General facilities for concealment of operations (Secs. **85** and **86**).

2. **Offensive mining.**—Assuming that the physical conditions favourable to an offensive have been found to exist, the engineer officer carrying out the reconnaissance must then determine in what way the employment of mining can be of most assistance to the assault. He must, therefore, be informed of the nature of attack in outline and the approximate date. He must be possessed of a knowledge of the enemy defences in order to guide him in the selection of suitable objectives. In formulating his plan of action he must take into consideration the possibilities of the existence of enemy protective systems and the chances of detection from other sources.

The outline scheme drawn up must include an approximate estimate of time, personnel, and material required. A rate of progress in excess of 6 feet per diem for sinking and 15 feet per diem for driving (*see* Secs. **92** and **93**) should rarely be taken as a basis of calculation, as allowance must be made for unforeseen delays. The time available for carrying out the work may be a limiting factor in the extent of mining operations that can be attempted. In this connection it should be noted that mines blown just short of an enemy position may still assist the attack by masking machine-gun and rifle fire and by their moral effect.

The final decision as to whether the results likely to be obtained are commensurate with the expenditure of labour and material must rest with the General Staff, to whom the engineer officer charged with the preparation of the scheme will act in an advisory capacity.

3. **Defensive mining.**—The first duty of the engineer officer carrying out the reconnaissance will be to establish the necessity for the adoption of defensive measures. Defensive mining, though frequently a most necessary form of insurance against underground attack, should be avoided whenever possible. It will always involve a heavy expenditure of labour and material in what must be, at least in so far as the main issue is concerned, purely passive defence. Furthermore, protective systems, when completed, will always involve the permanent retention of a staff for listening and maintenance purposes; unused listening galleries not only afford no protection, but are a source of danger to the defence owing to the possibility of the enemy breaking into them.

Definitely located sounds of mining (*see* Sec. **116**, para. 3) or other unmistakable signs may place beyond doubt that a hostile underground attack has been launched. Often, however, the evidence will be of an inconclusive nature, such as :—enemy surface works suspected to be mine entrances; large spoil dumps (especially if of a colour foreign to the surface soil); abnormal activity in enemy lines; the bringing up of large quantities of timber; sounds of pumping or other machinery; sudden disappearance of water in previously wet trenches or ditches. These signs, though frequently indicative of mining, may originate from other causes; the first four items may be due to dug-out construction, and the last to natural phenomena. Where the existence of a mining attack is suspected but cannot be proved, the engineer officer, in coming to a decision as to the necessity of defensive measures, must to a large extent be guided by the geological conditions, the distance apart of the opposing trench systems, and the value of the threatened position. An objective must normally be of outstanding importance to warrant mining operations from a distance of over 300 yards.

Even when the existence of a mining offensive has been clearly established, it is for consideration whether immunity would not be better attained by :—

i. A small permanent advance in which the hostile mine entrances are captured. Raids in which the ground is not permanently held can only be palliative; they may delay mining operations, but will not avert them. The same remark applies to the heavy bombardment of the surface works connected with mining.

ii. A withdrawal from the threatened position to positions in rear.

The advisability of adopting either of these alternatives to defensive mining must be decided by the General Staff. In order, however, to assist them in arriving at a decision, the engineer officer must furnish an outline scheme, which will include an approximate estimate of the labour, material, and time required to render the position secure against underground attack.

4. **Detailed reconnaissance.**—Preliminary work, in the nature of preparing the site, &c., will frequently have to be commenced as soon as the outline scheme has been approved; meantime a detailed scheme must be drawn up which should include the following :—

i. Accurate survey and geological section of locality. (Secs. **83** and **84**.)

ii. Position and design of mine entrances and galleries. (Sec. **85**.)
iii. Method of soil disposal and concealment of all surface works. (Sec. **86**.)
iv. Personnel required, their accommodation, and the system of shifts in which they will work. (Sec. **88**.)
v. Tools and material required and method of transport to site. (Sec. **87**.)

An accurate survey of the site will generally take some time to prepare. It is important, however, that this should not delay the work, for in the initial stages very precise methods of orientation are not essential.

82. *Surface features.*

The topography of any given locality in which mining is to be undertaken may exercise a strong influence on the methods employed. If, for example, the opposing lines are situated on a plain, mining works must generally be initiated with the sinking of deep shafts or inclines with the attendant difficulties of hoisting and possibly pumping. (Pl. **47**, Fig. 1.) On the other hand, if the enemy position be located on higher ground, shallow entrances may be suitable, since the amount of head-cover will increase as the enemy lines are approached. In extreme cases the galleries may be commenced from the surface, with a slight upward slope to facilitate drainage and evacuation of spoil. (Pl. **47**, Fig. 2.)

The advantages of a site inferior to that of the enemy are, however, frequently more than counterbalanced by his increased facilities for observation. Under such conditions the concealment of work and movement likely to betray mining activity will often present problems of great difficulty.

83. *Geology.*

1. The physical character of the formations to be penetrated by a mine system will control speed of excavation and type and quantity of timbering. It will also indicate the equipment required. The underground transmission of the sound of excavation, always a consideration of tactical importance in mine warfare, varies with the nature of the strata. The level and quantity of water likely to be encountered may be a ruling factor in determining the practicability of a mining enterprise.

It is evident, therefore, that a knowledge of the local geology is essential before a scheme of mining can be planned. A general idea of the lie of the strata may be gathered from observation of outcrops on the surface, and from examination of wells, escarpments, &c., in the vicinity. Reference should be made to any available geological maps of the locality. In many cases, however, it will be necessary to supplement such information by data obtained from small trial bore-holes drilled on the site. The services of an expert geologist will frequently be required.

2. Some of the more common geological formations are grouped below in accordance with their relative ease of excavation under conditions imposed by military mining :—

i. Excavated without picking (*see* Sec. **92**)—Soft sand and alluvium, some forms of clay and gravel.

ii. Excavated easily with pick—Tough clay, soft sandstone, shale, soft and medium chalk.

iii. Difficult to excavate with pick without the aid of blasting, but hand-drilling not so slow as to be impracticable (Sec. **70**)—Hard chalk, sandstone, conglomerate, schist, limestone, &c.

iv. Blasting, using machine drills, necessary if reasonable progress is to be made (Sec. **71**)—Granite, diorite, hard limestone, &c.

From the standpoint of ease of excavation, the first two groups afford suitable conditions for mining. The third group is practicable but unfavourable, while the fourth is ordinarily prohibitive.

3. Attention has already been drawn to the importance of carrying out work with as little noise as possible, in order that the position of galleries may not be detected by the enemy. It is evident that the audibility of mining operations will depend on the hardness of the stratum and the method of working it, and that sound will be transmitted more readily by solid formations than by those which are less solid and incoherent. In general, the above grouping of the rock formations, according to relative ease of excavation, also serves as a rough classification of the relative distance at which the sound of excavation can be heard. (Sec. **115**.)

Since success in offensive mining will, as a rule, be dependent on effecting surprise, the scope of such enterprises against an alert enemy will normally be confined to the soils enumerated in para. 2 (i).

4. When the geological formation consists of a series of thin beds of varying consistency, the angle of slope may prove an important factor. If the strata are tilted and the galleries have to pass from one bed to another, excavation and timbering will, as a rule, be more difficult than if the strata lie horizontally, thus making it possible to follow an individual bed. Further, when the *dip* of the beds is pronounced, a favourable working strata located at a suitable level may either rise to the surface before the objective is reached or sink to impracticable depths.

5. **Water** is one of the most serious obstacles with which the miner has to contend. Information on this head may be obtained by studying the sequence of strata, the distribution of springs and seepages, and by direct observation in wells and shafts or in bore-holes sunk for the purpose.

The varying circumstances under which water is encountered are to a large extent governed by the presence of superimposed pervious and impervious strata (*i.e.*, porous or non-porous to water). The conditions imposed may roughly be grouped under three headings :—

i. A stratum, pervious throughout the whole range of depth in which mining operations can take place, containing water (held up by impervious strata below) at a more or less defined level. Below this level the driving of galleries will seldom be practicable. It should also be noted that in many regions the water level has a seasonal fluctuation of several feet. This must be taken into account when deciding on the levels of galleries.

The chalk beds in which mining took place on the Somme front during the War of 1914-1919 afford a good example of these conditions. Pl. **48**, Fig. 1, shows the maximum and minimum water levels found to exist on a certain section of this front. Here the water level was at a minimum in November and a maximum in May. It follows that galleries constructed in dry chalk during the autumn below the maximum line will be flooded in the spring.

ii. A shallow pervious stratum lying over an impervious one. The water held up by the impervious layer will often render the upper stratum saturated and unworkable. In this case the obvious procedure is to get down into the underlying impervious bed, in which galleries may be driven under dry conditions. If, however, the water-logged stratum is thick, considerable difficulty may be encountered in sinking through it. (*See* Sec. **93**.)

iii. An impervious stratum lying over a pervious one. Under these conditions an artesian effect may be produced, water under pressure being encountered in the lower stratum (*see* Pl. **48**, Fig. 2). Provided mining is confined to the impervious bed, the workings will be dry, but if the saturated stratum below be penetrated, the water will rise to its natural level and flood the galleries.

Conditions (ii) and (iii) may often be combined. An example of such is shown on Pl. **48**, Fig. 3, being a typical section of the geological formation which obtained on portions of the Flanders front during the War of 1914-19.

Water forced through the fissures of an otherwise impervious stratum may sometimes be encountered. Natural underground springs of this nature are most common in rock, but in mine warfare seepages may often be induced in normally dry soils by the fissures caused by the explosion of mines.

84. *Survey.*

1. Reference should be made to the *Text-book of Topographical Surveying*, 1913, for information on the principles and methods of survey. This section will be confined to a short description of their special application to mining work.

2. **Surface survey.**—For the preliminary reconnaissance an existing trench map or, failing this, a prismatic compass traverse sketch will suffice. For the working plan, however, an accurate survey of the trench system from which mining operations are to be conducted will be required. A theodolite triangulation or traverse, or a combination of the two, must be carried out. The position of mine entrances must be fixed with precision in order that projected underground work may be properly co-related.

A periscope attachment will often be found of much service in theodolite work. Survey over exposed ground may be carried out at night with the aid of lights screened from enemy view.

The enemy positions are best plotted from air photographs. This requires very careful work. Air photographs are generally more or less distorted, mainly owing to the fact that the face of the camera is, as a rule, not quite horizontal when the picture is taken. The method of making the necessary corrections to eliminate errors of distortion, together with other hints on plotting, will be found in "Mapping from Air Photographs, 1920," issued under the authority of the General Staff, War Office. In offensive mining the accurate fixing of the position of objectives will naturally be of first importance.

3. **Underground survey.**—The procedure below ground is similar to that adopted in ordinary surface survey, but special short stands (1-foot 6-inch to 2-foot 6-inch legs) will be required for tripod instruments.

A prismatic compass or pocket sextant may be employed for rough work; good results may be obtained with a 4-inch prismatic compass mounted on a tripod. For important work, however, a 3-inch or 4-inch theodolite or a **Miners' Dial** (Pl. **50**) will be required. The latter instrument is an accurate form of compass for measuring magnetic bearings. The circular compass box is connected with the plate that carries it in such a way that it can revolve on this plate. By this means the instrument can, when desired, be used to measure angles in a similar manner to a theodolite. A telescope and sight vane are provided; the instrument is fitted with a vertical arc to enable readings to be made down inclines of all grades.

The miners' dial, though not quite so accurate as the small theodolite, is the most suitable for all-round work underground, since it can be used to take compass bearings (loose needle method), or as a theodolite to measure angles (fixed needle method).

It is most important that the underground survey should be accurately *tied in* to the surface plan. No difficulty will be presented in doing so where there are two or more entrances, the positions of which have been accurately fixed. Where, however, access to the mine system is gained by a single shaft, the only method is to ascertain the azimuth of a length of underground gallery by a carefully checked compass bearing.

For further information on mine survey, reference should be made to a standard text-book on this subject. The following is recommended—"Mine Surveying," by Bennett H. Brough (Charles Griffin and Co., Ltd.).

4. **Levelling.**—This is always important.

A *Dumpy* level or other similar instrument should be used for accurate work both above and below ground. A short staff, preferably telescopic, must be used in both instances; a long staff visible above the parapet is likely to invite hostile attention.

In preliminary surveys the Abney level may be used.

The depth of galleries should be referred to a convenient datum on the surface. The position of this datum should be clearly marked on the mine plan. Gallery depths should be shown at floor level.

The configuration of the ground above a mine system should be indicated on the mine plan by contours, referred to the same datum as that used for the galleries (*see* Pl. **92**). A vertical interval of 10 feet will generally suffice; indeed, conditions will seldom permit of the plotting of contours at closer intervals with any accuracy. The contouring of *No man's land* and the enemy position will be difficult. The heights of prominent features, the positions of which have been fixed from air photographs, may be obtained by angle of sight observations with a theodolite; they should be shown as spot levels. Approximate contours may be interpolated from these data and from any information furnished by existing contoured maps.

By referring the surface contours and depth of mine galleries to a common datum, the approximate depth of soil covering a gallery at any point in the system may easily be read off on the mine plan. These data are always required in the calculation of charges, and for important mines must be determined as accurately as possible.

5. **Cartography.**—The scale to be adopted for mine plans should be laid down. The use of different scales by various mining units tends to confusion.

The most satisfactory method is to take a scale which is a simple multiple of that used for trench maps of the locality (usually 1/10,000 or 1/20,000). A scale of 1/500 (41·7 feet to 1 inch) will be found a convenient size for record plans. 1/1,000 or 1/1,500 may be used to show extensive fronts. The following points should be observed in the preparation of mine plans:—

i. Scale to be shown and north point if the *grid* is omitted. It will frequently be convenient to give comparative scales (*e.g.*, metres and feet) to facilitate comparison with trench maps.
ii. The British lines should be situated at the bottom of the plan (*see* Pl. **92**).
iii. The plan should be gridded. It will be an advantage if the grid used corresponds with that of the trench map of the locality.
iv. The map co-ordinates of at least one point on the plan should be shown.

The standardization of the conventional signs used in plans of mine systems is essential. The use of colours, to differentiate between workings at different levels and between British and enemy work, will be of great assistance in rendering plans readily intelligible. The following conventional signs have been found to give clear results when coloured inks are available. :—

Item shown.	British.	Enemy.
1. Trenches and all surface works	Single thick line in black and marked "British Lines"	Single continuous line in black and marked "Enemy Lines."
2. Contours of surface	Chain dotted in burnt sienna	Chain dotted in burnt sienna.
3. Galleries	Thick continuous line in colours according to depth. Surface to 25 feet deep .... Yellow 25 feet to 50 feet deep .... Green 50 feet to 100 feet deep .... Blue Over 100 feet deep .... Violet	Definitely located:—Thick continuous line in red, irrespective of depth. Conjectured:—Dotted line in red.
	Destroyed or abandoned galleries are crossed out in correct colour (*see* Pl. **92**).	
4. Shafts	Rectangular outline in black	Rectangular outline in red.
5. Winzes (internal shafts)	Rectangular outline in colour coresponding to depth of top of winze.	—

Item shown.	British.	Enemy.
6. Inclines....	As for galleries, but the gradient should be shown (*see* Pl. 92).	—
7. Mines	i. Solid square ($\frac{1}{10}$-inch sides) of colour corresponding to depth, at position of charge. Date fired and nature of charge. ii. Hatched outline of crater formed in black (*see* Pl. 92).	i. Solid circle ($\frac{1}{10}$ inch diameter) of red, at the estimated position of charge. Date fired. ii. Hatched outline of crater formed in red.
8. Camouflets	i. Charge as for mines above .... ii. Dotted circle showing radius of rupture and of colour corresponding to depth.	i. Charge as for mines above. ii. Dotted circle in red showing estimated radius of rupture.
9. Spot levels	By a dot with the depth against it in correct colour.	—
10. Grid lines	Thin continuous line	in black.

When coloured inks or pencils cannot be obtained, the following conventional signs, using black ink and pencil, are recommended (*see* Pl. 92) :—

Item shown.	British.	Enemy.
1. Trenches and all surface works.	Single thick line marked "British Lines"	Single thick line marked "Enemy Lines."
2. Contours of surface.	Chain dotted line	Chain dotted line.
3. Galleries	Surface to 50 feet deep :— Double continuous line hatched in pencil thus Over 50 ft. deep :— Double continuous line with enclosed space thus Destroyed or abandoned galleries (*see* Pl. 92).	Definitely located :— Continuous line. Conjectured :— Dotted line. are crossed out
4. Shafts	Rectangular continuous outline	Rectangular continuous outline.
5. Winzes (interval shafts)	Rectangular dotted line	—
6. Inclines	As for galleries, but the gradient should be shown.	—
7. Mines	i. Solid square $\frac{1}{10}$-inch sides at position of charge. Date fired and nature of charge. ii. Solid hatched outline of crater (*see* Pl. 92).	i. Solid circle $\frac{1}{10}$ inch diameter, at the estimated position of charge. Date fired. ii. Skeleton hatched outline of crater (*see* Pl. 92).
8. Camouflets	i. Charge as for mines above. ii. Continuous circle showing radius of rupture.	i. Charge as for mines above. ii. Dotted circle showing estimated radius of rupture.
9. Spot levels	By a dot with the depth against it (*see* Pl. 92).	—
10. Grid lines	Continuous lines	in pencil.

85. *Site and nature of mine entrances.*

1. The selection of the sites for mine entrances will always require very careful consideration. Ideally, a mine entrance should fulfil the following conditions :—

i. Be within reasonable mining distance of the objective or area in which mine fighting is likely to take place.

ii. Be sufficiently retired so as to be well outside the destructive area of any mine likely to be fired, and to be reasonably safe from capture and damage by enemy raids.

iii. Be inconspicuous and accessible without coming under enemy observation.

iv. Be close to the site selected for soil disposal.

(i) and (ii) are two conflicting conditions, and the result will often be a compromise between them.

Access to the mine entrance will either be gained from an existing trench or from a trench specially constructed for the purpose. The latter alternative, though entailing more work, is often preferable ; the continual passage of mining personnel along a main trench may hamper and interfere with the work of the garrison. A trench dug specially to serve a mine entrance must be designed and carried out with great care, in order that the enemy may have no clue as to its real nature.

2. **Nature of entrances.**—The relative merits of shafts and inclines are discussed below.

A shaft provides the quicker method of getting down to the desired depth. In wet or shifting strata it is the only practicable method of sinking.

Inclines, when they can be used, afford greater facilities for the haulage of spoil than shafts ; they can be descended with greater rapidity and ease, and are better for ventilation. A length of incline can be constructed at a greater rate than an equivalent depth of shaft, but, measured solely from the point of view of the depth sunk, shaft sinking is the quicker.

It is important that the foot of an incline be well outside the area in which mine fighting is likely to take place, for, should the defenders be driven up the incline, they will be forced to fight the enemy from increasingly shallower levels the further they have to retire.

86. *Disposal of spoil.*

The disposal and concealment of the spoil hoisted to the surface is one of the most difficult problems encountered in military mining. A conspicuous spoil dump will at once reveal the fact that mining is in progress, and may aid the enemy in locating the site of the mine entrances. Where the colour of the spoil mined differs from the surface strata (*e.g.*, blue clay with loam on surface), the difficulties are increased. White chalk shows up most conspicuously in air photographs.

The quantity of spoil to be dealt with is often not appreciated (15 to 20 cubic feet of earth will be mined per foot advance of an average gallery, *see* Sec. **95**, para. 1), and a complete scheme of disposal should be worked out beforehand in detail. The following are the principal methods of concealment that may be employed :—

i. Gradually filling up natural or artificial depressions, aerial observation on the same being prevented by the use of camouflage. Craters and shell-holes are specially well adapted for spoil disposal, and the former may sometimes be blown deliberately at suitable points behind the lines for this purpose.

ii. The construction with mine spoil of dummy breastworks which to the enemy will appear as part of the surface defences. In order to permit of a straight run through of the trams carrying the spoil, and yet to maintain the appearance of an ordinary trench, flying traverses should be constructed, as shown on Pl. 47, Fig. 3.

iii. Dumps camouflaged with suitable materials such as surface soil, sods, or painted canvas. The usual camouflage practice of avoiding steep slopes or strong shadows must be adopted.

The methods of spoil disposal and concealment not only require most careful forethought, but also most constant supervision in execution. A few hours' careless work by the dumping party may render nugatory all the measures taken to conceal a dump. Difficulty of supervision will often be increased by the fact that in many places dumping of spoil can only be carried out at night.

87. *Transport of stores.*

1. The quantity of stores and material required in even a small mining operation is large. Materials for the construction of the penthouse and the approaches to it will have to be brought to the site before work is commenced. Hoisting and ventilating apparatus must be installed during the initial stages of the work. Trollies and trolley track, mine rescue apparatus, explosives, &c., and in many cases pumps and lighting plant, will have to be brought up as the work proceeds. The main item, however, will generally be timber required for the lining of entrances and galleries. The weight of timber required in difficult soil may be as much as 120 lbs. per foot run (*i.e.*, 4 man-loads).

It is thus essential that all stores be brought as near as possible to the site by mechanical or animal transport, in order that the carrying parties required may be reduced to a minimum.

The nearest point to which G.S. wagons can be brought at night in reasonable safety should be carefully investigated. The use of pack animals should also be considered. Trench tramways and similar transport facilities should be made use of to the utmost possible extent. It may be worth while, if the operation is on a large scale, to construct a tramway specially for the transport of mining stores. It is rarely possible, however, to get stores to the site without man-handling them over the last stage, but every effort must be made to reduce this distance to a minimum.

As soon as the existing transport facilities have been thoroughly investigated, positions should be selected for dumps of material. Suitable sites within about a hundred yards of the mine entrances, where carrying parties may dump the stores at night and from which the mining personnel at work can fetch them in daylight, should be reconnoitred. Sites for dumps at the maximum distance to which G.S. wagons or trench tramways can be advanced should also be investigated; similarly for lorry transport, if used. It is, of course, important that dumps should be concealed from direct enemy view, and as far as possible hidden from the air by the use of camouflage, &c.

88. *Organization of personnel.*

1. In order to give a guide as to requirements for mining operations in the future, the composition of mining units (tunnelling companies) during the War of 1914-1919 is outlined below.

The establishment laid down for tunnelling companies was 15 officers and 325 O.R. During the period in which mining activity was at its height, however, the strength of tunnelling companies was considerably augmented by infantry attached to them, so that these units frequently consisted of over 700 all ranks, including over 20 officers.

A company was organized into headquarters and 4 sections. It was commanded by a major assisted by an adjutant; the former was thus relieved of the bulk of administrative and routine duties, and able to concentrate on the direction and control of the mining operations. The remainder of the headquarter staff of 15 consisted of:—1 company serjeant-major, 1 company quartermaster-serjeant, 1 serjeant (foreman carpenter), 2 fitters, 2 miscellaneous trades, 1 tailor, 1 shoemaker, 1 surveyor, 1 storekeeper, 1 orderly, and 3 batmen. The personnel for transport consisted of 3 N.C.Os. and 13 men. A medical officer and 2 R.A.M.C. orderlies were also attached to headquarters.

The establishment for each section was 3 officers and 73 O.R., but, as already explained, these figures were generally considerably exceeded. A section was commanded by a captain; in addition to miners, it contained the following personnel:—1 serjeant (for executive and administration duties), 1 blacksmith, 1 carpenter, 1 storekeeper, 1 cook, and 3 batmen. The mining personnel consisted of 9 N.C.Os. and 56 men.

The transport of each company consisted of:—3 three-ton lorries, 1 thirty- cwt. lorry, 1 box-car, 1 water-cart, 2 G.S. wagons, 2 limbered G.S. wagons, 11 motor cycles, 6 bicycles.

2. Work will normally be carried out throughout the 24 hours; 8 hours will, generally speaking, be found to be the most satisfactory period of shifts.

It will be found essential to have the headquarters of the unit situated well to the rear, from three to five miles, or even farther from the forward defences, according to the conditions. By this arrangement officers and men returning to headquarters from work will be able to get complete rest, and transport can be parked and stores and workshops installed without undue risk.

Thus, a return to company headquarters after each shift will generally be impracticable. The most suitable arrangement will be to accommodate the men in advanced quarters, preferably dug-outs, a short distance from their work. This accommodation should be situated sufficiently far in rear ($\frac{1}{2}$ to 1 mile) to enable the men to live under conditions of moderate comfort when not on shift. Pl. 49, Fig. 2, shows diagrammatically a system of reliefs that has been found to work well when advanced billets are available. The hours of work of A, B, and C shifts are :—A, 0001—0800 hours ; B, 0800—1600 hours ; C, 1600—0001 hours ; D shift rests at company headquarters for 4 days, during which the men get a bath, and receive pay and a change of underclothing. At the end of 4 days D shift relieves A shift, who return to headquarters for 4 days' rest, and so on.

Under this scheme each man averages 6 hours' work per diem. It will seldom be possible to attain a larger number of working hours per day from each man over a long period, and conditions may often render it impracticable to maintain this standard. For instance, under some conditions it will not be possible to obtain suitable advanced quarters, and the men, when off shift, will have to live in the front trenches. When such is the case, they will usually require longer periods of rest at company headquarters, and a different scheme of shifts must be organized. Sometimes the trenches from which mining operations are in progress cannot be reached in daylight, and reliefs can only be carried out at night. The conditions must be carefully studied, and a system of shifts and reliefs got out which will best suit the circumstances and attain the maximum efficiency with the men available.

Each man should be relieved actually at the spot where he is working ; thus a man working at the face should not quit his post at the expiration of his tour of duty until he has been relieved by a man of the incoming shift and has *handed over* to him. The practice of bringing the shift, which has completed its tour of duty, to the surface before the relieving shift descends should be discountenanced.

It will be realized that, whatever system of reliefs is adopted, a careful tally must be kept of each shift so that they may be equalized in strength, and so that each may contain a proportion of the more skilled miners for working at the face. A card index system or some similar method installed at headquarters will be found of great assistance.

Work on a section basis will almost invariably be found the most satisfactory organization ; a section should be allotted a definite sector in which mining operations are in progress. The number of faces that can be worked by one section will naturally vary with the conditions. A section 70 strong may, under ideal conditions, drive 3 or 4 headings simultaneously, provided it receives assistance with the disposal of spoil on the surface. The actual footage driven by a section of given strength will always depend on the number of men required for the auxiliary services of pumping, ventilation, tramming, hoisting, &c., and on the system of reliefs in which the section is organized for work. This last factor, as explained above, will be dependent on the local conditions. It is thus impossible to give definite figures. The whole of one section will generally be absorbed in driving a long offensive gallery where a rapid rate of progress is of paramount importance.

The section commander will normally live at the headquarters of the company, and visit the work of his section daily. He will thus be able to keep in close touch with the O.C. company, supervise the arrangements for the supply of his section with rations, materials, tools, &c., and at the same time direct and control the work in hand. One subaltern of the section should always be on duty on the site of the work. As a rule, the best system of reliefs will be found to be 4 days in the trenches and 4 days' rest at the company headquarters, the two subalterns of the section relieving each other alternately.

Although each section of a tunnelling company organized during the War of 1914-1919 was more or less self-contained and could be sent on detachment, it was found advisable under normal conditions to retain the carpenter and blacksmith of each section at central workshops established at company headquarters. The shops were placed in charge of the foreman carpenter; orders for carpenters' and smiths' work were given to the central workshop by section commanders as required.

3. The services of the skilled miner to perform the more important mining work are practically essential. Experienced men, accustomed to working in the cramped and often sparsely ventilated galleries, must be employed in excavating at the face and timbering, if sound workmanship is to be combined with good progress. For shifting spoil, pumping, and similar underground work unskilled labour will serve the purpose, but the advantages will be considerable if this labour also is accustomed to the conditions of pit life. Many men experience an inborn abhorrence and dread of confined spaces, which long usage to underground work alone can overcome. Good work cannot be done while the subject is prone to this indefinable sensation, and, under conditions of stress, panic may easily set in.

It may, therefore, be assumed that, whenever mining operations are carried out on any scale in future wars, a large proportion of the personnel employed will be recruited from the ranks of the civil miner. The best work can only be obtained from men whose peculiarities are understood, and a few notes on the special characteristics of the miner will not be out of place.

The influence of the rigidly-enforced regulations, so necessary in civil miners to promote safety and facilitate organization, induces an instinctive respect for authority. Brought up in this school, the pitman readily accepts the yoke of military discipline, and knows how to obey. Developed by the nature of his calling, he also brings with him from civil life many of those other qualities invaluable in war. He is inured to danger by the frequent accidents inseparable from his trade, and accustomed to working in gangs where comradeship and leadership count for much. As with sailors on the sea, a fine bond of fellowship exists between all underground workers: a sound foundation on which to foster *esprit de corps*. Thus the average miner makes a good soldier with the minimum of training. He has a stout heart, and is a born fighter.

Physically the miner is tough and strong; he can stand hardship well and his output of work is phenomenal. At home he is accustomed to strenuous labour below ground and to complete freedom to do what he likes once the pithead has been quitted. He is apt, by the process of analogy, to consider the circumstances similar on active service when he has left the trenches for a period of rest. Tactful handling is required if good discipline is to be maintained, but at the same time it should be remembered that the nearer conditions can be brought to approximate to those at home the higher will be the output of work. The miner has a prodigious appetite, and requires plenty of meat and other nourishing food, if he is to give his best work. Drunkenness is a common failing; proclivities in this direction must be curbed, but there is some truth in the statement that the best workers are sometimes the hardest drinkers. In general, the miner does not march well; work will suffer if the men have to walk much more than a mile before going on shift.

Miners are liable to be afflicted with certain diseases seldom occurring in other walks of life. Miners' worm disease, an infectious illness, may sometimes be met with; miners' nystagmus, an affection of the eyes, is a fairly common complaint; carbon monoxide poisoning, so prevalent in mine warfare, requires special treatment. The men should, if possible, be attended by medical officers who have practised in mining districts and are accustomed to the idiosyncrasies of the miner and his ailments.

89. *Control of mining operations.*

1. A definite organization for the control of mining operations will always be necessary whenever mining operations on a large scale are likely to develop. Without experienced direction mining personnel are liable to be employed on unprofitable enterprises, and often to the furtherance of small local schemes. The futility of desultory underground attacks and the danger of wasting time and labour in constructing unnecessary defensive systems have already been explained. Centralization of control is essential if the best results are to be obtained from mining units.

Moreover, it is important that mining units should remain more or less permanently in the sector in which they are engaged. The conditions and previous history of mining operations in a given locality take considerable time to learn, and, even when complete handing-over notes have been prepared, points which may subsequently be of significance may be missed. Relief of units should, therefore, take place as seldom as possible; they should work under an organization which, during position warfare, is likely to be stationary (*e.g.*, a corps or army).

During the War of 1914-1919, tunnelling companies were army troops, and the following was the staff organized for their direction and control :—

At General Headquarters—

1 Inspector of Mines (with the rank of Brigadier-General).
2 Assistant Inspectors of Mines.
1 Mechanical and Electrical Engineer.
1 Geologist.
1 Clerk, 1 typist, and 1 draughtsman.

At each Army Headquarters—

1 Controller of Mines (with the rank of Lieut.-Colonel).
1 Assistant Controller of Mines.
1 Clerk and 1 draughtsman.

The Inspector of Mines at General Headquarters was charged with the following duties :—

i. Preparation under the instruction of the General Staff of mining schemes which were intended to have a bearing on the principal operations of the campaign, and the examination of mining schemes prepared by Armies.

ii. Inspection for the information of the Commander-in-Chief of the progress of all mining work.

iii. Advising the Engineer-in-Chief on general questions affecting personnel, organization, and equipment of the tunnelling companies.

The Controller of Mines at an Army Headquarters was the principal executive officer for mining operations, and was responsible for :—

i. Preparation, under the instructions of, the General Staff, of all mining schemes initiated within the Army, and the distribution and direction of the work of the mining personnel allotted to the Army. Preparation of important dug-out and sub-way schemes, and the general supervision of all underground work on the Army front.

ii. Co-operation with the Inspector of Mines in preparation of mining schemes connected with the operations initiated by General Headquarters.

iii. Advising the Chief Engineer of the Army on all questions connected with the promotion of officers and the selection of officers and men from other arms for transfer to mining units, so far as the Army to which he was appointed was affected.

iv. Advising the Chief Engineer on all questions connected with changes in and additions to the approved equipment, or special stores supplied to tunnelling companies from engineer parks.

The following was laid down with regard to mining schemes :—

i. No mining operations could be initiated without Army sanction.

ii. Important offensive mining schemes required approval from General Headquarters.

2. Progress reports were rendered weekly by units to Controllers of Mines, who collated this information and forwarded it to the Inspector of Mines. A facsimile of the form used for progress reports is given at the end of this chapter.

Mining plans were kept up to date by means of slip tracings forwarded with the progress reports. Progress in dug-out work was shown by means of sketches.

The firing of a mine, British or enemy, was reported by wire immediately to the Controller of Mines who retransmitted the information to the Inspector of Mines. Details of the result of a blow were forwarded later on a special form, a facsimile of which is also shown at the end of this chapter. One side of the form is prepared for reporting British and the other for enemy mines.

3. A **mine school**, under the direction of the Controller of Mines, was formed in each army, as it was found that mine rescue, listening, &c., could not be conveniently taught in the front trenches. The functions of these schools were :—

i. The training of all tunnelling company personnel in mine rescue and mine listening.

ii. The training of tunnelling officers in mining tactics and allied subjects.

iii. Training of personnel in dug-out construction.

iv. Testing and reporting on new explosives, instruments, and engineering appliances, with instructional demonstrations in the use of the same.

v. Supervision of mine rescue stations in the trenches, and the repair and issue of all apparatus for same.

(B 15360)c

SECRET.

Army Form W 3404.

Date 16/5/17.

WEEKLY MINE REPORT.

II *Corps.*

24th Tunnelling Company, R.E.

4th Division.

Strength of Company. (*From A.F. B 213.*)

—	Officers.	O.R.
R.E.	15	291
Permanently Attached Infantry	1	56
Temporarily Attached Infantry	1	34
Totals	17	381

Designation of Working.	Trench No. or Name.	Map Reference.	Shaft or Gallery.			Footage for Week.	No. of Days Worked.	Nature of Ground.	REPORT. Circumstances affecting progress. Results of listening. Mines and camouflets. General information.
			Depth.	Size inside Timbers.	Total Footage.				
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
A (left)	Ham Street	C 24 d 2.5	38	5′ 0″ × 2′ 6″	384	120	7	Blue clay	Clay becoming tougher, rendering progress slower.
C 2	„	C 24 a 9.7	52	„	152	52	3	„	No work since enemy blow of 12.5.17 owing to mine gas.
Main lateral	„	C 16 c 1.8	41	„	240	97	6	„	Lateral completed on 15.5.17.
B 3	H 2	G 1 a 2.51	84	4′ 6″ × 2′ 6″	580	165	7	„	Conditions normal. No enemy mining heard.

B 2

SECRET.

WEEKLY PROGRESS REPORT.

(Services other than Mining.)

Date 16/5/17.

II *Corps.*

24th Tunnelling Company.

4th Division.

Strength of Company.

(From A.F. B 213.)

—	Officers.	O.R.
R.E.	15	291
Permanently Attached Infantry	1	56
Temporarily Attached Infantry	1	34
Totals	17	381

Designation of Working.	Nature of Work or Service.	Map Reference.	Section Employed. No.	Days Worked.	Shifts per Day.	Personnel. O.R. Per Shift. R.E.	Personnel. O.R. Per Shift. P.A.I.*	Personnel. O.R. Average Working Party.	Probable Date of Completion.	Remarks. Circumstances affecting Progress (Working Parties, Material, Equipment, Transport, Enemy Activity, &c.).
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Dover Tunnel	Subway from Piccadilly to Trench R 6.	D 73	62	7	3	18	8	10	30.5.17	Work much delayed on 14th and 15th by hostile shelling.
A 3	Preparation railway bridge for demolition (mined charge).	S 26 c 4.5	28	5	3	9	—	—	14.5.17	5,000 lbs. ammonal. Completed.

(Dug-out progress to be shown by sketch.)

* P.A.I. = *Permanently attached infantry.*

SECRET.

(For Enemy Mine, Use Other Side.) Army Form W 3376.

MINE EXPLOSION (BRITISH).

FOURTH ARMY. III CORPS. 2nd DIVISION.

24th TUNNELLING COMPANY, R.E. SECTOR : CARENCY.

DATE : 2.10.16. TIME : 0830 hours.

Location and depth of charge	0 6 C 7.8 32 feet.
Nature of ground	Chalk.
Details of Charge : (Size, class of explosive, form of packing and primers used)	1,850 lbs. ammonal, in 50-lb. tins. Gun-cotton primer.
Tamping : (Lengths of Solid and Air-spaces)	60 feet solid ; no air-spaces.
Reasons and Authority for Mine	To destroy hostile gallery. Controller of Mines, Fourth Army.
Effects of Explosion : Dimensions of Crater	Diameter of surface level, 60 feet.
Underground Effects	40 feet of gallery destroyed ; no damage to remainder of system.
Estimated H.R.R.	48 feet.
Surface Effects	Average height crater lips 5 feet. Slight damage to trench C 2.
Gas Conditions	Slight. Work was resumed in gallery on following day.
If against enemy gallery, estimated distance	10 to 15 feet.
Infantry action regarding Crater :	Rear lip of crater consolidated.
(Particularly stating whether any new positions occupied appear adequately protected underground)	Adequately protected underground.
General Remarks	The full force of explosion must have penetrated enemy gallery. Enemy was hard at work just before firing. No enemy work has been heard in this vicinity since.

(Sketch attached)

Date.................. *Signed* ....

(B 15350)Q E 3

SECRET.

(For British Mine, Use Other Side.)

MINE EXPLOSION REPORT (ENEMY).

FOURTH ARMY. III CORPS. 2ND DIVISION.

24TH TUNNELLING COMPANY, R.E. SECTOR: CARENCY.

DATE: 12.10.16. TIME: 1656 HOURS.

Location of Blow	0 7 d 9.1.
Nature of Ground	Chalk.
Probable Depth of Charge	40 feet.
Probable Object of Mine	Destroy our gallery, A 2 (left).
Underground Damage	10 feet of end of A 2 (left) destroyed.
Surface Effects	Crater lips average height 7 feet. No damage to our trenches.
Dimensions of Crater (if any)	Approx. 90 feet.
Infantry Action regarding Crater: (Particularly stating whether any new positions occupied appear adequately protected underground)	Nil.
Gas Effects Underground	A 2 (left) full of gas.
Casualties: Underground	2 men killed by explosion, 1 gassed.
Surface	Nil.
General Remarks	The explosion of the mine has not materially altered the tactical situation underground, which remains satisfactory.

(Sketch attached)

Date .... *Signed* ....

CHAPTER XII.

METHODS OF CONSTRUCTION.

90. *Introductory remarks.*

From the standpoint of technique, no branch of military art has changed less, during the many centuries of its use, than mining. For reasons that will be discussed below, mine galleries are still largely excavated by hand tools, as they were in the days when all civil mining was carried out by the simplest methods. Various types of excavating machinery have been introduced from time to time with, on the whole, disappointing results. Although power-driven plant has now reached that stage of perfection which may render it of service in the construction of sub-ways and dug-outs in rear zones, machinery in its present form is quite unsuitable for mining work in the front line. Power excavators are heavy to transport to the site, cumbersome to install, liable to frequent breakdowns, and, worst of all, noisy in operation. They require specialists to run them, and a large supply of spare parts. Though the rate of progress of such machines, when actually in operation, may considerably exceed that attainable by hand, the average footage will, as a rule, be far below the latter, when the time expended in installation and all stoppages are taken into account.

The bulk of the work of excavation is still performed by the miner with pick or grafting tool and shovel, and, with the sole exception of boring machines (*see* Secs. **36, 70**, and **71**), modern science has made no important addition to the excavating tools at his disposal.

The methods of construction employed in military mining differ little from those adopted in elementary civil practice, except in so far as they are modified to meet tactical requirements, among which the performance of work with the minimum of noise is often a prominent feature. Under these circumstances screws should be used in place of nails to dispense with hammering. Timber should, when possible, be forced and not knocked into position. Frequent use of screw jacks may be made for this purpose, as also for removing broken or disused setts.

Front line conditions will not permit of the adoption of elaborate methods, necessitating ample transport facilities and the erection of conspicuous and vulnerable surface structures. Projects must be simple, straightforward in execution, and frequently perforce of an improvised nature. The technical problems encountered will often bear a close resemblance to those with which the mining pioneer and prospector has to contend in remote corners of the globe.

The importance of carrying out work strictly according to design cannot be overestimated. A twisted shaft or a crooked and undulating gallery may hamper the whole of the subsequent development of the system from the point of view of haulage, ventilation, and drainage. Hasty and scamped work never pays, and may prove disastrous.

Space will only permit of a brief description in this chapter of the more common methods of sinking and driving. For further information reference should be made to standard text-books on mining dealing with this subject. Competence in the execution of underground work can, however, only be gained by practical experience.

91. *Materials.*

Timber.—A **sett** is the collective term applied to 4 pieces of timber, suitably framed or jointed together, placed in position to support the walls and roof of a gallery or shaft. They may give support either direct or through the medium of 1 to 2-inch boarding, known as **lagging** or **sheeting,** running parallel to the direction of drive (*see* Pls. **51** and **52**). In the former instance the setts are termed **cases**, and in the latter **frames.**

Since cases in addition to affording the main support also furnish the lining, the width of the timber used will normally considerably exceed the thickness; 9-inch by 3-inch or 9-inch by 2-inch scantling is very suitable.

For frames rather stouter timber of square or rounded section will, as a rule, be required, since they will not form the lining, but will have to take the pressure on the surface of the boarding which they support.

The roof member of a gallery sett is called the cap or top-sill, the floor member the ground-sill, and the two side members side-trees or stanchions.

The 1-inch spreader, fixed as shown (Pl. **51**), has been found the most satisfactory method of framing setts for use in galleries. It transmits the side thrust well, and permits of the placing of the top-sill in position with the minimum of work.

Setts used in shafts and similar work should be framed with suitable carpenters' joints. The halved joints may be used for rough construction, but the halved and mitred joint is preferable in important work as it gives additional strength. It may sometimes be advisable to support the joints of setts in shafts with angle iron brackets.

Large quantities of timber will be used in all soils except firm rock; in loose and heavy soils the expenditure will be very high (about 3½ cubic feet of timber will be used per foot run of an ordinary gallery close-timbered with 9-inch by 3-inch).

Practically any nature of hard or soft wood is suitable. Its condition, provided its strength is unimpaired, is of no consequence; green unseasoned wood lasts well in damp galleries.

Economy in timber, in so far as it is consistent with sound work, must always be studied. Unsawn timber should be used wherever it will serve the purpose. For this reason frames for galleries will frequently be made of pit-props (Pl. **51**, Fig. 4), *i.e.*, rough poles of 4 to 6 inches diameter, while for lagging 1-inch to 2-inch boarding sawn out of logs will be used. The sides of the boarding are usually left untrimmed with the bark on, thus saving labour in preparation. Gallery cases may be made on similar lines. A proportion of sawn timber will, however, always be required in the construction of shafts and other special work.

The size of galleries and inclines should, as far as possible, be standardized, in order that the setts may be manufactured on a large scale at the Base.

Corrugated iron and expanded metal make excellent lagging in firm soils, and may be used in place of boarding.

Girders will occasionally be required in the construction of chambers and where exceptionally heavy pressures are encountered (for further details of their use *see* Chap. XVI).

Sandbags will be used in large quantities for the removal of spoil.

92. *Driving.*

1. **Size of galleries.**—The larger the section of a gallery the more timber is required, and the greater is the volume of spoil to be removed. Galleries of small dimensions are, therefore, desirable; on the other hand, a limiting size will be reached, beyond which men will not have enough room to work efficiently at the face or to pass one another in the completed gallery.

4 feet 3 inches by 2 feet 3 inches is about the minimum convenient section; it may be adopted in soils requiring close-timbering. Rather larger galleries may be constructed with advantage in soils which stand well; 4 feet 10 inches by 2 feet 9 inches was the standard size adopted for use in chalk during the War of 1914-1919; 6 feet 4 inches by 2 feet 9 inches was the size employed for galleries sufficiently large to permit of men walking upright (mainly used in dug-out construction, *see* Chap. XVI). The figures given above are in each case internal dimensions.

2. **Timbering.**—Cases or, alternatively, frames and sheeting may be used according to the nature of the soil (*see* Pl. **52**).

Cases make a strong neat lining, and are specially suitable for use in soils which develop pressure after the gallery has been constructed. They may be placed together (close-timbering) or, when the ground permits, at intervals up to about 1 foot apart. Cases should be at least 7 inches in width. Timber 2 to 3 inches thick is generally sufficient, but, where exceptionally heavy pressures are encountered, thicker wood may be required.

Frames and sheeting are, as a rule, a more economical form of timbering for galleries in hard soils. The frames should be placed at intervals varying from 1 to 6 feet, according to roof and side pressure encountered. This is also the system of timbering usually adopted when galleries are driven by **spiling,** as explained in para. 4.

The amount of lagging required will depend on the firmness of the ground, and in good soils, such as hard chalk, it may only be necessary to lag the roof. In rock, timbering may frequently be dispensed with. The roof should be cut in the shape of an arch to distribute the overhead pressure on to the sides (Pl. **52,** Fig. 2).

3. **Methods of work.**—In nearly all soils the work of excavation is most efficiently performed by working to a *cut,* that is to say, a narrow channel cut in the face, to which the remainder of the face is broken.

The method of excavation known as **kicking** is the most rapid means of progress in certain kinds of clays and sand. It has a great advantage over pick-work, in that the ground is broken away comparatively silently. Galleries should, therefore, whenever practicable, be driven by this means when in the vicinity of the enemy. Work is carried out with the **grafting tool** (Pl. **53,** Fig. 1). The miner lies down face uppermost, and with his back supported by a board, termed a *kicking board,* fixed across the gallery. He then digs, as it were, horizontally, giving the thrust to his tool by pushing his back against the kicking board and working to a cut made at the bottom of the face.

The pick must always be used in hard and tough soils if reasonable progress is to be made. The sound of picking is audible over a wide range, and detection by an alert enemy is almost certain. Pl. **53**, Fig. 2, shows a design of miners' pick suitable for all-round work.

The miner kneels to his work when picking, and excavates to a cut, usually formed on one side of the face. Picks require frequent sharpening when the ground is hard; the face-men should be supplied with several spare sharpened pick-heads.

It may be necessary in very hard ground to assist progress by blasting (Chap. IX).

Push-picks (Pl. **53**, Fig. 3) may be used for comparatively silent work in soils too hard to be excavated by kicking with the grafting tool, but the rate of driving is slow. The shape and size of the blade used will be varied to suit the nature of soil worked.

Pl. **53**, Fig. 4, shows the Service pattern of miners' shovel employed for removing spoil.

In placing cases in position, the ground-sill is first laid level. Grooves are then cut for the side-trees, and finally the top-sill is placed in position; no more earth than is absolutely necessary should be cut away above the top-sill to do this. Except where there is no doubt as to the solidity of roof and sides, galleries should never be pushed forward ahead of the timbering with a view to inserting several setts at a time. This endangers the lives of those working, and, if the face or sides begin to *run*, involves an immense amount of labour.

4. **Spiling** must always be adopted in bad and doubtful ground liable to *run*. It consists in driving boards to support the roof (the sides as well in some cases) ahead of the excavation. Pl. **54** illustrates the method. The whaling board of 4-inch by 2-inch timber is placed on chocks resting on the top-sill of the ordinary frame; there is thus enough space to allow the spiling boards to be forced through between the whaling board and the top-sill. The spiling boards are maintained at the correct angle by a distance-piece bearing on the spiling boards of the sett behind, as shown.

In very heavy ground the spiling boards may bend with the weight before they can be driven home; in such cases intermediate setts, Pl. **54**, Fig. 2, must be used. The forward sett supports the end of the spiling boards, while the back one serves as a distance-piece to maintain the angle of drive. The boards are driven from underneath the cap. This method necessitates the excavation of ground between setts in two distinct operations; first to place the intermediate sett, and then to place the permanent sett.

If it is necessary to pick out the ground ahead of the spiling boards to facilitate driving, only enough should be removed to enable one board to be driven at a time.

It may be necessary in extreme cases (*e.g.*, loose sand) to use face-boards to support the face, while the roof and sides of the gallery are excavated (Pl. **54**, Fig. 3).

5. **Breaking-away galleries.**—A false frame should be used in breaking away a gallery from the bottom of the shaft. This is placed against the wall in which the gallery is to be driven. The side-trees are strutted as shown on Pl. **52**, Figs. 4 and 5, in order to take the thrust of

the side walls of the shaft. The removal of sufficient timbering to enable the placing of the first sett can then be proceeded with. This sett should be firmly fixed to the shaft timbering, so that the sides of the shaft may have a bearing against it and be prevented from collapsing when the false frame is removed.

In breaking out one gallery from another, the top-sills must be strutted with a false frame before the side-trees can be removed to form the opening for the new gallery. The work is then similar to that described above.

In changing the direction of a gallery the bend should be made gradually, when using cases, by fitting them close together at one side and leaving intervals at the other.

6. **Direction and gradient.**—The direction of a gallery will be laid out by compass or theodolite (Sec. **84**); great care must be taken to ensure that it is maintained. The best method of doing this is to hang two plummets, indicating the required centre-line of the gallery, from the roof (Pl. **55**, Fig. 1), and to take a *shot* on each case or frame as it is placed in position. The centre-line should be marked on each ground-sill, and, if the sett is found to be out of alignment, its position must be adjusted.

The gradient of a gallery should frequently be checked with a level and templet cut to the correct slope.

7. **Footage** driven per shift will depend on many factors, of which the most important are :—

i. Nature of soil.
ii. Number of men employed at face.
iii. Necessity for quiet work.
iv. Facilities for removal of spoil.

The number of men actually employed at the face in excavating a gallery of normal dimensions will vary from 3 to 1 per shift, according to the necessity for making rapid progress. Three men will be required at the face if the gallery is to be driven at a maximum speed, *i.e.*, 1 man picking or kicking, 1 man bagging the spoil, and 1 man preparing timber and resting. Work at the face must be carried on continuously at high pressure, the men relieving each other at the face every 20 minutes to half an hour. When it is not essential to push forward the gallery at high speed, one man, who does the entire work of excavating, bagging spoil, and timbering, may be employed; this will be much more economical in labour, but the footage attained per shift at each heading will, of course, be comparatively small. In the latter instance it will often be advisable, in order to obtain reasonable footage, to give a man a definite task to perform. Where, however, a gallery is to be driven forward at maximum speed and three men are employed at the face, the best method of obtaining good progress is to encourage a wholesome rivalry between each shift as to which can attain the best footage during their period of work. Tendency to scamp work, however, must be rigorously checked.

Progress at the rate of 40 feet per diem has been maintained over a period of a week in hard chalk with the pick assisted by blasting, and an average speed of 30 feet per diem has been recorded during a period of 14 days in blue clay with the grafting tool, under conditions necessitating quiet work. The above, however, are exceptional figures; they will only be achieved by shifts of skilled men trained to work together.

An average progress of at least 15 feet per diem may be expected in good ground, but where the soil is difficult the rate of advance may be much slower.

For methods of chamber construction *see* Sec. **122**.

93. *Sinking.*

1. The **dimensions of shafts** will be governed by the depth to be sunk and by the amount of spoil to be dealt with. It is obvious that a larger haulage-way will be required for a shaft serving several headings worked simultaneously than for one through which little spoil is to be evacuated. It is always better to err on the large side. A shaft of inadequate section will hamper the subsequent progress and restrict ventilation.

A 7-foot by 5-foot shaft (internal dimensions) is a convenient size for deep work. A 4-foot by 3-foot section may suffice for a shaft constructed merely to furnish an exit, but this size should be regarded as a minimum. When spoil is to be evacuated in any quantity, the shaft should not be smaller than 6 feet by 4 feet.

2. **Timbering and design.**—A good type of shaft timbering is shown on Pl. **56**. It consists of setts placed at every 3 to 4 feet, hung from each other by iron hooks, and strutted by distance-pieces placed at the corners. The interval between each sett is lagged with boarding.

It is preferable to divide deep main shafts, 7 feet by 5 feet in size and over, into two by a strut placed across each sett (Pl. **56**). This serves the double purpose of strengthening the longer side of each sett and of enabling two separate compartments to be formed, one for the ladderway and the other for haulage. The ladderway should be made in stages as shown, so that, should a man slip, he cannot fall far.

Cases, in place of frames and lagging, may be used for short shafts. The cases should be held in position by battens nailed across them (Pl. **57**, Fig. 1). This method has the advantage of being simpler for unskilled men to carry out. The shaft constructed, however, is not so strong, and it is difficult, when sinking to any depth, to maintain a vertical direction and to avoid twist.

3. **Method of work.**—The site for the shaft should first be levelled, and a penthouse constructed over it to afford protection and concealment from aerial observation. Alternatively, the shaft may be commenced from a chamber constructed at a short depth below the surface and with inclines leading into it (Pl. **57**, Fig. 1). Measures should be taken to prevent flooding from surface water.

The **collar sett**, the frame from which the shaft timbering is hung, should then be bedded in and levelled. In some cases it may be necessary to place the collar sett on cross-bearers to obtain additional bearing surface (Pl. **56**, Fig. 1). Sinking operations are then commenced from the collar sett, and the timbering fixed in position as the work proceeds. A plumb-bob should be used from time to time to ensure that a vertical direction is maintained; care must also be taken to see that each sett or case is placed square with the one above, otherwise the shaft may develop a twist as it descends.

When the ground is not sufficiently firm to permit of the lagging being placed in position after the lower sett has been hung, the lagging boards may be spiled down ahead of each sett. Pl. **57**, Fig. 2, shows a shaft constructed in this manner.

One or two men, according to the size of the shaft, will be required at the shaft bottom to carry out the excavation and timbering. Two men will normally be required for hoisting, and they should relieve the men at the shaft bottom at intervals of half an hour or so.

Special methods of sinking will have to be adopted when running sand or very loose soil of more than a few feet in thickness is encountered. **Spiling** may be employed to get through the shifting stratum or **steel tubbing** may be used.

4. **Spiling.**—The method of spiling employed in sinking through running soil is similar to that adopted in driving, but longer spiling boards, extending over several shaft setts, are used.

The boards are driven down behind a collar sett of special design (Pl. **58**, Fig. 1) as far ahead of the excavation as they will go. A portion of the earth is then excavated, and the spiling boards are then driven in again ; setts are fixed in position to take the thrust on the spiling boards as the work proceeds. The secret of success lies in excavating only small quantities of spoil at a time and in driving the boarding as far ahead of the excavation as possible. This applies particularly to sinking operations in running sand, which is in a semi-fluid state. If too much soil is taken out, the floor, which is under pressure from the surrounding sand, will rise up in the shaft. This will cause the formation of cavities behind the shaft timbering and the subsequent settlement of the ground surrounding it ; the foundations of the collar sett will be disturbed, very heavy pressure will be set up, and the shaft will be lost.

The spiling boards should not be less than 2 inches thick. They should be furnished with a cutting edge at the lower end. The boards should, if possible, be rather longer than the depth of the running stratum to be traversed. When this is impracticable, a fresh set of spiling boards must be driven inside the first ones. This will materially reduce the size of the shaft, and must be taken into account in deciding on the dimensions at surface level. Thus, in the example given (Pl. **58**, Fig. 2), a shaft 7 feet by 5 feet at surface level becomes 6 feet by 4 feet at a depth of 10 feet, and for each fresh set of spiling boards inserted a reduction of 1 foot each way will take place. Generally speaking, it is not practicable to sink by spiling through more than 20 feet thickness of running sand.

5. **Steel tubbing** (Pl. **59**, Fig. 1), if obtainable, affords the most satisfactory means of sinking through running sand. It is made up in panels which are bolted together ; an angle iron cutting edge is fixed to the base of the first ring of tubbing. A hole is dug to take the first section of tubbing. So long as the soil is firm it is excavated just ahead of the cutting edge, and the tubbing is forced down by means of jacks working against the penthouse roof. As the work proceeds, fresh rings of tubbing are bolted on as required. When the running sand is reached, the tubbing is jacked down into the semi-fluid stratum as far as it will go. The roof of the penthouse must be loaded with rails or sandbags to obtain the weight

necessary for this purpose. The subsequent procedure is similar to that adopted in spiling; it is essential to keep the tubbing jacked down as far ahead of the excavation as possible (Pl. **59**, Fig. 2).

A stratum of 25 feet of running sand is about the maximum depth that can be traversed with tubbing. Cementation and freezing methods are frequently adopted in commercial undertakings for sinking through thick layers of running soil, but the large amount of plant required precludes their use on active service.

6. Footage.—Progress will vary considerably with the nature of the ground, and will necessarily be very slow in sinking through bad soils such as running sand, for which it is impossible to give figures. An average advance of 6 to 8 feet per 24 hours may be expected in good ground. The latter has often been exceeded, but the importance of putting absolutely reliable timbering in all shaft work renders it seldom advisable to attempt sinking at abnormal speeds.

94. *Inclines.*

1. **Size and design.**—Inclines used as mine entrances will generally be rather wider and higher than the galleries they serve. A vertical section of 6 feet by 4 feet 6 inches is a convenient size for a main incline through which much spoil is to be evacuated.

The angle of slope will vary according to conditions; it should never be greater than 60° to the horizontal. Slopes of 1 in 2 or 1 in 3 are generally adopted.

Precautions must always be taken to prevent flooding from surface water. A good method is to dig into the parapet a short passage, at the end of which the incline is commenced (Pl. **60**, Fig. 2). This passage should be at least 5 feet long and about 1 foot above the level of the trench floor. It should be roofed over and camouflaged. As in the case of shafts, it will frequently be preferable to start deep inclines from a chamber constructed a short distance below the surface (*see* Pl. **57**, Fig. 1).

Large inclines may be divided into two by vertical struts, as shown on Pl. **60**, Fig. 3. A ladderway is fitted in one of the compartments thus formed, and the other is used for the haulage of spoil.

2. **Timbering.**—Cases or frames and sheeting are used for the lining. They are placed in position as already described for galleries. The uprights of the setts should, as a general rule, be placed normal to the slope (Pl. **60**, Fig. 1). An alternative method, when cases are used, is to place the uprights vertical (Pl. **60**, Fig. 2) and step them down. This design has the advantage of providing steps, but the timbering is not so strong, and longer side-trees must be used; those shorter than 6 feet give insufficient head-room.

It is advisable, even in hard ground that stands well, to close-timber at least the first 15 feet of inclines driven from the surface, in order to provide additional strength against shell fire.

3. Details of work are similar to those already described for galleries. The slope of the incline should frequently be checked with level and templet. Footage will depend to a large extent on the angle of slope at

which the incline is driven, and will in any case be less than that attained in galleries under similar conditions. An average progress of about 10 feet per diem may be reckoned on in good soil, when the slope does not exceed 1 in 1.

95. *Removal of spoil.*

1. The spoil at the face must be placed in receptacles which will facilitate handling at the face and transportation along the galleries, up the shaft or incline, and finally to the spoil dump. Sandbags are the most suitable form; they may be used several times until worn out. Failing sandbags, wicker baskets or wooden boxes will serve the purpose, but they are far less satisfactory.

In order that the capacity of the tramming and hoisting systems installed may be sufficient to deal with the output of spoil, it is advisable first to work out the approximate volume of spoil that will have to be dealt with per foot advance of a gallery. In doing this, allowance must be made for the fact that the excavated earth, owing to voids, occupies about one-third greater space than the virgin soil. Thus, when 3-inch timbering is used, the volume of spoil excavated per foot advance of a standard gallery, 4 feet 10 inches by 2 feet 9 inches internal dimensions, would be as follows :—

Volume of earth excavated per foot advance=(4 feet 10 inches+8 inches) (2 feet 9 inches+6 inches)=18 cubic feet.

$\therefore$ actual volume of spoil$=18\times\frac{4}{3}=24$ cubic feet.

A sandbag holds approximately ½ cubic foot of spoil, hence about 48 sandbags must be removed per foot advance of the gallery.

2. **Tramming.**—The best method of transporting spoil from the face is to load it on small 40 cm. gauge trucks (miners' trucks), which are run along the galleries on wooden track; this operation is usually termed *tramming*.

The design of **Miners' truck** supplied in the Service is shown on Pl. **61**, Fig. 1. The wheels are rubber tyred to lessen noise, and the wheel bearings must be kept well greased to prevent squeaking. The 40 cm. gauge wooden track, a suitable design of which is shown on Pl. **62**, is screwed to the floor of the gallery.

The bags of spoil are dragged a little distance from the face and loaded on the miners' truck which is pushed or pulled by hand to the bottom of the shaft or incline. A truck will take 6 to 8 bags, and thus loaded can easily be manipulated on the level by one man.

It will be necessary to have several trucks at work simultaneously in long galleries through which much spoil is trammed. Passing-ways must be formed at intervals along the gallery, and a traffic system instituted. It should be organized on the principle of making trucks returning empty to the face get into the passing-ways, so that loaded trucks may have a clear run from heading to hoist.

3. **Hoisting.**—Economy in man-power is always the chief factor to study in preparing a hoisting scheme. Vertical hoisting (*i.e.*, in shafts) has the advantage of reducing friction to a minimum; on the other hand,

inclines give a mechanical advantage varying with the slope at which they are laid.

Hoisting will invariably be by hand-power; the type of plant installed will naturally depend on the rate at which it is necessary to evacuate spoil and the depth of shaft or incline. Direct haul, a rope running over a single pulley block (Pl. **61**, Fig. 2), may suffice for a shallow shaft or short incline, but, generally speaking, it will be necessary to install a windlass or winch giving a suitable mechanical advantage.

Such apparatus should be placed clear of the top of the shaft or incline, in order that traffic may not be obstructed. For shafts, the best arrangement is to set the windlass back a little distance from the collar sett, and to pass the haulage rope through a pulley block attached to the roof of the penthouse (Pl. **61**, Fig. 3). For inclines, a separate chamber for the windlass or winch may be constructed (Pl. **60**, Fig. 4).

Wire rope (1 inch to 2 inches circumference) should be used for hoisting; cordage will not stand the wear, and soon breaks.

In shafts, the most satisfactory method of attaching the bags to the rope of the hoisting apparatus is to splice an iron hook to the end of the rope, and to take a turn round the two or more sandbags to be raised (Pl. **61**, Figs. 2 and 3). In inclines, the same method may sometimes be employed, a smooth board being used for the bags to slide on (Pl. **60**, Fig. 4), or, alternatively, mono-rail haulage of the nature shown on Pl. **63** may be installed. In large inclines dealing with much spoil, however, labour will often be saved by hauling the truck loaded with sandbags to the surface, although the ratio of nett to gross load will be decreased thereby. This last method is specially suitable where 40 cm. track can be run direct from the head of incline to spoil dump, as by this means handling of bags will be reduced.

Friction in inclines through which heavy truckloads are hauled to the surface will be much reduced by the use of steel rails fixed to sleepers. Pl. **65**, Fig. 2, shows a miners' truck adapted for incline work under these conditions; the *sprag*, which must be hooked up when the truck is running down, provides a safety device against the hoisting rope parting.

The **Windlass** is the most generally useful apparatus for mine haulage; it may be used for either shaft or incline. The diameter of the drum will vary from 6 to 12 inches, and the radius of the crank-handle from 1 foot 2 inches to 1 foot 6 inches. The machine, which should be constructed for double manning (one man each side), may be designed to give a mechanical advantage varying from 2 to 6 according to requirements. A good design of windlass is shown on Pl. **64.**

The **Winch** (Pl. **65**, Fig. 1) gives a greater mechanical advantage than the windlass; 14 or 15 to 1 is a suitable ratio. Winches will be installed where heavy loads, beyond the power of the 2-man windlass, are to be dealt with. Their use will mainly be confined to those inclines in which it is desired to haul heavy truck-loads of bags to the surface. They will seldom be of service for shafts, as the rate of hoisting is too slow compared with the load normally lifted.

Pl. **66** shows an improvised double drum winch giving a mechanical advantage of 10 to 1.

The following is a summary of results obtained from hoisting experiments carried out during the War of 1914-1919.

Shafts.

Hoisting apparatus.	Mechanical advantage.	Depth of shaft.	No. of men.	Bags per trip.	Time of haul.	Bags hoisted per 24 hours.
		feet.			mins.	
Single pulley wheel	1	40	1	1	¼	1,200
Windlass	5	40	1	2	½	1,400
Windlass	2½	100	2	2	1	1,200

Inclines (*slope* 1 *in* 2).

Hoisting apparatus.	Mechanical advantage.	Depth of incline.	No. of men.	Bags per trip.	Time of haul.	Bags hoisted per 24 hours.
		feet.			mins.	
Single pulley wheel and shute	1	40	1	2	½	1,000
Windlass and mono-rail	4	100	2	4	2	800
Windlass and truck	4½	100	2	8	4	1,200
Differential drum winch and truck	10	100	2	8	4	1,000
Winch and truck on steel rails	14	100	2	24	10	1,400

Approximately 1,100 bags per 24 hours will be produced from a gallery driven at the rate of 30 feet per diem. Thus, in the case of shafts not more than 100 feet deep, a two-man windlass working at high pressure will be able to deal with this amount of spoil. The winch and truck is the most efficient hoisting apparatus for inclines. On the other hand, the windlass has the advantage of being easily manufactured locally; the capacity of the windlass and truck system will be sufficient to meet requirements under normal conditions of progress.

For disposal of spoil *see* Sec. **86**.

96. *Drainage.*

1. The practicability of mining in water-bearing strata has been discussed in Sec. **83**, para. 5; this section will be confined to a description of the methods employed to evacuate water when encountered.

Water, even in small quantities, is always a serious hindrance to progress, and will usually necessitate the permanent employment of one or more men per shift on the unproductive work of pumping.

The drainage scheme of a mine system should be designed on the principle of leading by gravitation all water from the galleries to a sump formed at the bottom of the shaft or incline, where it may be dealt with by one central pumping installation. For this reason galleries in soils likely to contain water should be driven with a slight upward gradient (1 in 50 is sufficient) from the bottom of the shaft or incline. All water encountered in the galleries will then flow down by gravity to the bottom of the shaft or incline, where a sump is formed.

The collection of water into small sumps at various points in the galleries of a system should be avoided whenever possible, for a large amount of unproductive labour will have to be expended in emptying these sumps into the main sump from which the water is pumped to the surface.

2. **Pumps.**—Occasional baling with a bucket, which is hoisted to the surface, may be the most efficient method of dealing with water when the yield is very small (a few gallons per hour). Hand pumps, however, will generally be the most satisfactory method of evacuation.

A detailed description of the Service pattern hand lift and force pump will be found in M.E., Vol. VI, Sec. **28**. Two men are required to work it for lifts over 20 feet. The pump is designed to raise water 60 feet, but for mining work it is not advisable to rely on a combined lift and force of more than 40 feet.

When large volumes of water beyond the capacity of hand pumps have to be dealt with, power pumps, usually electrically driven, must be installed; several suitable patterns are described in M.E., Vol. VI, Chap. VIII.

Water from mine workings will, as a rule, contain much mud in suspension. A sandbag should be placed over the strainer with which the Service lift and force pump is provided. Even when this precaution is taken, the valves are very liable to get clogged with mud and grit, and loose threads and strands from the sandbags themselves may give much trouble. Pumps will invariably require frequent overhaul and cleaning. The same difficulty will be experienced with power-driven pumps, and, if possible, the type installed should be designed for dealing with sludge water.

It will usually be necessary, when pumping by hand, to raise the water from shafts over 40 feet deep in two stages. A second pump is installed in a chamber constructed off the shaft about half-way up (Pl. **67**).

Deep shafts, sunk through a water-logged stratum to an impervious stratum below, should be provided with a water-ring just below the junction between the two strata (Pl. **67**). The bulk of the water which cannot be kept out by caulking may then be collected in a chamber formed in the side of the shaft. The advantages of the water-ring are that the height through which the bulk of the water has to be pumped is reduced, and that the lower portion of the shaft is kept much drier.

97. *Ventilation.*

1. The two main sources of contamination of the air underground are exhalations from the human lungs and the gaseous products of the explosion of mines.

Of the former little need be said by way of explanation; the conditions under which the air deteriorates do not differ materially from those in any other confined space occupied by animal life. Unless the air is continually changed it is gradually exhausted of oxygen, which is replaced by the carbon dioxide and other impurities expelled in breathing. Carbon dioxide alone, however, is not an active poison; air containing a far larger percentage than the normal can be breathed without serious ill-effects, but the subject will become enervated and disinclined to exertion. During strenuous labour at the face the miner will exhaust the air more rapidly than would otherwise be the case. Hence an ample supply of fresh air is essential to efficient work.

Moreover, although excess of carbon dioxide is not actively harmful, long periods spent in ill-ventilated galleries are most deleterious to health, and may seriously increase the sick-rate of personnel.

Mine gas is far more lethal. Its principal and most dangerous constituent, carbon monoxide, is so poisonous that the breathing of air containing 0·5 per cent. or even less of this gas may cause death (*see* Chap. XIV). Specially rigorous methods of ventilation are, therefore, necessary to rid galleries of carbon monoxide before work can be resumed.

2. Ventilation beneath the surface will be effected by :—
   i. Natural methods.
   ii. Artificial methods.

Every effort should be made to encourage the former, since forced ventilation will always entail additional labour and plant.

3. **Natural ventilation.**—If two mine entrances are connected up underground by a gallery, a continuous current of air is forthwith induced throughout the whole length; one of the entrances becomes an upcast, and the other a downcast (Pl. **68**, Fig. 1). This is the basic principle of mine ventilation by natural means. The value of a lateral in a fighting system as a means of assisting ventilation is therefore apparent.

Even under adverse conditions disturbances in the atmosphere on the surface will always induce currents in the air of the mine system, once a through connection has been made. On the other hand, the desirability of creating a strong through draught should always be borne in mind when designing a mine system, and galleries should be made as straight as possible wherever tactical conditions will permit, in order not to obstruct currents of air. It is preferable that the mine entrances should not be sited at the same level, and that they should face opposite directions; by this means the fullest advantage will be taken of wind on the surface. A good draught in the upcast may be fostered by creating a strong cross current of air at the entrance (Pl. **68**, Fig. 2), much the same as a cowl is used on a chimney. The draught in the upcast may also be assisted by placing a brazier at the foot of the shaft or incline. This method, however, is only recommended in cases of emergency; there is a danger of poisonous fumes (containing carbon monoxide) from the fire penetrating the system.

The air in the galleries driven out from the lateral, though far from pure, will generally be sufficiently good to permit of the galleries being used by listening patrols. If, however, strenuous work is to be performed, or there is any suspicion of the presence of mine gas in the galleries, forced ventilation of the nature described in para. 4 must be provided. The ventilation of two adjacent galleries driven out far from the lateral may be improved by connecting them with a cross-cut (Pl. **68**, Fig. 1).

Natural ventilation may sometimes be effected in single galleries, to which there is only one entrance, by dividing the entrance and gallery into two passages with bratticing (air-proof canvas), one passage so formed becoming an upcast and the other a downcast (Pl. **68**, Fig. 2). Generally speaking, however, it will be easier and more efficient to install forced ventilation in single galleries.

4. **Artificial ventilation** will almost invariably be required in driving headings, for the air in galleries more than 60 feet from a source of pure air (*i.e.*, a lateral with good through ventilation or the outside air) becomes so bad as to prohibit work. Shafts can, as a rule, be driven to a depth of 100 feet from the surface before it is necessary to employ artificial ventilation.

The following apparatus may be used :—

i. Bellows.
ii. Air-pumps.
iii. Fans.

Bellows, about 5 feet in length and similar to those used in smithies, give a good supply of air up to distances of 1,000 feet : Pl. **55**, Fig. 2, shows the method of mounting. The weight of sandbags placed on top of the bellows must be adjusted to suit the pressure against which it is required to work. The apparatus is worked by one man. Using 2-inch hose and worked at the rate of 15 strokes per minute, it will deliver 18 cubic feet of air per minute to a distance of 1,000 feet.

Air-pumps.—Pl. **69** shows a useful type of pump manufactured by Messrs. Holman Bros., Ltd., of Camborne. This pump will deliver a larger volume of air to long distances than bellows, but requires two men to operate it. When worked at the rate of 45 double strokes per minute, it will deliver 18 cubic feet of air per minute through 2-inch hose to a distance of 1,600 feet.

Fans.—Hand-driven geared rotary fans will seldom be used. They require large diameter piping which takes some time to install ; they are also inclined to be noisy in operation. Electrically driven power fans will, however, be of great assistance in gassy galleries, where a large volume of air is required to disperse the carbon monoxide.

Piping.—Armoured rubber hose has been found the most satisfactory method of air delivery for the following reasons :—

i. Ease of installation and extension without noise.
ii. Freedom from leakage.
iii. Flexibility, allowing simple adjustment to bends and irregularities.
iv. Occasional value in maintaining air connection with entombed men through blown ground.

The size of hose used will vary from 2 to 3 inches in diameter. 2-inch hose will generally give an adequate supply of air up to distances of 1,600 feet, provided mine gas is not encountered.

Failing hose, or where large volumes of air are constantly necessary, 4½ to 6-inch diameter stove piping may be employed. The joints may be made air-tight with putty over which a rubber band is stretched. The old inner tubes of motor-car tyres, cut up into suitable lengths, form excellent bands for this purpose.

5. **Gas doors.**—Although a through circulation of air is to be encouraged in mine systems, this feature will have obvious disadvantages should a gallery be flooded with gas after a blow, for, if good natural ventilation exists, the whole of the system may rapidly become filled with mine gas. The best method of overcoming this difficulty is to provide gas doors (Pl. **70**) at suitable intervals in the system, so that a gassy gallery can be shut off from the rest of the system if desired. In some cases it is a good plan to place a gas door in the fighting gallery at its junction with the lateral. The gas door will normally be left open, but will be so adjusted that, should a hostile blow penetrate the head of the gallery, the gas door will automatically be closed by the subsequent rush of mine gas.

98. *Lighting.*

1. **Electricity,** supplied from a petrol or oil-driven set situated in a dug-out near the mine system, is the most satisfactory source of illumination.

Electric light is clean, and does not vitiate the atmosphere. Direct current is preferable to alternating current; the latter should never be used in offensive operations which it is desired to conceal, as the surging of the current is liable to detection by the enemy, and to arouse his suspicions.

2. Candles should be used where the magnitude of the operations does not permit of the installation of electric light. Candles will not burn in an atmosphere containing more than 10 per cent. of carbon dioxide. This fact is a useful indicator of foul air due to inadequate ventilation. Circumstances, however, may occasionally necessitate work being carried out in an atmosphere which will not support the combustion of a candle. In such cases portable accumulator lamps, of the types described in para. 3, must be used, or, if these are not available, acetylene flares.

3. **Portable accumulator lamps.**—The danger of introducing naked lights into galleries in which mine gas may be present in quantities sufficient to produce an explosion (Sec. **105**) has led to the use of portable electric lamps, in which the current is supplied from a small secondary battery. They are principally used in mine rescue work. A lamp of suitable design is shown on Pl. **71**. It weighs 6½ lbs., and is switched on or off by giving a partial rotation to the top part, keeping the bottom part in a fixed position. The makers (The Thor Electric Safety Lamp Co., Ltd.) claim that a lamp with fully charged battery will give 10 hours light. A feature of the lamp is that it is so constructed as to be practically unbreakable if dropped.

4. **Hand torches.**—Officers and shift N.C.Os. should be provided with hand torches of the dry cell type; any of the more reliable patterns on the market are suitable. The torches are not designed to give continuous light, and should only be used intermittently for inspection work, &c.

99. *Laying mines.*

1. The laying of mines will involve :—
   - i. The construction of mine chamber.
   - ii. Loading of explosive.
   - iii. Tamping.

2. **Chamber.**—The cubic contents of the charge will govern the size of chamber to be constructed. The charge must be concentrated; as a rule, the length of chamber formed should not be more than twice the breadth.

Chambers of a cross-section approximating to that of an ordinary gallery may be driven for charges not exceeding 5,000 lbs., but, to avoid spaces, the dimensions should be a multiple of those of the containers in which the explosive is packed. The chamber should be driven at right angles to the direction of the gallery in order to assist tamping.

Special chambers must be constructed for very large charges; Pl. **72** shows a suitable design, of which the following features should be noted :—

- i. The chamber is constructed by driving two headings, each 4 feet 6 inches wide, side by side.
- ii. The chamber is dimensioned to suit the dimensions of the explosive containers (50-lb. ammonal tins).
- iii. The points of detonation are evenly distributed throughout the charge.
- iv. Simplicity of wiring arrangements for firing. The electric detonators and leads are inserted from the central compartment, as shown, after the two outer compartments have been filled with explosive. When this has been done, the central compartment is loaded. By this means all jointing and preliminary testing of leads and detonators can be carried out prior to placing them in the chamber.

It will frequently happen in mine fighting that there is no time to make a chamber for the charge, which under these circumstances must be laid in the existing gallery. Care must be taken that spaces into which the explosive containers cannot be fitted are tightly packed with sandbags.

3. **Loading.**—The explosive is best transported to the chamber on miners' trucks. The galleries and chamber should be lighted by electric lamps during the operation; the use of naked lights should be prohibited. Electric firing will normally be employed for firing mines; two or three separate circuits should be inserted. Large charges should be provided with several points of detonation (*see* Sec. **37**).

4. The tamping used consists of sandbags well bonded together, or rammed earth. The length of tamping should not be less than 1½ times the radius of rupture of the mine.

If circumstances permit, the tamping of the charge may be improved by making two right-angled bends in the gallery leading to the charge (*see* Pl. **92**). Economy of labour may be effected by using air-spaces in the latter half of the tamping. Each air-space should not be more than 10 feet in length, and an equivalent length of tamping should be inserted before another air-space is commenced.

It will sometimes be advisable, in order to have a supply of tamping ready to hand, to stack sandbags on one side of the galleries in the vicinity of the chamber.

5. In emergency, as, for instance, when the enemy has broken into a gallery, it may be necessary to fire small charges with little or no tamping. It is preferable that the portable charges, kept for use in eventualities of this nature, should be in the form of cylindrical torpedoes 6 to 8 inches in diameter. These can be inserted in a bore-hole, made in the side of a gallery with an earth auger; by this means a certain amount of tamping will be obtained.

CHAPTER XIII.

CALCULATION OF CHARGES AND THEIR EFFECTS IN MINE WARFARE.

100. *Explanation of terms, &c.*

1. The calculation of concentrated mined charges for use in demolition work has been described in Part I, Sec. **49.** Concentrated charges of explosive are almost invariably used in mine warfare, but in these operations it is necessary to predict with far greater precision the surface effects that will be produced, and also to estimate as accurately as possible the range of the internal pressures created beneath the surface by the explosion. To do this, the action of a concentrated charge exploded underground must be analysed in some detail.

2. Consider the explosion of a charge O (Pl. **73,** Fig. 1) buried in homogeneous soil at such a depth that its action cannot reach the surface. A spherical chamber of compression* V will be formed by the expanding gases, and in the earth surrounding this chamber compressive stresses will be set up, the limit of which are approximately defined in the section by the circle HKL (for further details *see* Sec. **103**).

3. Now consider the case in which the charge is sufficiently near the surface for the effects of the explosion to reach it (Pl. **73,** Fig. 2).

A chamber of compression will be formed as before, and then the explosive force acting along the line of least resistance OA, which, except in cases where the surface of the ground departs considerably from the horizontal, corresponds with the depth of the charge, will break through to the surface forming a crater circular in plan and of radius AB.

4. The ratio $\frac{AB}{OA}$ or $\frac{\text{radius of crater}}{\text{L.L.R.}}$ is called the **index of a mine,** a numerical factor of first importance in mine calculations. A mine of index $= 1$, that is to say one in which the radius of crater formed is equal

---

* The roof and sides of the chamber of compression usually fall in after the explosion has spent its force, but in very plastic soils it may occasionally remain intact.

to L.L.R., is termed a **common mine.** Mines of index greater than unity are termed **overcharged mines**, those of less **undercharged mines.** A charge of the nature considered in para. 2, so small in comparison with the L.L.R. that it will not break surface, is known as a **camouflet.** The largest charge that can be blown at a given depth without breaking surface is termed a **maximum camouflet.**

5. Craters are frequently referred to in terms of the ratio of their diameter to the L.L.R., when they are known as one-lined, two-lined, three-lined, &c., according as to whether the length of the diameter is one, two, or three times that of the L.L.R. Thus, the crater formed by a common mine is a two-lined crater.

Immediately outside the circumference of the crater proper, the diameter of which, as already explained, is that of the actual hole formed in the earth measured at surface level, mounds of debris, termed the **crater lips** (shown by *BDF* and *CEG* in section on Pl. **73**, Fig. 2), will be thrown up by the explosion. In addition, the ground in the vicinity of the crater edge will be shaken and fissured. Thus, on level ground the zone, within which all personnel will be killed and defences crushed and buried, will be a circle of centre coinciding with that of the crater, but of larger contents. The radius of this circle is termed the **radius of destruction.**

6. As in the example of a camouflet (discussed in para. 2), compressive stresses will be set up in the earth surrounding the charge, but in this case the horizontal force will be greater than the vertical force, since a large proportion of the latter will be expended in the formation of the crater. The limit of the extent of these forces is thus approximately defined in section by the ellipse *QHKLR* (Pl. **73**, Fig. 2) with centre at *O* and major and minor axes *OH* and *OK* (for further details *see* Sec. **103**).

101. *Calculation of charges for mines.*

1. The size of charge required to produce a crater of given radius depends on the depth at which it is laid (*i.e.*, the L.L.R.), the nature of the soil, and the nature of explosive used. If—

n = index of the mine $\left(\frac{\text{Radius of crater}}{\text{L.L.R.}}\right)$,

L = depth of charge or L.L.R. in feet,

s = soil factor, a variable dependent on the nature of the soil,

e = explosive factor, a variable dependent on the nature of explosive used,

C = charge of explosive in lbs.,

the relation between these variables is expressed by the equation

$$C = \frac{s}{10e}L^3\left(\sqrt{1+n^2} - 0{\cdot}41\right)^3.$$

This formula gives accurate results for mines of index ranging between 0 and 3. The values of the expression $(\sqrt{1+n^2} - 0{\cdot}41)^3$ between $n = 0$ and $n = 3$ are given in the following table.

n	$(\sqrt{1+n^2}-0{\cdot}41)^3$.	n	$(\sqrt{1+n^2}-0{\cdot}41)^3$.
0	0·20		
0·10	0·21	1·60	3·22
0·20	0·23	1·70	3·80
0·30	0·26	1·80	4·50
0·40	0·30	1·90	5·25
0·50	0·35	2·00	6·08
0·60	0·43	2·10	7·00
0·70	0·53	2·20	8·10
0·80	0·66	2·30	9·25
0·90	0·82	2·40	10·50
1·00	1·00	2·50	11·86
1·10	1·25	2·60	13·40
1·20	1·52	2·70	15·07
1·30	1·86	2·80	16·80
1·40	2·25	2·90	18·75
1·50	2·69	3·00	20·80

2. The **explosive factor** is expressed in terms of the number of times the power of an explosive exceeds that of Service black gunpowder when used in a mine. Thus, taking the explosive factor of Service black gunpowder as unity, the factors of the following high explosives likely to be used in mine warfare are :—

Ammonal	3·0
Sabulite	2·9
Blastine	2·8
Permite	2·6
Alumatol	2·5
Amatol $\left(\frac{\text{80 Amm. nitrate}}{\text{20 T.N.T.}}\right)$	2·4
Perdite	2·3
Donarite	2·1
Tri-nitro-anisol	1·7

3. The **soil factor** cannot be stated with the same precision as the explosive factor, as the value for the same kind of soil varies in different localities according to the lie of the strata, amount of water present, &c. Below are given the average values of s for various soils, obtained experimentally from the results of a large number of mines.

Made ground (embankments, &c.)	Light sandy soil	0·7
	Heavy clay soil	0·9
Virgin soil	Soft sand	1·0
	Hard sand	1·1
	Gravel	1·3
	Sandy loam, clay	1·4
	Blue clay	1·5
	Soft chalk	1·6
	Hard chalk	1·7
	Soft rock	1·8 to 2·5
	Hard rock or masonry	2·5 to 4·0

Where great accuracy is desirable, these figures should only be taken as an initial guide, and the actual value of the soil factor for the particular locality should be ascertained. This can be done by measuring the diameter of crater formed by a given charge at known depth, and solving for s in the formula.

4. **Common mines.**—It will be noted that $(\sqrt{1+n^2} - 0 \cdot 41)^3 = 1$, when $n = 1$. Hence a simplified formula may be used for common mines, viz.,

$$C = \frac{s}{10e} L^3.$$

The depth L at which the charge C, of a mine of index n at depth L_1, will form a common mine is given by the formula—

$$L = L_1 (\sqrt{1+n^2} - 0 \cdot 41),$$

for by the general formula

$$\sqrt[3]{C \frac{10e}{s}} = L_1 (\sqrt{1+n^2} - 0 \cdot 41);$$

and by that for a common mine

$$\sqrt[3]{C \frac{10e}{s}} = L.$$

The above equation is of importance in calculating radii of rupture (Sec. **103**).

5. **Maximum camouflet.**—When $n = 0$, $(\sqrt{1+n^2} - 0 \cdot 41)^3 = 0 \cdot 20$ thus the equation for a maximum camouflet is

$$C = \frac{s}{10e} 0 \cdot 20 \, L^3.$$

In other words, at a given depth one-fifth of the charge of a common mine will just fail to break surface. This result has been found to be correct in practice.

The depth L_0, at which the charge of a common mine of depth L will form a maximum camouflet, is approximately $1 \cdot 7L$.

For from the formula given in para. 4

$$L = L_0 (\sqrt{1+n^2} - 0 \cdot 41)$$

and here $n = 0$,

$$\therefore L_0 = \frac{L}{0 \cdot 59} = 1 \cdot 7L \text{ (approximately).}$$

102. *Calculation of depth of crater and other surface effects.*

1. **Depth of crater.**—The wedge of earth thrown out by the explosion of a mine will approximate in shape to that of a blunt inverted cone (with apex below the centre of the charge), of which the figure *BMNPC* (Pl. 73, Fig. 2) is a section; but this void is partially filled up again by the earth which falls back under the action of gravity, so that the figure *BSCA* represents a section of the final shape of the crater. In an undercharged mine the proportion of earth which falls back into the crater is high, and the

depth of the crater is thus considerably less than that at which the charge is laid, but as the charge is increased a larger proportion of earth is thrown outside the crater, while the void formed below the charge by the chamber of compression is correspondingly greater. As a result, the depth of the crater of a heavily overcharged mine exceeds that of the charge.

The depth of the craters of mines of indices between 0·5 and 3 may be calculated from the formula

$$p = \frac{L}{3}(2n - 1)$$

where p is the depth of crater in feet.

It will be observed that when $n = 2$ the depth of the crater is equal to the L.L.R., and that mines of index greater than 2 form craters of depth greater than that of the charge. The depth of the crater of a common mine is $\frac{L}{3}$. When $n = \frac{1}{2}$, then $p = 0$, or, in other words, the hole formed by the explosion is completely filled up by the earth which falls back into it. This is found to be approximately correct in practice.

2. **Crater lips.**—The height of the crater lips is frequently of considerable importance in mine fighting, since the field of fire of our own or of hostile troops and the amount of cover afforded may be dependent on this factor (*see* Sec. **80**, paras. 7 and 8). It is not possible to give a formula for this dimension, since it varies so much with the nature of the ground. The debris of mines blown in rock and compact soils are scattered over a larger area than in the case of friable soils the cohesion of which is comparatively small; thus, under similar conditions, the looser the soil the higher will be the lips formed. Generally speaking, a three-lined crater gives the highest lips. In friable soils, such as sand or clay, the average height of the lips of a three-lined crater blown on level ground will be about $\frac{1}{6}$ the L.L.R., and that of the lips formed by a common mine about $\frac{1}{8}$ the L.L.R. These figures can only be taken as a rough guide; if the surface of the ground is tightly compressed so as to form a crust, the height of the lips will be reduced in consequence. This is a marked feature of craters blown in ground the surface of which is frozen.

The height of the crater lips of mines blown on a slope will always be greater in the direction of the downward slope, and, where the inclination exceeds 1 in 15, practically no lip will be formed on the upper edge of the crater.

The width of the base of crater lips is also very variable. The width in the case of a three-lined crater blown in soft soil on level ground is generally about equal to the L.L.R.; it is rather greater than this dimension for more heavily charged mines and slightly less for a common mine.

3. **Radius of destruction.**—If f is the radius of destruction in feet, then for mines of index between $\frac{1}{2}$ and 3

$$f = L\sqrt{1 + 2n^2}.$$

Thus for a common mine

$$f = L\sqrt{3}\ .$$

103. *Calculation of radii of rupture.*

1. The pressure created in the soil at any given point by the explosion of a mine varies inversely as the square of the distance from the centre of the charge. Thus, the locus of equal pressures set up will be the surface of an ellipsoid (*see* Sec. **100**, para. 6), of which the major axis is horizontal. In the case of a camouflet the axes are approximately equal, and the locus of equal pressures is a sphere (Sec. **100**, para. 2), but the heavier the charge used at a given depth the greater is the difference between the major and the minor axes of the ellipsoid.

The **effective radius of rupture** in any given direction is the greatest distance from the centre of the charge at which an untamped gallery will be destroyed by the explosion.

The **maximum radius of rupture** in any given direction is the least distance from the centre of the charge at which an untamped gallery will be undamaged by the explosion.

It is clear that, to ascertain whether a hostile gallery at known distance will be destroyed by a given charge, the effective radius of rupture must be determined, and that the maximum radius of rupture will be required in estimating the damage likely to be caused to galleries of the system from which the mine is fired. In either case it is generally sufficiently accurate to calculate either the horizontal or the vertical radii of rupture (*i.e.*, the major and minor axes of the ellipse), and, where great accuracy is required, to interpolate for intermediate positions. The horizontal radius of rupture and the vertical radius of rupture will be referred to hereafter as the H.R.R. and the V.R.R. respectively.

2. **Calculation of radii of rupture.**—The effective H.R.R. of a common mine may be expressed in terms of its ratio (K) to the depth (L) of the charge; that is to say

$$\text{Effective H.R.R.} = KL.$$

The effective H.R.R. of undercharged and overcharged mines is approximately equal to that of a common mine of the same charge. Hence by the formula given in Sec. **101**, para. 4, the effective H.R.R. of any mine of depth L and index n will be given by the equation :—

$$\text{Effective H.R.R.} = KL\,(\sqrt{1+n^2} - 0{\cdot}41).$$

Since $L\,(\sqrt{1+n^2} - 0{\cdot}41) = \sqrt[3]{C\dfrac{10e}{s}}$, the effective H.R.R. may also be expressed as—

$$\text{Effective H.R.R.} = K\sqrt[3]{C\frac{10e}{s}}.$$

The effective V.R.R. and the maximum H.R.R. and V.R.R. of any mine vary directly as the effective H.R.R., and may be expressed in terms of this distance as follows :—

Effective V.R.R. = 0·7 effective H.R.R.
Maximum H.R.R. = 1·2 effective H.R.R.
" V.R.R. = 1·0 effective H.R.R.

Thus, the following is a summary of the formulæ :—

$$\text{Effective H.R.R.} = KL(\sqrt{1+n^2} - 0{\cdot}41), \text{ or } KL\sqrt[3]{C\frac{10e}{s}}.$$

$$\text{,, V.R.R.} = 0{\cdot}7KL(\sqrt{1+n^2} - 0{\cdot}41), \text{ or } 0{\cdot}7KL\sqrt[3]{C\frac{10e}{s}}.$$

$$\text{Maximum H.R.R.} = 1{\cdot}2KL(\sqrt{1+n^2} - 0{\cdot}41), \text{ or } 1{\cdot}2KL\sqrt[3]{C\frac{10e}{s}}.$$

$$\text{Maximum V.R.R.} = 1{\cdot}0KL(\sqrt{1+n^2} - 0{\cdot}41), \text{ or } 1.0KL\sqrt[3]{C\frac{10e}{s}}.$$

The value of K is highest in soft friable ground. The approximate values for the following soils are :—

Rock	1·4
Hard chalk	1·5
Soft chalk	1·6 to 1·7
Blue clay	1·9
Loam	2·0
Sand	2·1
Made ground	2·0 to 2·3

The above table should only be taken as an initial guide pending the determination of a more accurate value for K, based on the observation of a series of results obtained in the soil in which mine fighting is taking place.

Radii of rupture can seldom be calculated with great precision. The lie of the strata, planes of cleavage, and the proximity to the charge of ground shaken by a previous mine are factors for which it is impossible to make allowance in formulæ, and their influence (often very considerable) on the range of the underground pressures is largely a matter of guesswork based on experience.

The formulæ are frequently most unreliable for mines of exceptionally large charges (20,000 lbs. and over). The vast upheaval and shaking effect produced by the explosion is often sufficient to cause small land-slides and subsidences, with the result that the radii of rupture in the direction in which these take place are far in excess of the normal. The maximum H.R.R. of several of the large mines fired during the battle of the Messines Ridge in 1917 was found to be more than double that which had been anticipated.

CHAPTER XIV.

MINE GAS AND MINE RESCUE.

104. *General.*

Mine gas is the term applied to the gases produced by the explosion of a mine, and refers in particular to carbon monoxide (CO) which is its most dangerous constituent.

The importance of a study of the nature and effects of mine gas may be gathered from the fact that in mining operations during the War of 1914-1919, casualties due to CO poisoning alone far exceeded those caused by the direct action of enemy mines, while the explosion of mine gas, which has flooded a system, subsequent to a blow, may also be a source of heavy casualties. The nature and danger of CO poisoning must, therefore, be impressed on all ranks; special precautions must be taken in galleries in which the existence of this gas is suspected; adequate mine rescue apparatus must be installed, and measures must be taken to reduce the risk of the ignition of mine gas penetrating a system after a blow.

105. *Explosions of mine gas.*

1. The inflammable gases generated by the detonation of a high explosive vary in quantity and composition according to the explosive used, its quality, and other conditions. CO will invariably be present and, as a rule, hydrogen and methane (firedamp). All these gases are combustible and, when mixed with the air of the galleries in the right proportions, explosive.

The tendency of the gases to explode will depend on certain factors:—

i. The amount of gas present.
ii. The initial velocity of the gases issuing from the seat of the explosion.
iii. The size of the galleries.

The greater the density and velocity of the gases, the greater will be the liability to explode; small galleries will increase the pressure and concentration of the gas.

2. Naked lights should never be carried in galleries where mine gas is likely to be encountered in large quantities. Mine gas may collect in explosive quantities in the blind end of a gallery; it may also be encountered in opening up disused workings in the neighbourhood of which a mine has been exploded. Generally speaking, however, explosions of mine gas are most to be feared immediately after the explosion of a mine before the hydrogen and methane have had time to disperse.

It should be impressed on all men that when an enemy blow occurs, all naked lights must immediately be extinguished. Explosions have frequently occurred through miners endeavouring to re-light candles which have been extinguished by a blow.

When explosive gases are ignited, they do not, as a rule, explode at the point of ignition, but at a certain distance away. The flame passes down the gallery till it reaches a point at which, if there is sufficient gas to feed it, vibrations are set up, and these become more and more rapid until explosion occurs. Where the gas is not in sufficient quantity or is in a non-explosive percentage, the flame becomes spent. The result is that evidences of damage done to a gallery will seldom be found at the point of ignition, but some distance away, and men in the vicinity of where the gas has been fired suffer from burns and not from injuries caused by the force of the explosion.

One of the gravest dangers to which men are exposed by a mine gas explosion is due to the partial vacuum induced in the mine system after the explosion. This will result in the flooding of the system by fresh supplies of gas from the vicinity of the exploded charge. This second flow of gas will, as a rule, consist mainly of CO; a number of the casualties from explosions of gas in mines may be found, therefore, to be due to CO poisoning.

106. *Mine gas poisoning.*

1. Casualties from poisoning are liable to be far more frequent than those due to the explosion of mine gas. As has been explained, the latter are only likely to occur immediately after a blow, while the former may arise weeks or even months after the charge, which generated the mine gas, was fired. Cases of poisoning from nitrous fumes have been known to occur, but, in general, poisoning will always be due to CO.

The other constituents of mine gas disperse rapidly after a mine has been fired. CO, however, is of approximately the same density as air, and practically insoluble in water; it is thus most difficult to evacuate from galleries. The clearing of CO from a gallery is further complicated by the fact that this gas is driven into the fissures and pockets formed by the force of the explosion from which it gradually oozes out. This feature is most marked in porous soils, such as chalk, in which galleries may take weeks to clear, only to be filled again with gas as soon as work is resumed and the ground in the affected area is disturbed. In some cases pockets may be encountered when working through blown ground; the gas may break through into the gallery in distinct puffs with a hissing sound, showing that it is escaping under pressure.

Galleries which have been freed of gas may again suddenly be flooded owing to :—

i. Sudden settlement of the ground above an area impregnated with CO forcing the latter into the gallery. Such settlements may be caused by a blow (frequently quite distinct) or by natural forces (rain, &c.).

ii. A fall in the atmospheric pressure.

iii. Rise of water level.

Gas percolating through the ground may take peculiar directions, and appear in a gallery unconnected with and at a considerable distance from those affected by the explosion. Fumes from explosives frequently lose their distinctive odour after percolating through the soil (CO is itself odourless), and become consequently much more insidious. Cases have occurred in which the miners working in neighbouring galleries have been so little disturbed by a blow that they have continued at work. In course of time the mine gas has penetrated these galleries, and poisoned the men. Men must, therefore, be warned to come to the surface immediately they hear a blow, no matter how distant. They should not return to their work till the workings have been reported clear of gas.

Though CO will invariably be formed in all mine explosions, the proportion generated is largely dependent on the amount of free oxygen present at the instant of detonation. If there be excess of oxygen, the tendency will be to form more carbon dioxide and less CO. The amount of CO created may, therefore, vary with the nature of explosive used and the conditions under which it is fired. Gun-cotton always gives off large volumes of CO, while the gaseous products of ammonal may contain comparatively little of this gas. Charges, which through age or dampness tend to burn instead of detonating, usually produce CO in abnormally large quantities; in wet sites trouble from this cause may be frequent.

The soil and workings are more liable to be impregnated with CO after a camouflet has been fired than after a mine, for in the former case the mine gas has not the same opportunities to escape to the surface.

107. *Nature of CO poisoning.*

1. The affinity of the blood to CO is very much greater than to oxygen. Hence, when an atmosphere containing CO is breathed, the oxygen in the blood is gradually replaced by CO, so that all the tissues of the body suffer from oxygen starvation.

The action of CO is cumulative; that is to say, it will gradually be absorbed by the blood, although there may be only a small percentage present in the air. Air in which only 0·1 per cent. CO is present must be regarded as dangerous. It is this cumulative action which makes CO such a dangerous and insidious poison. For example, when a man has been obliged to come out of the mine owing to feeling the effects of gas, his blood is already dangerously saturated with CO, so that, should he again descend, only very short exposure will be necessary to render him unconscious.

A man at work absorbs more CO than when at rest, and the more strenuous the work the more CO will he absorb, and the more rapidly will symptoms of poisoning develop. For instance, at rest 0·1 per cent. CO will cause symptoms to appear in about two hours, whereas at work only 40 minutes exposure would be necessary. 0·2 per cent. causes loss of consciousness in 20 to 30 minutes in a man at work, and 0·3 per cent. in 10 to 15 minutes. If CO be present in large quantity, loss of consciousness will develop suddenly within a few minutes. Where ventilation is defective, the action of CO is intensified, and symptoms of poisoning will appear more rapidly.

When exposed to gas, men should proceed out of the galleries as quietly as possible, in order to conserve the small oxygen supply available in the blood. Anxiety, excitement, or marked mental effort act in the same way as muscular exertion.

Unless a man is removed from an atmosphere containing CO soon after he loses consciousness, death will ensue. Hence the necessity of the provision of mine rescue apparatus within easy reach of the mine system.

Prolonged exposure to air containing small quantities of CO is much more injurious to the human system than short exposure to air containing large quantities. It is after prolonged exposure to comparatively small percentages of CO that relapses, after apparent recovery, are so common, and serious after-effects develop; whereas after short exposure to a very high percentage, complete recovery is generally assured, once the patient regains consciousness.

A certain degree of tolerance to CO may become established in some individuals; some men are much more susceptible to CO poisoning than others. No man, however, is immune against it.

2. **Symptoms of CO poisoning.**—When CO is present in large quantities, loss of consciousness will develop in a few minutes with practically no warning symptoms. When present in smaller amounts, the onset is gradual and insidious. The first symptom generally complained of is slight giddiness, accompanied sometimes by noises in the ears. Shortness of breath and palpitation of the heart, which are exaggerated by the slightest exertion, and slight confusion of the mind then develop; these symptoms are quickly followed by a characteristic loss of power in the limbs. When this stage is reached, very little exertion will produce loss of consciousness.

In some cases the above-mentioned symptoms are absent, and the first indication to attract attention is the feeling of utter powerlessness in the legs. In yet others the onset is still more insidious, the man either dropping without any warning, or becoming languid and drowsy with an irresistible desire to rest; the mind also becomes so quickly blurred over that unconsciousness develops before the man is able to appreciate the danger. Men should, therefore, work in pairs wherever there is a suspicion of gas; listening, especially, should be carried out in parties of two.

When the percentage of CO is very small and its effect only comes out after prolonged exposure, headache, noises in the ears, and giddiness are the most prominent symptoms.

The cheeks of those overcome by CO frequently assume a pink hue, and the lips a vivid carmine tint; to those who have died of CO poisoning this sometimes gives the face a wonderfully life-like appearance.

The characteristic powerlessness of the limbs produced by CO poisoning has important bearings on mine rescue work. When a man has been gassed, he should not be allowed to make his way to the surface unaided. The exertion of walking or crawling and of climbing the ladder of the shaft or incline may bring on powerlessness of the limbs and feebleness of grip, with the result that he may fall to the bottom unless roped. In some cases CO also causes sensory disturbances. Miners who have been slightly gassed will declare that, when ascending the ladder, the rungs felt as if they were twice their normal size, and that it seemed to them as if they were putting their feet on some yielding substance. A man who has been gassed, no matter how slightly, should not be permitted to make his way to the surface without being roped. It has also been found that exposure to fresh air often renders a man unconscious after he has been gassed. Great care must, therefore, be taken at the mine entrance to prevent accidents to men through suddenly falling back as they reach the surface.

108. *Detection of CO.*

CO is a colourless, odourless, and tasteless gas. Further, its presence cannot be identified by any simple chemical test which can easily be applied to the atmosphere of a mine system. The effect of CO on small birds and mice is the best method of detecting the presence of this gas.

Canaries or white mice are generally used; the former are preferable. These absorb the poisonous gas much more quickly than man, as their rate of breathing and circulation is much more rapid. A canary or mouse would be affected in about two minutes in an atmosphere containing a percentage of CO which would begin to produce a noticeable effect on a man in half an hour. They may, thus, give warning of danger before poisoning of the human system sets in. Birds and mice, when not being used as detectors, should always be kept in good air. If they are kept in the tainted atmosphere of mine galleries, a certain tolerance to CO may become established, and they become less efficient detectors.

Canaries are more sensitive to CO than mice. Moreover, the fall of a canary from its perch can readily be seen, while a mouse will, as a rule, huddle up into a corner, and may require prodding to ascertain whether it is still alive. The earliest sign of distress in a canary is a ruffling of the feathers of the breast; then the wings move in a restless manner, it sways and assumes a position of roosting, and remains so till it falls. In higher percentages it flutters its wings, pants, and quickly falls from its perch. A mouse, when affected, becomes restless, pants, and, after staggering about, rolls over. The cages in which animals are carried should be wired on three sides, so that the air of the gallery can always reach them at once.

109. *Mine rescue.*

1. **Breathing apparatus.**—The box respirator is an efficient counter to poison gas of the nature used in gas shells and other forms of gas attack, because it contains chemicals which absorb the poison with which the air is laden. There is, however, no known substance which, when used in the filter of a box respirator, will act as a satisfactory eliminator of CO. **Hence box respirators afford no protection against air containing CO.** Many deaths have been caused through an erroneous impression that a box respirator would furnish at least partial immunity from CO poisoning. Atmosphere containing CO in a dangerous quantity cannot be entered without self-contained oxygen breathing apparatus, by means of which the wearer is independent of the nature of the surrounding atmosphere.

The "**Proto**" self-contained breathing apparatus was the standard equipment used during the War of 1914-1919. It is designed to supply the wearer with a factitious but respirable air, entirely independent of the surrounding atmosphere, for fully two hours at a time. The "**Salvus**" apparatus, a smaller and lighter breathing set, was also used; it will provide the wearer with air for about half an hour. The principle of both the Proto and the Salvus equipments is the same. The wearer breathes the same air over and over again; the carbon dioxide is absorbed from the air after each expiration by passing it through caustic soda, and at the same time the requisite quantity of oxygen is restored to it from small oxygen cylinders; thus rendering it pure and fit to be again inhaled. Pl. **74** shows a diagram of the Proto apparatus, and Pl. **75** shows the apparatus in use; the oxygen cylinders are strapped on to the back of the wearer.

Space does not permit of a detailed explanation of the working parts, method of re-charging apparatus, &c. For instructions on the care and maintenance of Proto and Salvus sets, reference should be made to the handbook and pamphlets issued by the manufacturers, Messrs. Siebe, Gorman and Co., Ltd. Much valuable information will also be obtained from "Recent practice in the use of self-contained breathing apparatus," by Rex C. Smart (C. Griffin and Co., Ltd.). This book deals with the experience gained in mine rescue work during the War of 1914-1919.

2. **Rescue apparatus.**—Pl. **76** shows a type of mine stretcher used for removing from the galleries men overcome by mine gas. It is so constructed that it can be dragged along the floor of a gallery or hauled up a shaft.

The administration of oxygen is of the utmost value in cases of CO poisoning. It drives out the CO from the blood five times more quickly than air. The "**Novita**" oxygen reviving apparatus (*see* Pl. 77) was used for this purpose during the War of 1914-1919. It consists of a cylinder of oxygen to which an india-rubber bag is attached. The flow of oxygen into the bag, which should be kept about half full, is adjusted by means of a valve. The oxygen is applied to the patient by means of a mask which fits over the mouth.

3. **First aid treatment.**—The patient must be treated immediately. The points to aim at are:—first, the restoration of breathing, and secondly, after breathing is restored, the promotion of warmth and circulation. Artificial respiration should be applied (Schaefer's method) in conjunction with the oxygen reviving apparatus. The efforts to restore life must be persevered with for a considerable time; a number of cases have occurred where life was thought to be extinct, and yet energetic treatment was successful in restoring animation.

Schaefer's method of artificial respiration is as follows:—

i. Lay the patient face downwards with the arms extended. Turn the face to the side. Kneel astride or on one side of the patient.

ii. Place the hands on the small of the patient's back, one on each side, with the thumbs parallel and nearly touching (Pl. **77**, Fig. 1).

iii. Bend forward with the arms straight so as to allow the weight of the operator to bear on his wrists, and thus make a steady firm downward pressure on the lower part of the patient's back (the loins and lower ribs), as shown on Pl. **77**, Fig. 2. (This part of the operation should occupy the time necessary to count slowly—one, two, three.)

iv. Immediately after making the downward pressure, the operator should swing backwards so as to relax the pressure, but without lifting his hands from the patient's body (Fig. 1). (This part of the operation should occupy the time necessary to count slowly—one, two.)

v. Repeat the forward and backward movements (that is, the pressure and relaxation of pressure) without any marked pause between the movements. The downward pressure forces the air out of the lungs, and the relaxation of pressure causes the air to be drawn in again.

vi. Continue the movements at the rate of about 12 per minute until natural breathing has recommenced.

vii. When natural breathing has fairly begun, cease the movements. Watch the patient closely, and, if natural breathing become shallow, very slow, or ceases, repeat the movements as before.

The supply of oxygen to the patient should be continued for some time after natural breathing has been restored; this will have the effect of lessening the severity of the after-effects, which in some cases are very distressing.

Owing to the action of CO in reducing the temperature of the blood, warmth is essential in the treatment of all gas poisoning cases. The patient should be wrapped in dry blankets, and warmth in the body promoted by means of hot water-bottles applied to the pit of the stomach, the armpits, the sides of the chest, and the soles of the feet. Energetic friction of the skin of the chest and of the limbs in an upward direction will also increase body heat, and stimulate the circulation. When the patient is able to swallow, hot strong coffee may be given; no other stimulant should be administered without the authority of a medical officer. Phenacetin, asperin, &c. should never be given to relieve headache; serious cases of heart failure have followed the administration of such drugs in gas poisoning cases.

Rest is absolutely essential to successful treatment. Under no circumstances must the patient be walked about after he has come to. Muscular exertion means the needless expenditure of the small available supply of oxygen in the blood, and attempts at walking may lead to loss of consciousness. If possible, no man who has been gassed should be permitted to march back from the trenches. Men who have been unconscious should, if possible, not be removed to the dressing station for at least two hours after they have come to. It will be found that, if rest is insisted upon, recovery will be greatly accelerated, and serious after-effects avoided.

110. *Mine rescue stations.*

1. A mine rescue station should be installed in close proximity to all mine systems in a dug-out constructed especially for the purpose. Its position should be known to all ranks. Where convenient one station may serve a group of workings, but, if possible, it should be situated not more than 200 yards away from any mine entrance.

The rescue dug-out should always be isolated from the mine system. Accidents have occurred by gas penetrating the dug-out after a blow, where this has not been done. Stations should be made as damp-proof as possible. They should not contain any material other than rescue apparatus, and no rescue material other than life lines (kept at mine entrances) should be stored elsewhere. Stations must be kept scrupulously clean and tidy, so that all equipment can be got at without delay. Breathing apparatus should be coupled up ready for immediate use and hung up on pegs; it should never be kept in the boxes in which it is packed.

2. Rescue stations during the War of 1914-1919 were organized as follows:—Two trained mine rescue men were on constant duty at a station; these men had a thorough knowledge of the position of each mine served, and were familiar with the various workings. To prevent tampering with the apparatus, only authorized persons were allowed to enter the rescue station.

The amount of apparatus kept at a station depended on the extent of workings served and the prevalence of mine gas. The following may be taken as a guide:—

Breathing and reviving apparatus.

4 Proto sets.
4 Salvus sets.
4 Novita oxygen reviving sets.
6 sponge rubber goggles.

Spare oxygen cylinders, tins of caustic soda, and small spares for apparatus, such as washers, nose clips, &c.

Other rescue stores.

6 blankets.
1 primus stove.
6 hot water-bottles.
2 tins café au lait.
10 miners' electric lamps.
10 spare accumulators for same.
1 trench stretcher.
2 mine stretchers.
3 life lines.
1 hand-saw.
1 hand-axe.
6 canaries or white mice.
4 small testing cages.
2 large living cages for mice or canaries.

111. *Organization of mine rescue work.*

1. The following orders should be clearly impressed on all ranks and immediately complied with on a mine explosion occurring:—

i. All ranks working below are to come to the surface at once.
ii. All naked lights are to be extinguished.
iii. No man is to descend to the mine workings without self-contained breathing apparatus till they are reported clear of gas.

2. The rescue men at the station should be warned immediately an explosion occurs, and informed as far as possible of its location. They should put on the breathing apparatus, descend to the locality at once, and examine the damage done. No naked lights are to be used; the rescue

men must be equipped with miners' electric lamps (Sec. 98, para. 3). The rescue men should proceed with the evacuation of any men they may find overcome with gas. No man who has been gassed is to ascend the shaft or incline without being roped. When an explosion occurs, all fit men who have been trained in mine rescue work should, on coming to the surface, report at the mine rescue station. Here, the senior present will issue them with breathing apparatus, and organize further mine rescue parties as required.

3. On completion of rescue work, all apparatus must be thoroughly cleaned and overhauled; the empty cylinders of oxygen must be replaced, and the caustic soda renewed; equipment and spares must be replenished from company headquarters, where a store of apparatus should be kept; defective apparatus should be sent for repair (normally to the mine school, *see* Sec. 89, para. 3). The officer in charge of the section where the explosion occurred should see that the above is carried out immediately rescue work is over, so that the apparatus may be ready for use again at once.

NOTE.—For further information on the subjects dealt with in this chapter reference should be made to *Mine Rescue Work on the Western Front* and to Chaps. XIX, XX, and XXI, Vol. II (*Diseases of the War*) of the Official Medical History of the War, published by HM. Stationery Office.

CHAPTER XV.

LISTENING.

112. *Theory of listening instruments.*

1. The importance of listening in mine warfare has already been emphasized. It provides the principal, and frequently the only, means of obtaining intelligence of enemy mining activity. Much information can be gained with the unaided ear; indeed, at close ranges this is often the most satisfactory method of listening. Various instruments, however, are employed underground to increase the distance at which sounds can be heard, and to assist in ascertaining their nature and direction, just as field glasses are used above-ground to increase the range of vision.

2. Sounds transmitted through the earth and listened to in the air are usually of small intensity. This is due to the great difference in the velocity of propagation of sound in earth and in air respectively. Sound travels in earth with a velocity varying from 1,000 to 3,000 metres per second, according to the nature of the soil; in air the velocity is about 330 metres per second. As a result, the sound waves are for the greater part reflected at the surface dividing the two media, which are, therefore, almost entirely separated acoustically.

It is for this reason that earth sounds will be picked up more easily in a gallery if the ear be placed against the wall or floor. By this means the sound waves reach the listener direct from the earth, and by avoiding passage through the air are not reduced in intensity. It is true that a small air-space exists between the earth and the drum of the ear, but this, being an enclosed column, oscillates with the vibrations of the surface in contact with it, and under these circumstances actually assists in the transmission of the sound waves.

The passage of sound vibrations from the earth to solid or liquid substances with which it is in close contact takes place with very slight loss. Hence, if an iron bar be driven into the ground and the ear applied against the free end, hearing will be improved, for the bar will collect sound waves over a large area. A more sensitive device may be constructed by burying the base of a bowl, filled with water, in the earth, and immersing the ear in the liquid.

The iron bar and the water bowl constitute primitive listening apparatus, and depend on a principle on which the action of all listening instruments is based, viz., the collection of sound vibrations direct from the earth.

3. The obvious inconvenience of placing the ear against an iron bar or in a bowl of water may be overcome by two methods :—

i. The stethoscope.
ii. Electrical means.

i. The **stethoscope method**.—The property possessed by an enclosed column of air of accurately transmitting sound waves, received from the material enclosing it, has been referred to in para. 2. The stethoscope is a practical application of this phenomenon. The device, as used in listening apparatus, consists merely of two lengths of rubber tubing, each connected at one end to the instrument and fitted at the other with suitably shaped ear-pieces.

If the water bowl (described in para. 2) be replaced by a bottle to the neck of which the stethoscope tubing is attached (Pl. **78**, Fig. 1) a stethoscope listening instrument will be constructed. The columns of air enclosed within the tubes will, provided the latter forms the only exit from the bottle, convey to the ears even the most minute vibrations of the water. In fact, the **Water-bottle** is a very sensitive listening apparatus, and is a useful makeshift in default of more suitable equipment.

To prepare the bottle for use, fill it completely with water and place it on the ground. Blow gently down the narrow neck A until a little water flows out of B and air bubbles appear at the surface. The water is then at correct level. Close B securely with a stopper, and insert the stethoscope tubing in A. The apparatus is then ready for use.

ii. The **electrical method** consists in the use of telephone apparatus specially adapted to transmit the sound waves received by the instrument to the listener. This system is adopted in numerous forms of listening instruments of which the Seismophone, described in Sec. **114**, is typical.

4. **Quality of sound.**—A field glass or telescope of high power is of little value if the definition is poor and the field of view blurred;

the observer will experience difficulty in identifying and ascertaining the nature of objects portrayed. Similarly, a highly sensitive listening instrument falls far short of what is required if the sound waves are much distorted in transmission. The sounds heard will be confused, and the listener will not be able to identify their source. Picking may sound similar to footsteps or talking, and, in general, it will not be possible for the brain to *visualise* the nature of sounds.

The perfect instrument would be one in which all vibrations, though intensified, are identical in quality with those which reach the naked ear. This ideal cannot be attained in practice, but it is essential that the sound waves transmitted should suffer the minimum of distortion.

Water, judged from this standpoint, gives exceptionally poor results. The vibrations transmitted lose much in quality, and noises are hard to identify : hence, the unsuitability of the " Water-bottle " for general use. Of the numerous substances which give favourable results with respect to the actual transmission of sound, mercury has been found to give the most accurate and faithful reproduction of sound waves. This is the medium used in the geophone described in the following section.

113. *The geophone.*

1. The geophone is the most suitable instrument for all-round work that has been devised. Its sensitiveness is excellent, and the range of hearing is at least double that attainable with the unaided ear. The superiority of this contrivance over other types of listening apparatus, however, lies mainly in the good quality and comparatively clear definition of the sound waves reproduced. The accuracy with which, under favourable conditions, it enables the direction of sound to be gauged is also an asset of first importance.

The action of the geophone is identical in principle with that of the stethoscope water-bottle, but mercury enclosed between two mica diaphragms replaces the water. The details of construction of the geophone *pot* are clearly shown on the plan and section on Pl. **78**, Fig. 2.

Geophones in which lead held between two rubber rings replaces the mercury mass have also been used, but the quality of sound reproduced is comparatively poor. They have, however, the merit of cheapness of manufacture.

A complete geophone set consists of two pots, a stethoscope, and a small compass (Pl. 79).

One geophone pot (a tube of the stethoscope being attached to each nipple) is sufficient, if the instrument is to be used only to identify sounds and gauge their distance. Two pots must be used, however, when it is desired to determine the direction of the sound as described in the following para.

2. **Determination of sound direction.**—A man of normal hearing, when spoken to, is able without visual aid to gauge the direction from which he has been addressed. This instinct, which is not possessed by people entirely deaf in one ear, seems chiefly due to the fact that a sound made either to the right or left does not reach the two ears at precisely

the same time. The brain is able to appreciate this small difference, and estimates instinctively the direction from which the sound comes. It is this same faculty of the brain which is employed to determine the direction of sound transmitted through the ground. With a geophone pot connected to each ear, the listener is in a position to apply to earth-borne sounds that sense of direction which he employs subconsciously in everyday life to sounds in the air.

If the geophone pots be placed on the ground at about the same interval apart as the ears, and the ground be tapped gently at various points a little distance away, the listener, with his eyes closed, will be able to tell instinctively whether the blows are made to his right, left, or front.

There is a close analogy between this sense of sound direction and that of stereoscopic vision. Just as the latter is improved by binoculars with object glasses spaced further apart than the width of the eyes, so sound direction may be determined with greater accuracy, if the geophone pots be placed at a greater interval apart than that between the ears. It should be noted, however, that, if the pots be placed too far apart, the brain will be *unable to superimpose* the two sounds. They will then be heard as two separate sounds, and all sense of sound direction will be lost. With trained listeners the most satisfactory interval for the pots has been found to be the width of the shoulders.

The procedure adopted to ascertain the direction of a given sound is as follows :—The pots are placed in the position (say) L1 R1 (Pl. **80**, Fig. 1), and the sensation is experienced of a sound coming from the right. The pots are then placed in a second position (say) L2 R2 in which the sound appears to come from the left. A *bracket* has thus been obtained, and the direction of the sound must lie within the angle L2 OR1. By a system of trial and error the size of this angle can be reduced till finally a position L3 R3 (say) is obtained at which the sound appears to be immediately in front; that is to say, the direction of the sound is approximately AO. To obtain an accurate reading, the pots should then be placed rather farther apart, and positions L4 R4 and L5 R5 found at which the sound can just be distinguished as coming from the left and the right respectively. The mean of these two positions will be the direction of the source of the sound, a compass bearing of which is then taken. Working with the geophone pots in a vertical plane it is also possible by this method to ascertain whether the sound is above or below the listener. It is much more difficult, however, to obtain accurate results than by observations taken on the horizontal plane.

It is obviously of first importance that the pots and stethoscope tubes of a geophone set should be identical if accurate direction readings are to be obtained. The following points must be looked to.

i. The pots should be a pair (to ensure this the box and the two pots of a set are marked with the same number).

ii. The rubber tubes of the stethoscope must be of equal length.

iii. The stethoscope tubes should be attached to the lower nipples of the pots, the upper nipples being in each case plugged. Rubber stoppers are attached to each nipple of a geophone for this purpose.

iv. The tubes, ear-pieces, and nipples of the pots must be free from obstruction. The nipples, when the pot is not in use, should always be plugged to prevent dirt getting in.

The geophone being a delicate instrument, its efficiency is easily impaired by rough treatment.

114. *Electrical listening instruments—The seismophone.*

The special feature of all electrical listening instruments is that they enable listening to be carried out from a distance. The transmitting portion of the apparatus may be left in a gassy or otherwise dangerous gallery, or be tamped in with a charge, while the listener is situated in a safe position some distance away. The installation of central listening stations is also rendered possible.

Electrical instruments are inferior to the geophone both in sensitiveness and accuracy of sound reproduction, but their use is invaluable under conditions for which the latter is unsuitable.

Of the numerous electrical listening instruments designed during the War of 1914-1919, the seismophone, mainly owing to its simplicity and reliability, gave the most satisfactory results. It increases the range of hearing of the unaided ear by about 50 per cent. The quality of sound reproduced, compared with other instruments of its class, is good.

In principle the seismophone is merely a specialized form of telephone. The transmitter or detector (Pl. **81**, Fig. 1) consists of a lead mass M isolated from the brass base AB and the cover CD by two rubber rings, shown in section by R_1, R_2 and R_3, R_4. Two carbon discs E_1 and E_2 are attached to the cover CD and the mass M respectively. They are separated from each other by carbon granules, and thus form a microphone similar to that used in the ordinary telephone. The cover CD contains two terminals T_1, T_2, the latter being insulated from the cover and connected to the mass M by a flexible insulated wire. These two terminals are connected by leads to the terminals H_1, H_2 outside the wooden box enclosing the instrument. The receiving portion of the apparatus consists of a double ear-piece telephone receiver. A diagram of the connections is shown on Pl. **81**, Fig. 2. The action of the seismophone is identical with that of the ordinary telephone. Vibrations of the mass M will be recorded by the microphone E_1 E_2, and will, by virtue of the current furnished by the battery included in the circuit, be transmitted to the receiver. The sensitiveness of the microphone may be adjusted by slightly screwing or unscrewing the nut F, by which means the pressure on the carbon granules is altered.

The seismophone is easily affected by moisture, and in damp galleries should be enclosed in a water-tight box designed for the purpose (Pl. **81**, Fig. 3).

115. *Range of sounds—Judging distance.*

The distance over which sounds can be heard varies greatly with the acoustical properties of the soil. Thus, picking can be heard with the aid of the geophone at a distance of over 500 feet in hard rock, but at less than 100 feet in some varieties of soft sand and clay. Naturally, the range of hearing also depends largely on the nature of the sound; picking is generally the first sound to be heard, and talking the last. In clays, which permit of the adoption of the more silent method of *kicking* (Sec. 92), timbering and shovelling are generally the first audible indications of work. The following table gives approximate maximum distances in feet at which various sounds can be heard in average chalk, blue clay, and sandy clay.

Nature of sound.	Naked ear.	Seismophone.	Geophone.
AVERAGE CHALK.			
	Feet.	Feet.	Feet.
Picking	150	200	300
Shovelling	70	70	120
Walking (timbered floor)	50	70	80
Falling earth	35	50	60
Dragging sandbags	30	45	55
Talking	12	40	50
BLUE CLAY.			
Picking	125	140	160
Shovelling	50	75	110
Walking (timbered floor)	40	50	60
Falling earth	30	45	50
Dragging sandbags	15	25	35
Talking	6	15	30
SANDY CLAY.			
Picking	50	70	100
Shovelling	10	25	30
Walking (timbered floor)	10	20	25
Falling earth	5	15	20
Dragging sandbags	5	12	18
Talking	5	10	15

The above figures can only be taken as a rough guide; a local range table, based on experience and experiments, should always be prepared for the soil in which mining operations are in progress.

It will be found that the audibility of sounds in strata of varying consistency fluctuates considerably from point to point. For instance, if picking in chalk through which a bed of hard flint runs be listened to, the sound will be much more intense when the pick strikes the flint than when the softer chalk is struck. Sound travels more easily along strata beds than across them. Thus, if the flint bed just referred to also outcrops in the listening gallery, the sound vibration will be much more intense than otherwise. The *dip* of the strata and the relative depths of the listener and the gallery in which work is proceeding must, therefore, be studied. Audibility in blown and shaken ground varies enormously; it is usually far below that in virgin soil. Much depends on the way fissures run; the transmission of sound between two galleries connected by a fissure may be quite good, and under these conditions sounds may frequently be heard more clearly with the naked ear than with the aid of an instrument.

The energy with which a tool is worked will, of course, have considerable effect on the range at which picking can be heard. In the case of such sounds as falling earth, dragging sandbags, tramming, &c., the timbering of a gallery in which the sound originates may be an important factor. The floor of a close-timbered gallery frequently acts as a sounding board, and materially assists the propagation of the sound waves. The range at which walking can be heard will, in addition to the above, depend much on the footwear of the subject.

It will be realized from what has been stated that judging the distance of underground sounds is an art, acquired by much practice and experience, rather than an exact science. Some men have the gift of estimating distance with astounding accuracy, while others, of similar experience and endowed with equally acute hearing, are entirely at sea. Doubtless the secret lies in the possession of a mental capacity to gauge the various factors bearing on the situation, and of a painstaking temperament that does not tire in making frequent observations and averaging the results.

The approach of a hostile gallery once indicated must be listened to at irregular and frequent intervals during day and night, and the progress noted from day to day. In this connection often one of the most satisfactory checks on distance is to note when a particular sound just becomes audible, and to compare it with the sound range table. Thus, in average chalk when the sound of falling earth can just be heard with the geophone, the gallery should be about 60 feet away (*see* table). Nearly all listeners are inclined to underestimate the distance of a hostile gallery; this tendency is especially marked at close ranges.

116. *Practical application of listening.*

1. It has been explained that the geophone and, at close ranges, the unaided ear furnish the principal means of obtaining information of the nature and location of enemy work, while the seismophone is specially suitable for positions to which access with the geophone is dangerous or impracticable (gassy galleries, tamped-in charges, &c.), and for central listening systems (Sec. **117**).

The amount of listening necessary will naturally vary with the conditions. Two short listening periods daily will generally suffice at localities where no enemy work has been reported. On the other hand, the enemy must be kept under careful observation from all galleries within listening range, and it may be advisable to carry out listening continuously throughout the 24 hours. The hours of visiting a listening post should be changed from day to day, in order to reduce the likelihood of failure to detect the approach of a gallery through the enemy working during certain periods of the 24 hours only.

Listening should normally be carried out by patrols of two or more specially trained men, the numbers depending on the extent of the system and the amount of hostile work. These patrols should be placed in charge of a reliable N.C.O., or on a large and active front it may be necessary to detail an officer for this duty.

Each listener, furnished with a geophone, should be given a series of posts to visit during his tour of duty. He will record the result of his observations on the prescribed mine listening report (*see* end of this section), and will also give information immediately of any sounds of special importance which he may hear. Listening posts should, as a general rule, be constructed off the main galleries; they should be made as comfortable and as dry as possible. The approaches of posts in close proximity to the enemy should be covered with straw or old sandbags to deaden the sound of walking. The listener should not wear equipment or articles liable to produce creaking sounds; the slightest noise is disturbing, and leads to the production of inaccurate results. Silence must be maintained in listening posts, and not more than two men should be allowed in together. They should communicate with each other in a low whisper.

It will generally be necessary, when listening is in progress, to cease any underground work in the vicinity. Surface noises may also interfere seriously with listening in some localities, and it may be necessary under these circumstances to draw up, in conjunction with the infantry garrison, a programme of listening periods during which work, rifle fire, and all walking ceases. The hours of these periods should be varied from day to day, lest the enemy should ascertain when they occur, and arrange to cease work underground during their duration.

The most accurate method of locating a sound is to determine its direction with the geophone from two or more galleries (Pl. **80**, Fig. 2). The results given should be fairly accurate if intersections can be obtained at a favourable angle. The position of listening posts, however, will often be unsuitable for the adoption of this method; in such cases the direction having been determined, the distance of the sound must be estimated by its intensity, &c. (Sec. **115**).

The difficulty of estimating direction and distance will be much increased when the sound of several headings working simultaneously is audible in one locality, and great skill is required to pick out and concentrate separately on each sound in turn.

2. A careful record should be kept of all listening carried out; an example of the form of mine listening report used during the War of 1914 1919 is given below.

MINE LISTENING REPORT.

A.F. W 3379.

Date. 27/11/17.

Listener's name—Sapper Evans.

Name of gallery.	Time.	Sounds heard.	Estimated distance in feet.	Estimated direction.	Remarks.
A1	1400 to 1615 hours.	Picking and shovelling.	40	N.30° W.	Continuous work.
A2	1400 to 1615 hours.	Picking	120	E.15° N.	Same gallery as in 1.
B4	1400 to 1800 hours.	Nil.	—	—	—
B5	1530 hours	Walking	50	Not determined	Probably enemy listening patrol.

These reports were made out in duplicate daily to cover the previous 24 hours; one copy was retained with the officer in charge on the spot, and the other sent to the headquarters of the unit.

The correlation and plotting of listening reports is of great importance. A plan of the mining front should be used for this purpose on which the position and progress of enemy galleries are recorded. Small flags (separate colours being used to differentiate between hostile galleries under construction and those completed, &c.) provide a good method of showing the situation at a glance. Separate listening post diaries should be kept for individual posts of special importance; in these diaries entries of all sounds that have been heard during the previous 24 hours should be made daily. Nil reports should be recorded.

3. Listening, in addition to being an important and indispensable adjunct to all mining operations, provides one of the means of detecting suspected hostile mining (*see* Sec. **81**, para. 3) where no defensive system exists.

In such cases, a deep dug-out is the most satisfactory point from which to listen. Where such facilities do not exist, a hole at least 4 feet deep should be dug in the ground. The geophone is the best instrument to use, but, if not available, listening may be carried out by burying a bowl of water in the ground and immersing the ear in the water. Surface sounds are most deceptive when listening is carried out from the surface, and every endeavour must be made to eliminate them. The ground should be cleared of all men within at least 50 yards radius, and all work in the vicinity stopped.

On a front where mining attacks are prevalent, reports from the infantry garrison of sounds of hostile mining are likely to be frequent. The untrained, however, are very liable to attribute surface sounds to mining, and even skilled miners are easily deceived. The engineer officer detailed to investigate a report of hostile mining should, therefore, first collect all the available information which has given rise to the suspicions, and should endeavour to trace the reported sounds to their source. It will frequently be found that the sounds which have caused apprehension may be accounted for by causes other than mining. Suspicious sounds have been traced to driving in pickets, hammering sandbags, noise of feet on duckboards, wind in telephone wires, rats, moles, &c.

117. *Central listening systems.*

The necessity of reducing to a minimum the large personnel, that must be permanently retained for listening duties in extensive mine systems, has led to the introduction of central listening. By this means often as much as 50 per cent. of the listening staff that would otherwise be required may be dispensed with. Central listening systems are best suited to wide fronts on which enemy activity has more or less died down.

A central listening system, briefly described, consists of a series of seismophone detectors distributed in the main listening galleries and connected up to a central listening station on lines similar to a telephone exchange.

Detectors.—The seismophone is the most suitable, but other electrical detectors may be used. The sensitiveness of each detector should be standardized before it is installed.

Buzzer sets.—The detectors must frequently be tested to see that all is in order. This can be done by sending a man to tap each in turn, but labour will be saved if a small buzzer set is placed near and in the circuit of each detector. The buzzer is adjusted so that it will only operate when a current of increased strength is sent through the circuit.

In addition to providing a means of testing detectors, the buzzer sets enable the listener at the central station to signal to the geophone patrol, as will be described later.

Wiring.—Particular attention must be paid to wiring, both in the central station and throughout the system. Insulation of all cables on small bobbin insulators is the most satisfactory method; failing this, they should be cleated to the mine timbers. Staples should on no account be used. As it is not required to listen to more than one post at a time, a single well-insulated main running to each detector and a common return will suffice.

E1, Mark II cable used in electric firing is quite satisfactory, or, alternatively, signal cable of about the same conductivity may be used. Considerable labour will be saved in installation if twin cable is used for the portion of the circuit between the detectors and the lateral.

Cells.—A very small current is sufficient for good reproduction of sound if the circuit is well insulated throughout. The two Leclanché cells, provided with the ordinary seismophone set, will be satisfactory for posts not more than 1,200 to 1,500 feet from the central station, but additional cells must be put in for longer distances. Cells are in more or less continual use as each post is connected up in turn at the switchboard. It is, therefore, advisable to have two on three separate batteries which can be used in rotation, in order that the polarized cells may regain their strength. A switch with suitable connections is placed on the switch-board for this purpose (Pl. **82**).

Central station.—This should be situated under cover, preferably in a dug-out, in the centre of the system and some little distance behind it. The station must be roomy, furnished with the necessary table, chairs, shelves, cupboards, &c., well lighted, and kept scrupulously clean. Given these conditions the listeners will have reason to take a pride and interest in their work. No matter how keen a man may be, results will not be of the best, if the shift is spent in a cramped chamber among a tangle of wires, old apparatus, and candle grease; moreover, under these conditions much unnecessary work is involved in locating the defect in a faulty circuit.

Switchboard.—The connections to the various posts should be of the wandering plug and socket type. Pl. **82** shows a satisfactory type of switch-board. It consists of a diagram of the mine system with sockets at the points on it corresponding to the position of the detectors. The listening apparatus switches, cells, &c., are installed on the table below. A galvanometer is provided to test the various circuits.

The plan of the system should be diagrammatic only, so that it may be useless to the enemy if captured. On the other hand, it must be sufficiently clear to enable the listener to retain the entire system in his mind's eye, and to keep in mental touch with his work. With the aid of the diagram he will be in a better position to reason for himself whether sounds heard emanate from work being carried out within the system, or whether they merit further investigation by the geophone patrol as explained below.

Receivers.—The double ear-piece type of receiver, supplied with the seismophone set, is quite satisfactory, but the receivers used in civil telephone exchanges also give good results. The station should be equipped with two or more receivers connected up in parallel. This enables an officer to *listen in* with the central observer and check his observations, when desired.

Mode of work.—The method of operation is as follows. The central listener puts the battery in circuit by means of the battery switch. He then inserts the wandering plug in the socket on the plan corresponding to the post at which he wishes to listen. If he wishes to test the circuit, he connects up the galvanometer by means of the switch provided for the purpose. He signals, when required, by depressing the buzzer key; this automatically places in circuit the additional cells to operate the buzzer.

It cannot be too strongly emphasized that central listening systems do not entirely replace the listening patrol. The former must be regarded mainly as detectors of sound, the source and nature of which, as soon as reported, must be investigated with the geophone. Central listening systems, on the other hand, permit of the maintenance of general observation over the whole mining front, with the result that the efforts of the listening patrol may be directed and concentrated on threatened points. Thus, economy in the numbers required for patrol work is effected.

As the final verification and location of enemy work must rest with the patrol, using either the geophone or the unaided ear according to local conditions, the responsibility of the central listener for observation of any given sound should cease as soon as he has called the attention of the patrol to it and received an acknowledgment. For communication between the central station and the listening patrol the following has been found the most satisfactory arrangement. The patrol is provided with a watch, which is placed on the detector of the post where listening is in progress. On hearing a sound that needs closer investigation, the central listener runs rapidly over his board till he picks up the sound of the watch. He then, by a prearranged dot and dash code, signals through on the buzzer key to the buzzer at the post where the patrol is situated a request for the patrol to visit the post near which activity is suspected. The patrol acknowledges the message by light taps on the detector. Having noted the time of receiving the acknowledgment, the central listener carries on with listening at the remainder of the posts.

A listening report, similar to that already described for listening patrols, should be made out at the central listening station.

118. *Training.*

It will be realized, from what has been said in the previous sections of this chapter, that proficiency in listening can only be obtained after careful study and much practical experience. It is essential that a proportion of the officers and other ranks of mining units should receive special training in this branch of underground warfare.

Listening formed one of the principal subjects in the curriculum of Mine Schools, instituted on the Western front during the War of 1914-1919, and, whenever mining warfare develops, it will be found necessary to provide facilities behind the lines for training.

The potential listener, apart from being possessed of unimpaired hearing, should be of a calm, steady, and unexcitable disposition. In the silence of an underground gallery the beating of the heart or heavy breathing heard through a sensitive instrument may easily be attributed by the imaginative and nervy to hostile work. The excitable man will be too apt to jump to conclusions, and liable to furnish exaggerated reports based on insufficient data.

Training should aim at enabling the listener to say what the enemy is doing and where he is. First with the unaided ear, and afterwards with the geophone and seismophone, the student should be taught to identify picking, walking, dragging of sandbags, and the numerous other sounds connected with underground work. As he gains in proficiency he should be given instruction and frequent practice in estimating the distance of sounds. He must be trained in determination of direction by the geophone. The course should also include instruction in electrical apparatus and central listening systems.

Pl. **83** shows a convenient system of galleries for practical listening instruction and testing ; it will be seen that the lay-out furnishes a large variety of distances. A central listening system should be installed in a portion of the listening galleries and practical instruction given in its use.

The listening circle (Pl. 84) is a valuable aid in the elementary stages of training to find direction with the geophone. The central shaft is about 9 feet deep, circular in plan, and about 5 feet in diameter; it is covered in to exclude surface sounds. The tapping circle consists of a trench, about 5 feet deep and 3 feet wide, dug on a circle of 25 to 30 feet radius. The instructor taps the ground at selected positions in the tapping circle, and the listener in the shaft estimates the direction of the sounds. To facilitate the checking of results, the circumferences of the central shaft and tapping circles are divided up. A convenient method is to split each into 36 equal parts (*i.e.*, arcs of 10°); pegs, numbered consecutively, are placed at each division. The numbering on the pegs in the shaft is rotated through 90° (*see* Pl. 84). If the direction of the tapping has been determined correctly by the listener, the number of the peg opposite the right-hand geophone pot will give the number of the peg in the tapping circle at which the sound was made. A trained listener should not make an error exceeding 10°.

CHAPTER XVI.

TUNNELLED DUG-OUTS AND SUB-WAYS.

119. *Use of underground protection.*

The devastating effects of the intense and prolonged bombardments, to which defences are likely to be subjected in position warfare, are best countered by the provision of ample shell-proof accommodation for the garrison. This will generally, when the soil permits, take the form of deep dug-outs with frequent exits to the surface and intercommunicating passages. Sub-ways (long underground passages replacing surface communications) are also invaluable. They provide at all times a safe means of access to the positions they serve, and during an attack enable reinforcements, ammunition, and supplies to be pushed up unhindered by the hostile barrage. In addition, the replacement of lengths of communication trenches, subject to intermittent destructive trench mortar bombardment, by sub-ways will enable the large working parties, required to repair and keep open the former, to be dispensed with. Dug-outs will also be required in back areas, at rail-heads, bases, &c. to afford shelter during air raids or long-range bombardments.

Hence the construction of dug-outs and sub-ways may often constitute the main field of activity of mining units. All tunnelled work, however, takes considerable time, and necessitates the expenditure of much labour and material. It should, therefore, only be undertaken when the conditions which call for the provision of shell or bomb-proof shelter are likely to be of some duration.

Tunnelled dug-outs have the following advantages over concrete and cut-and-cover dug-outs :—

i. Their construction involves less labour in proportion to the accommodation given, and affords more immediate results.

ii. They give complete protection, both from actual penetration and serious concussion effects.

iii. Their exact position can, as a rule, be better concealed, although the spoil removed from them may indicate their existence in a particular locality.

The disadvantages of tunnelled dug-outs are :—

i. Difficulty of exit, owing to the depth to which they have to be taken.

ii. Ventilation, lighting, and drainage are often very difficult problems.

iii. The nature of the strata may prevent the siting of a dug-out in the best tactical position.

The nature of underground protection, which is likely to be required, includes the following :—

i. Command headquarters for companies, battalions, and higher formations.

ii. Machine-gun emplacements.

iii. Observation posts.

iv. Living dug-outs for infantry garrisons and artillery.

v. Trench mortar emplacements.

vi. Sub-ways.

vii. Dressing stations.

Typical examples of dug-out design will be found in Manual of Field Works (All Arms) (1921), Chap. XV, and this subject is dealt with in further detail in M.E., Vol. II. This chapter will, therefore, be mainly confined to describing the details of execution of the work.

120. *Reconnaissance, materials, &c.*

1. The technical principles involved are similar to those already laid down for mining (Chap. XII), and differ only in their interpretation to meet the new conditions. For instance, the method of driving inclines and galleries is identical with that adopted in mining, but the dimensions will generally be greater in order to provide ample head-room and passing way.

As in mining, reconnaissance prior to the commencement of work is essential. The nature of the strata must be ascertained.

This will frequently outweigh all other considerations in the selection of the site ; in low-lying and marshy ground the construction of dug-outs will naturally be restricted to localities where mining is possible. Badly water-logged soils are, as a rule, quite impracticable. Even if an impervious stratum exists a short distance below the water-saturated surface, the amount of pumping rendered necessary may be prohibitive; it will usually be preferable to provide protection by other means, *e.g.*, reinforced concrete shelters. Occasionally it may be possible to drive a gallery with a slight upward slope into the side of a hill or face of a cliff and thus secure natural drainage, but living rooms in wet soils will always be damp and unhealthy.

A plan should be made of the site, and working drawings prepared. Accurate execution of the work is essential. Tortuous and badly graded passages will be a source of continual trouble. Inclines, galleries, and chambers should be carefully surveyed as the work proceeds.

The transport of stores to the site, access of the mining personnel to their work, their accommodation when off duty, and the arrangements of reliefs will seldom present such difficult problems as are encountered in mining, and the more remote the site of work from the front line, the easier will their solution become. Nevertheless, these questions must invariably be given careful consideration.

2. **Disposal of spoil** is always important, and, unless the amount of earth to be dealt with is realized, and a scheme of disposal thought out beforehand and rigidly enforced, conspicuous heaps are certain to be formed. It is useless to defer their concealment until the work is finished; this, in fact, only shows the enemy that the excavation is complete, and that the dug-outs are in use. Spoil heaps, not in direct enemy view, will be revealed by air photographs. Constant supervision is necessary to prevent the sites of dug-outs and sub-ways being given away. (For methods of spoil disposal, *see* Sec. **86**.)

Transportation and hoisting spoil will be carried out on the lines described in Sec. **95**, with the exception that the installation of haulage plant (windlass or winch) at the head of small inclines, only to be used for the evacuation of spoil for a short time, will seldom be worth while. In wide and extensive sub-ways tip-trucks running on 40 cm. track may be used with advantage.

3. **Materials.**—The timber required will be similar to that used in mine systems, but the setts and frames will be of larger dimensions, while frequent use will be made of rolled steel joists in the construction of the chambers. The following will give a general idea of the materials normally employed.

Inclines and galleries :—

9-inch by 3-inch timber setts, 6 feet 4 inches by 2 feet 9 inches internal dimensions (Pl. **51**, Fig. 1).

9-inch by 3-inch timber setts, 4 feet 10 inches by 2 feet 9 inches internal dimensions (Pl. **51**, Fig. 2).

3-inch to 6-inch pit-prop frames, 6 feet 4 inches by 2 feet 9 inches internal dimensions.

Chambers :—

Pit-props, 4½ to 6 inches diameter.
Steel girders (R.S.J.), of which the more common sizes are :—

Dimensions in inches (depth by width of flange by thickness of web).	Weight per foot run in lbs.	Length in feet.	Safe distributed load in tons.
5 × 3 × 0·22	11	9	3½
8 × 4 × 0·28	18	16	4
9 × 4 × 0·30	21	18	5
10 × 5 × 0·36	30	20	7½
12 × 5 × 0·35	32	22	9

The 9-foot by 5-inch by 3-inch girder is the size normally used (but *see* Sec. **122**, para. 1). Lagging (1 to 2-inch boarding) will be required for passages and chambers. In damp situations and in work of a more or less permanent nature, concrete may be employed for lining chambers and passages.

4. **Head-cover.**—Complete protection against shells of large calibre (9-inch and over) can seldom be gained without descending to impracticable depths. Direct hits on dug-outs and passages by *superheavy* artillery are, however, not likely to occur. Generally speaking, all underground work should be provided with sufficient head-cover to exclude 8-inch howitzer and heavy trench mortar shell fitted with delay action fuze. The cover required under these circumstances will be as follows :—

Made earth	35 feet.
Clay	30 feet.
Gravel	25 feet.
Chalk	25 to 20 feet.
Hard rock	15 feet.

121. *Inclines and galleries.*

1. **Inclines.**—Ease of access and egress is one of the first essentials in dug-out design. A chamber, no matter where situated, which is reached by a single narrow and tortuous passage, is at all times inconvenient and a source of danger to the occupants, owing to the possibility of the one exit being blocked. In the case of dug-outs constructed to shelter the garrison of a defended position, not only do the above objections obtain, but it is also of vital importance that the occupants should, on receiving warning of attack, be able to get to the surface in time to meet it. It is mainly for this reason that dug-outs are seldom provided in the front defences of a locality, but are sited sufficiently far in rear to render remote the likelihood of the occupants being *trapped*.

The fact that troops will carry their full fighting kit must also be taken into consideration. Entrances should consist normally of inclines, of gradient not steeper than 1 in 1, descending to the required level. Shafts are most unsuitable entrances, Isolated dug-outs must have at least two entrances not less than 40 feet apart. In practice it is often preferable to construct dug-outs in groups connected up by passages served with numerous entrances, as shown in the outline drawing on Pl. **85**. In the case of sub-ways frequent exits to the trench system should be provided (Pl. **89**). These will enable the work of construction to be carried out from several points simultaneously, and when completed will improve communication and ventilation. The exits of sub-ways, especially those at the forward end, should be prepared for defence against enemy raids and attacks. Examples of the methods that may be employed are shown on Pl. **91**, Fig. 1.

The timbering of the inclines for dug-outs and sub-ways does not differ from that already described in Sec. **94** for mining, except that it is essential that head-room of at least 6 feet be given. Setts with 5-foot legs will give sufficient head-room in a 45° incline with timbering normal to the slope. If vertical timbering is adopted, the legs of the setts must give at least 6 feet in the clear.

Inclines exposed to heavy shell fire should, as a general rule, be close-timbered throughout, and under any circumstances for at least the first 15 feet of descent. No attempt, however, should be made to give additional strength to the head of an incline by the use of concrete and girders; no practical means will make it proof against a direct hit, and the presence of these materials only increase the difficulties of clearing and repair.

It is essential that entrances should be prevented from becoming sumps for the drainage of the trench from which they lead. For this reason they should never commence from the bottom of a trench (*see* Sec. **94**, para. 1).

2. **Galleries.**—The internal dimensions of dug-out galleries should be at least 6 feet 4 inches by 2 feet 9 inches. The galleries of main sub-ways should be rather larger; they should be 6 feet 6 inches high, and may vary from 3 feet 6 inches to 4 feet wide. The latter width allows sufficient room for up and down traffic, and does not cramp a man's movements.

In bad and doubtful ground galleries must be close-timbered, but in soils, which stand well, setts, or frames made of pit-props, may be spaced at intervals. Top lagging of $1\frac{1}{2}$ to 2 inches must always be used in such cases, and, except in soils such as hard chalk and rock, side lagging of 1 to $1\frac{1}{2}$-inch boarding, corrugated iron, or expanded metal is also necessary.

When there is any doubt as to the solidity of the roof, work should be carried out by *spiling* (Sec. **92**, para. 4). In loose and heavy ground this is the only method to adopt.

3. **Working parties and footage.**—The working parties required and the footage driven per shift will not differ materially from the data already given for mining. Although considerably more earth must be excavated in dug-out and sub-way galleries, which are spacious compared with those normally used in mine warfare, the additional working room afforded will, if anything, increase the rate of progress attainable. More men, however, must be detailed to deal with the larger volume of spoil. In medium soil 4 feet may be reckoned as average progress per 8-hour shift. Under exceptional conditions, however, where speed of execution, regardless of economy in labour, was of paramount importance, some remarkable

footages have been achieved in driving sub-ways with skilled labour. In numerous instances during the War of 1914-1919 an average daily footage of over 30 feet was maintained continuously for upwards of 14 days.

122. *Construction of dug-out chambers.*

1. The **roof.**—The head-room provided in dug-out chambers should not be less than 6 feet 6 inches in the clear. Girders, supported on stanchions, will generally be required to take the roof span.

It is important in designing chambers to keep to a fixed width, in order that the length and section of R.S.J. used may be standardized. A joist 9 feet in length and 5 inches by 3 inches in section was the standard size used in dug-out construction during the War of 1914-1919. A span of 9 feet (giving at least 8 feet width in the clear) provides adequate room for office or bunking accommodation, and, generally speaking, is a satisfactory and economical dimension. Spans much in excess of 9 feet will require girders of large section to support them; moreover, difficulty will be experienced in getting long girders down the inclines and round the corners of passages to the site.

The spacing of the girders will depend on their section and the nature of roof supported. In hard soils which stand well, spacing at 3-foot or even 4-foot intervals will be adequate over a span of 9 feet. In loose and heavy soils, spacing at 2-foot centres or less will be necessary, and in some cases the girder will require intermediate support in addition (Pl. **86**, Fig. 2).

The girders must be side-strutted to prevent them rolling over or buckling. For a 9-foot span, 4 struts of 4-inch by 3-inch timber, wedged in tightly at 3-foot intervals, will suffice.

2. **Supporting pillars and stanchions.**—Pillars of solid ground should always be left between chambers constructed in soft and medium soils. The thickness of the pillars in clay should not be less than 20 feet, while in chalk 12 feet will be adequate.

Pit-props, 4½ to 7 inches in diameter, will normally be used as stanchions for the girders, but in very heavy ground R.S.J. may be required for this purpose (Pl. **86**, Fig. 2).

3. **Girder clips.**—To prevent the stanchions from being pushed inwards they should be connected to the girders by clips designed for the purpose. Pl. **87**, Figs. 1, 2, and 3, show a type of universal clip forged from mild steel, which may be used to connect either a pit-prop or R.S.J. stanchion to the girder. Fig. 5 shows an alternative design of universal clip made of cast-steel. In default of supplies of the above articles from the base, the hair-pin clip (Fig. 4) may be manufactured on the spot from wrought iron. It is weak, and at best a makeshift.

Foot-soles, 12 by 12 by 3 inches, should be used to give foundation to the stanchions in all but exceptionally hard ground. Ground-sills will be required in loose and heavy soils. These will normally consist of pit-props let into the floor, but in very bad soils it may be necessary to use joists fixed to the stanchions with girder clips (Pl. **86**, Fig. 2).

4. **Excavation.**—Spiling (Sec. **92**, para. 4) should always be adopted, except in very firm ground. The excavation of the whole face in one piece without timbering should never be attempted, as falls are very liable to occur. These, apart from endangering the lives of men working, will delay progress, and may seriously weaken the overhead cover.

A good method of excavation is as follows :—The sides of the chamber are first cut out by passages made 2 feet 6 inches wide and the full height of the chamber (Pl. **88**, Fig. 1). The spiling boards are driven forward as the work proceeds. When both sides have been removed to the depth at which the next girder comes, the stanchions are set in position. The top of the buttress, which has been formed, is then cut out ; the remaining spiling boards of the roof are driven forward, and the whole of these boards are held in position by a temporary beam supported on either side of the buttress by pit-props. The new girder is then placed in position, and the distance-pieces, whaling board, and wedges are set forward. The remainder of the buttress in the centre may then be removed.

An alternative method is to drive a pilot-gallery as shown on Pl. **88**, Fig. 2. If the span be 9 feet, a pilot-gallery 5 feet by 2 feet 6 inches is an economical size. The passage, which must be timbered, should run approximately along the centre-line of the chamber. Such a gallery serves as a useful check on levels and direction. If the chamber, when complete, is to connect up with a passage other than that from which the work is being carried out, it is as well to drive the pilot-gallery right through to this second passage straight-away, and thus secure through ventilation prior to starting the chamber proper. Provided, however, that the gallery is at least 10 feet in advance of the chamber, this distance is sufficient, and, where speed is of great importance, a working place for two more men is available. The manner of excavating the chamber and setting the girders, stanchions, &c., in position is identical with that described in the first method.

5. **Breaking away chamber from the gallery.**—This operation requires considerable forethought and care in execution, for the height of the chamber will generally be greater than the passage. The method shown on Pl. **86**, Fig. 1, in which a chamber 6 feet 6 inches high (from floor to bottom flange of girders) is constructed off a gallery 6 feet 4 inches by 2 feet 9 inches (internal dimensions), is a good one. It permits of the chamber being spiled straight-away from the side of the gallery, and of the standard gallery setts being used for the false work, which is reduced to a minimum.

As will be seen from the drawing, a step is formed at the point which will ultimately be the threshold of the chamber entrance, and the standard setts, off which it is intended to break away the chamber, will be raised 10 inches above the final floor level of the dug-out. To start the chamber, the caps of the three raised setts, marked B, are temporarily propped, the legs removed, and a girder put in their place as shown. The chamber is then spiled straight off the side of the gallery as previously stated. When the excavation of the chamber is finished, the top-sills and remaining legs of the setts B are replaced by lagging and a girder supported on pit-props. The ground-sills are then removed, and the 10-inch step taken out to reduce this portion of the chamber to the correct floor-level.

6. **Working parties and footage.**—The working party for the construction of a 9-foot wide chamber (without pilot-gallery) should normally be disposed as under :—

2 men picking.
4 men filling sandbags and timbering, who relieve pick-men after suitable periods.

Progress per 8-hour shift will, under normal conditions, average 2 feet.

In driving the pilot-gallery the working party may be disposed of as follows :—

Pilot-gallery { 1 man picking / 1 man filling sandbags } relieve each other.

Chamber face { 2 men picking. / 4 men filling sandbags and timbering, who relieve pick-men after suitable periods.

Progress per 8-hour shift will, under normal conditions, average 2 feet 6 inches.

123. *Constructional details.*

1. **Drainage.**—In ground so wet as to render pumping necessary, the water should be collected by gravitation into one or more sumps situated in the galleries (*see* Sec. **96**). Correct levels are of the greatest importance. The chamber floor should be about 1 foot above the gallery floor-level, and should drain towards it. Galleries should have a fall of at least 1/50 towards the sump to assist drainage.

When the roof is wet, a good method to protect the occupants from drips is to line the chamber with corrugated iron, as shown on Pl. **86**, Fig. 2. In shattered chalk and rock considerable inconvenience may be caused in wet weather by water leaking through the fissures in the roof. This may often be reduced by filling in shell-holes on the surface above the dug-out with clay.

2. **Floors.**—In firm dry soils the natural earth will make a good floor surface, and no flooring material will be required for ordinary dug-outs. Where, however, much traffic is anticipated, as in the case of important sub-ways, wooden or concrete flooring will be found essential ; otherwise, large holes will be worn in the floor even in hard soils, and travelling be made difficult.

In soft and wet soils the floors of all underground chambers and galleries will rapidly become a quagmire if no additional flooring is provided. Cement concrete reinforced with expanded metal is the most satisfactory flooring to use ; the expanded metal should be nailed or wired to the ground-sills, and 1 to 3 inches of concrete laid on it.

Ordinary trench boards should never be allowed in passage ways or chambers ; they collect filth, obstruct the drainage, and reduce the available head-room.

3. **Bunking, &c.**—Suitable dimensions for bunks are 6 feet 6 inches by 2 feet ; they should consist of a frame of light scantling over which expanded metal or two layers of fine mesh wire netting is tightly stretched. Chambers 8 feet wide may be bunked in three tiers (Pl. **86**, Fig. 2), but,

owing to lack of air, only two tiers should be put in chambers of smaller width. It will be found that the best use of available space will be made by installing the bunks along the length of the chamber, as shown on Pl. **85**, Fig. 3. This leaves a passage way of convenient width on one side of the chamber, on the blank wall of which a seat may be provided and pegs above for hanging kit (Pl. **86**, Fig. 2).

Tables installed in offices should generally be fixed to one of the chamber walls or to the floor.

4. **Ventilation.**—During the process of construction it will generally be necessary to use air-pumps or bellows to provide the men at the face with air until through ventilation has been obtained. All passages and chambers, however, should be as far as possible self-ventilating when completed; that is to say, they should be served by two or more exits, rising to the surface some distance apart and, if possible, facing in different directions, so that good through ventilation is obtained (Sec. **97**). In long chambers and passages ventilation may be assisted by bore-holes driven through the roof at intervals with suitable boring apparatus (Sec. **36**). The bores will act as upcasts, and carry off foul air. Ventilation may be further improved in large systems by the installation of the kitchens underground. These should, other considerations permitting, be sited in such a position that the galleries and chambers may derive the full benefit of the draught induced by the fires. A large bore-hole or shaft should be constructed for the flue.

It may occasionally be necessary to employ artificial ventilation in extensive sub-ways serving a large system of dug-outs to supplement natural ventilation. Powerful electric fans will be used to sweep an air-current through the whole system.

Dug-outs and sub-ways should under no circumstances be connected up direct with mine systems; the risk incurred of poisoning from mine gas (*see* Chap. XIV) is too great to compensate for any advantages that may be gained from such an arrangement.

5. **Protection against poison gas** will always be a difficult problem; counter-measures which have formerly been efficacious may prove quite inadequate against attacks with new gases. It is, therefore, inadvisable to lay down the methods of protection too closely. A description of the anti-gas measures adopted during the War of 1914-1919 is given in Manual of Field Works (All Arms), 1921, Sec. **45**.

It will be realized that the more efficient the ventilation of an underground system, the more rapidly will it fill with gas. Whatever the anti-gas measures adopted, they must be capable of being put into operation immediately the alarm is given. A gas drill must be thought out and practised, and the arrangements for protection frequently inspected.

When electric fans are installed in dug-out and sub-way systems, they may be so designed that during a gas attack the air supply is drawn through a filter placed in the intake. This filter is similar to that used in a box respirator, but on a much larger scale. By this means the system can be furnished with a supply of filtered air while the gas attack lasts. Ventilation holes are best blocked with tapered wooden plugs covered with blanketing; this should be placed near at hand ready for use.

6. **Illumination.**—This is almost as important as ventilation. Darkness begets dirt; an ill-lighted dug-out rapidly accumulates rubbish and garbage of every description, and becomes unhealthy and verminous. The same remarks apply to sub-ways; indeed, unless a sub-way can be well lighted it is almost worthless; men will prefer to risk the journey over the surface rather than grope their way painfully along dark galleries.

Electric light should be installed in all large dug-out systems and subways. In special cases the current may be supplied from existing civil power stations, but there is always the risk of breakage of cables or disablement of generating stations by shells or bombing. The installation of small petrol or oil-driven lighting sets, in a more or less central situation within the system, is the most satisfactory method. The engines and generators should be laid on concrete foundations. Duplicate sets should be provided to enable repairs to be effected, and to avoid intermittent breakdowns of the lighting system. In large installations a separate dug-out should be constructed for the main switchboard. The exhaust gases must be led, well clear of the dug-out system, up a shaft or incline constructed for the purpose. Advantage may sometimes be taken of the heat generated by the installation to provide drying rooms for clothes; air heated over the exhaust pipes may be led by vents into adjacent chambers. Drying rooms, however, should otherwise be entirely separate from generating stations, and access to them should not be provided off the same branch-gallery.

The lamps are best placed in the corners of the roof, and protected by expanded metal guards (Pl. **91**, Fig. 2). 15 candle-power lamps placed at 40-foot intervals will be found to give adequate illumination in subways.

Isolated dug-outs which cannot be included in an electric light circuit should be illuminated with oil lamps; candles are wasteful, and at best a poor substitute.

7. **Fire precautions.**—The timber lining of chambers and galleries will burn fiercely once thoroughly ignited, and combustion will be assisted by the through draught of air, a feature of all well-designed underground systems. The usual emergency fire-fighting appliances (pails of water and sand) should be installed; once, however, a fire has gained a firm footing, the only method of extinguishing it is to evacuate all occupants, and to smother the conflagration by sealing all exits.

Special precautions must be taken with regard to the petrol and oil stored in a dug-out system for electric lighting plant, &c. Cooking lamps and stoves are always a source of danger and should frequently be inspected.

8. The timbering of dug-outs and sub-ways requires frequent inspection if they are to be kept in a good state of repair. In addition to ordinary wear and tear, *dry rot* may set in and, unless immediately checked, may rapidly cause great damage. The conditions are usually very suitable for the spread of this timber disease.

During active operations of the nature cited in Sec. **124**, para. 2, repair gangs must be employed permanently on duty in sub-ways, in order that damage caused by shell fire to entrances, exits, &c., may immediately be repaired.

124. *Sub-ways.*

1. The function of sub-ways has been briefly outlined in Sec. **119**, and in subsequent sections numerous references have been made to constructional details, &c., of sub-ways, where these differ materially from those practised in ordinary dug-out construction.

Wherever suitable soil exists, sub-ways are likely to be a feature of the defence of centres of resistance in protracted position warfare. Starting on a small scale, the network of underground passages providing communication from front to rear and connecting up dug-outs, machine-gun and trench mortar emplacements, command posts, &c., will gradually grow till an extensive system on the lines of the diagram shown on Pl. **89** has been constructed. It is important, therefore, when siting and designing underground works in the earlier periods of the development of a defensive position, that the possibility of their being eventually connected up by a sub-way system should not be overlooked.

Large sub-way systems will usually have 40 cm. tram track installed throughout to facilitate the transport of ammunition and supplies.

2. A good example of sub-ways constructed with the special object of assisting an attack is given on Pl. **90**, which is a plan of a sub-way system constructed on the Arras front to assist the British offensive on 9th April, 1917. A number of disused underground quarries, which had been excavated in the hard chalk to provide building stone, were discovered in the vicinity of Arras. These caves, many of which were of considerable size, had head-cover varying from 20 to 60 feet, and this afforded excellent protection against shell fire. . The more suitable ones were, in the months prior to the offensive, connected up by sub-ways (*see* Pl. **90**) leading from a large sewer tunnel on the outskirts of Arras to the front line. Accommodation was provided for some 11,000 men, who were thus able to reach the point of deployment without exposure to shell fire.

3. In the above-mentioned example, as on several other occasions during the War of 1914-1919, shallow sub-ways (with 3 to 5 feet head-cover) were, prior to an offensive, pushed out in advance of the forward positions, with a view to providing communication trenches across *No man's land* (*see* Pl. **90**.) Underground communication of this nature rapidly becomes congested during the advance following a successful assault, and it was generally found advisable to open up the sub-ways to the surface and by this means to form a rough communication trench. Bore-holes charged with explosives (Sec. **36**) may be driven at the end of such sub-ways. These are exploded at the moment the assault is launched, in order to prolong the communication trench and to cut a passage through the hostile wire entanglements if within range.

In some instances during the War of 1914-1919, fire trenches, machine-gun and trench mortar emplacements, &c., were constructed prior to an attack at suitable tactical points in advance of the forward positions. These works were excavated just below the surface off shallow sub-ways of the nature just described, and opened up in *No man's land* at the moment the infantry attack was launched. Opportunities for work of this nature may occur in future operations.

4. **Water supply.**—Sub-ways serving large dug-out systems must be furnished with an adequate supply of water. When practicable, a well should be sunk, and a pump-house and water point installed. Pl. **91**, Fig. 3, shows a suitable design. When good water cannot be obtained locally, it must be led up by a pipe-line. Large underground reservoirs should be maintained under these circumstances, so that, should the pipe-line be cut, no shortage will be experienced while the damage is being repaired. Efficient reservoirs of a temporary nature can be rapidly made by cutting out cavities of the required dimensions in the soil and lining them with tarpaulins.

5. **Latrines** are not a desirable adjunct to sub-ways, but they may be essential during offensive operations where men cannot use outside latrines in safety. Latrines require very careful supervision. They should be shut off from the sub-way by wooden doors ; ventilation may be obtained by boring vent-holes to the surface. Latrines must be well lighted.

INDEX.

A.

B.—*continued.*

C.

C.—*continued.*

D.

D.—*continued.*

E.

E.—*continued.*

F.

F.—*continued.*

H.—*continued.*

L.—*continued.*

M.

M.—*continued.*

M.—*continued.*

N.

O.

O.—*continued.*

P.

Q.

R.

R.—*continued.*

S.

S.—*continued.*

T.

T.—*continued.*

U.

V.

V.—*continued.*

W.

Printed under the authority of HIS MAJESTY'S STATIONERY OFFICE,
By HARRISON AND SONS, LTD., 44–47, St. Martin's Lane, London, W.C. 2,
Printers in Ordinary to His Majesty.

(B 15350) Wt. 19527—4815/245 10M 4/23 H & S, Ltd. G.S. 218

USE OF SAFETY FUZE.

Fig. 1. Safety fuze No. 11 cut on slant.

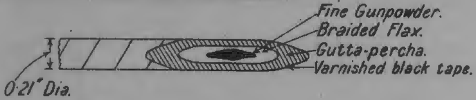


Fig. 2. Safety fuze. Scarfed cut unsevered.

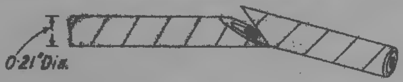


Fig. 3. Semi-Circular nick in safety fuze.

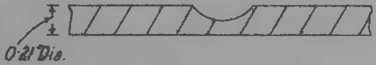


Fig. 4. Safety fuze nicked joint.

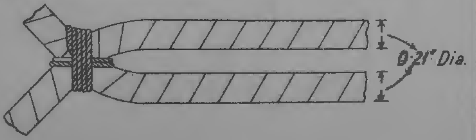
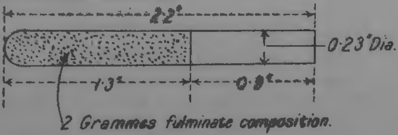


Fig. 5. No. 8. Detonator, Mark VII.



Malby & Sons, Lith.

CONNECTING UP DETONATORS.

Fig. 1. Commercial Cap. (10 Standard Sizes.)

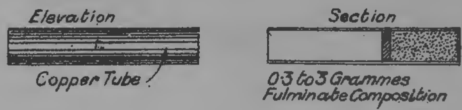


Fig. 2. Connecting Detonator to Safety Fuze.

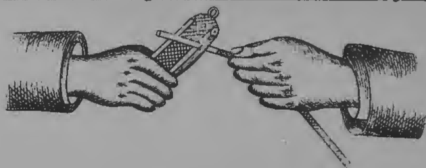
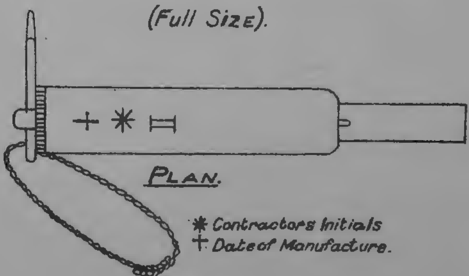
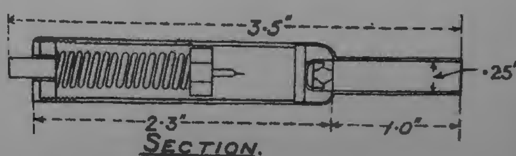


Fig. 3. Igniter, Safety Fuze, Percussion.

(Full Size).





Malby &

Plate 3.

USE OF CORDEAU DETONANT.

Fig. 1. Firing Cordeau Detonant.

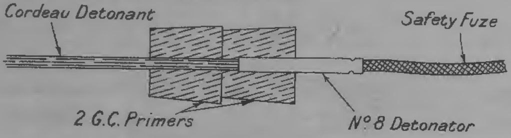


Fig. 2.

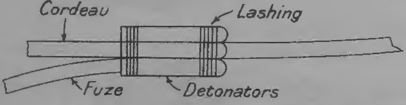


Fig. 3.

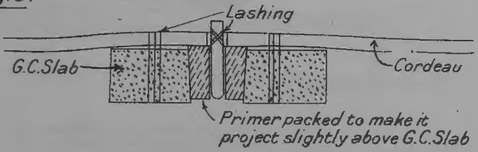


Fig. 4.

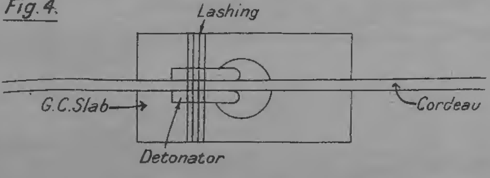
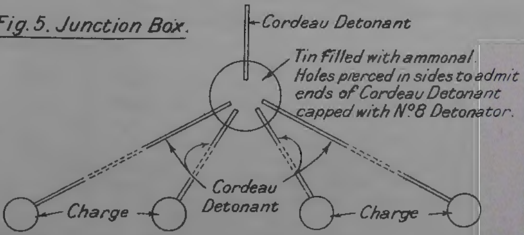


Fig. 5. Junction Box.



Malby & Sons, Lith.

Plate 4.

ELECTRIC DETONATORS AND FUZES.

FULL SIZE.

Fig. 1. No. 13. Detonator, electric, Mark III.

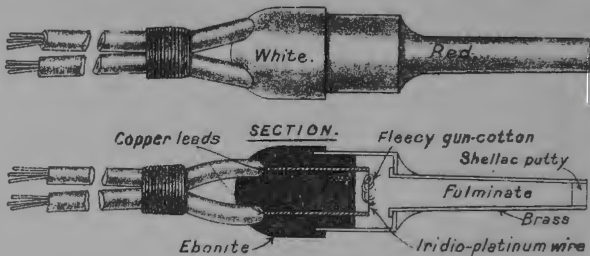
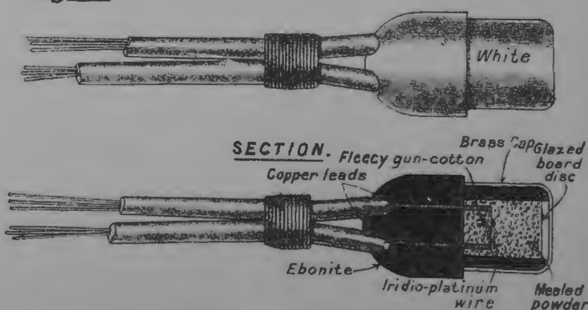


Fig. 2. No. 14 Fuze, electric, Mark III.



CIRCUITS & CABLES.

FIG. 1. CABLE, ELECTRIC E1, MARK II.

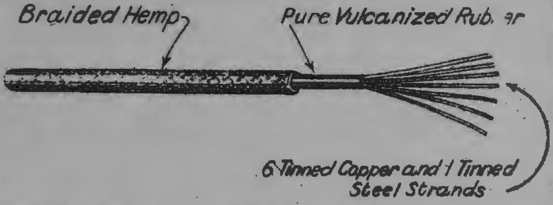


FIG. 2. WIRE. ELECTRIC, S11 MARK. III.

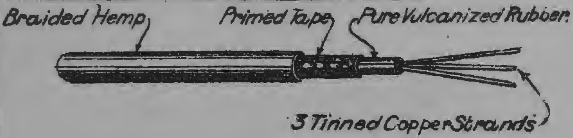


Fig. 3. Circuit insulated throughout.

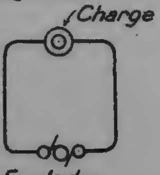


Fig. 4. Circuit with bare wire return.

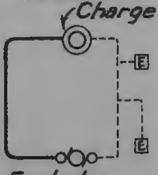
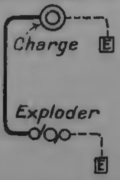


Fig. 5. Circuit with earth return.



Note

Insulated Cable. ——

Bare wire conductor. - - -

Malby & Sons, Lith.

Plate 6.

JOINTING CABLES.

(*For clearness cables are shown as single-stranded conductors*).

FIG. 1.

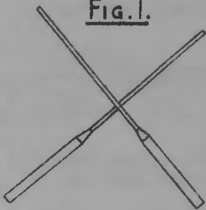


FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

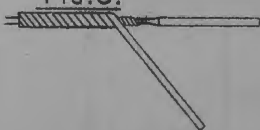
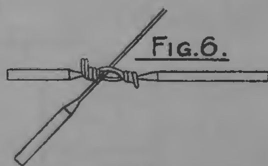


FIG. 6.



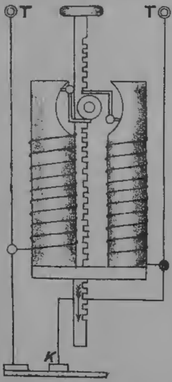
0927

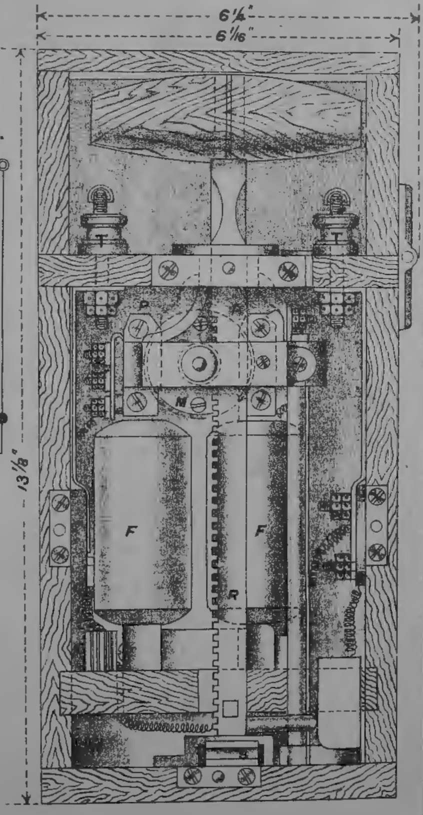
Malby & Sons Lith

EXPLODER, DYNAMO, ELECTRIC QUANTITY,

MARK V.

DIAGRAM OF CONNECTIONS.





ELEVATION (*NEAR SIDE REMOVED.*)

77, 19527/4613/243.

ELECTRICAL TESTING APPARATUS.

FIG. 1. "Q" AND "I" DETECTOR.

FIG. 2. DIAGRAM OF CONNECTIONS.

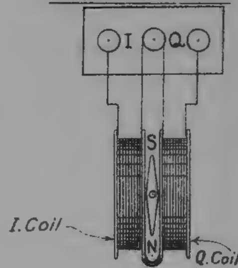


FIG. 3. TEST CELL (*Half Full Size*).

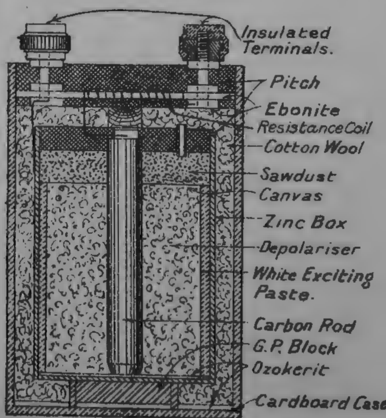
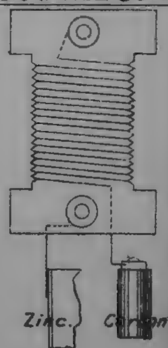


FIG. 4. DIAGRAM OF CONNECTIONS OF RESISTANCE COIL.



Malby & Sons

CONTINUITY & WHEATSTONE BRIDGE TESTS.

FIG. 1. CONTINUITY TEST. *(Diagram of connections)*

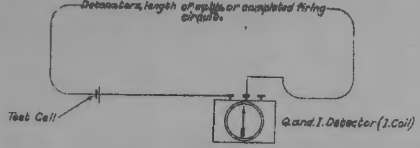
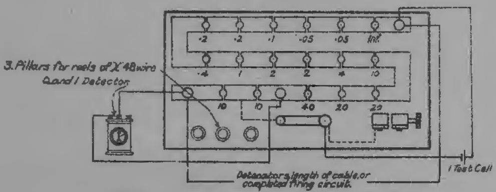
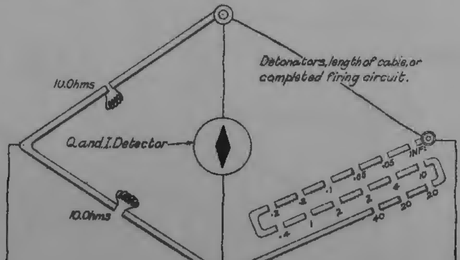


FIG. 2. BOX OF RESISTANCE COILS CONNECTED UP FOR WHEATSTONE BRIDGE.



NOTE. Connections within the box are shown by dotted lines. For clearness, no resistance plugs are shown.

FIG. 3. DIAGRAM OF CONNECTIONS FOR WHEATSTONE BRIDGE.

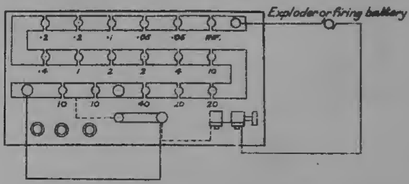


Malby & Sons, Lith.

Plate 10.

FUSION TEST.

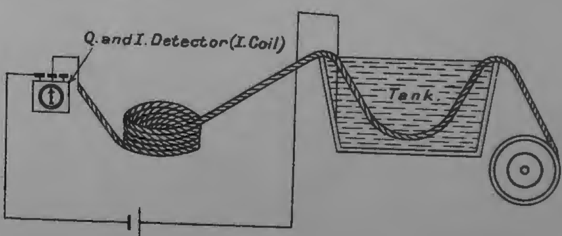
Fig. 1. Box of Resistance Coils connected up for Fusion Test.



When exploder is being tested the Contact Key should be cut out by a short lead as shown.

NOTE. Connections within the box are shown by dotted lines.

Fig. 2. Testing Cables

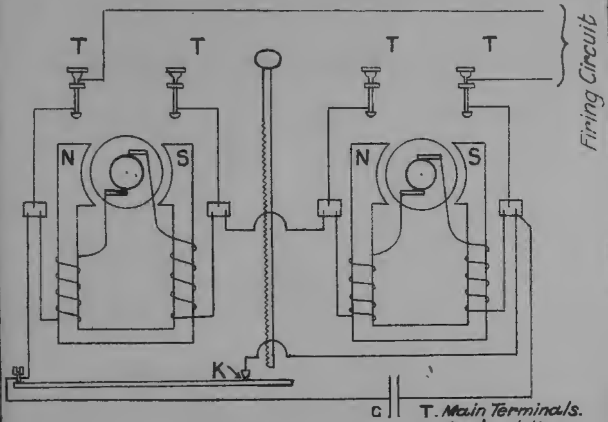


Jolly & Sons, Ltd.

INERT CELLS.

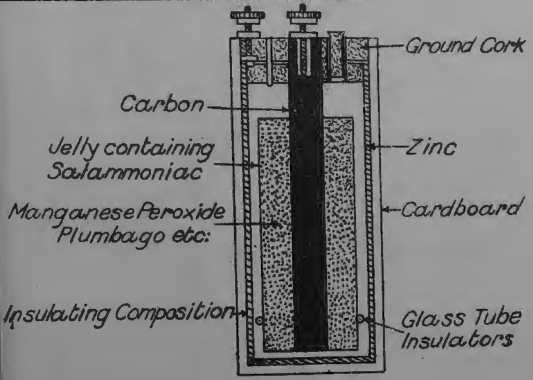
FIG.1. COUPLED EXPLODERS.

DIAGRAM OF CONNECTIONS.



T. *Main Terminals.*
K. *Contact Key.*
C. *Condenser.*

FIG.2. CELL, ELECTRIC, INERT.



Malby & Sons, Lith

DIVIDED CIRCUITS.

Fig. 1.

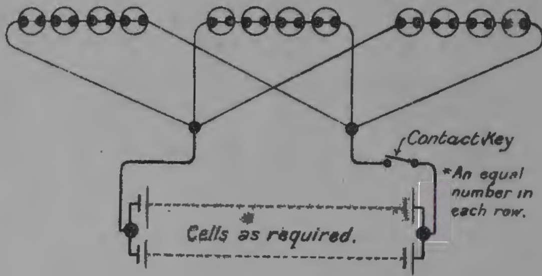
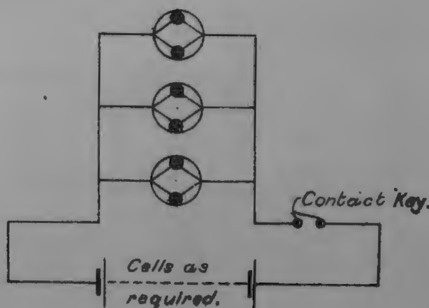


Fig. 2.



Charges shown thus

Detonators " "

Harby & Sons Ltd.

CHARGES IN BAGS.

Fig. 1.

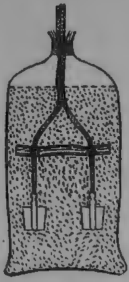


Fig. 2.

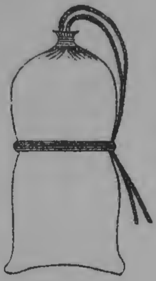
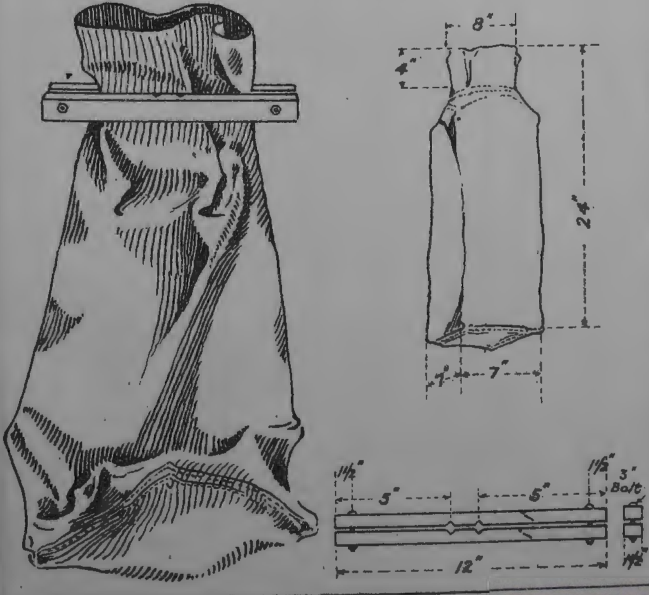
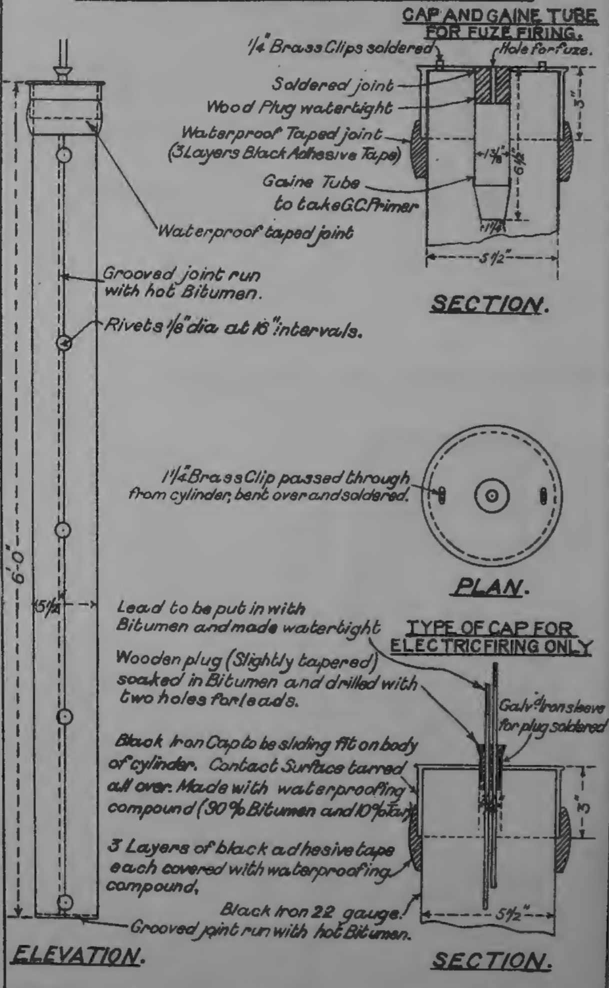


Fig. 3. Waterproof bag with clamps.



Malby & Sons, Lith.

CYLINDER FOR BORE-HOLE CHARGES.



9977

EARTH AUGER.

MANGNALL-IRVING THRUST-BORER.

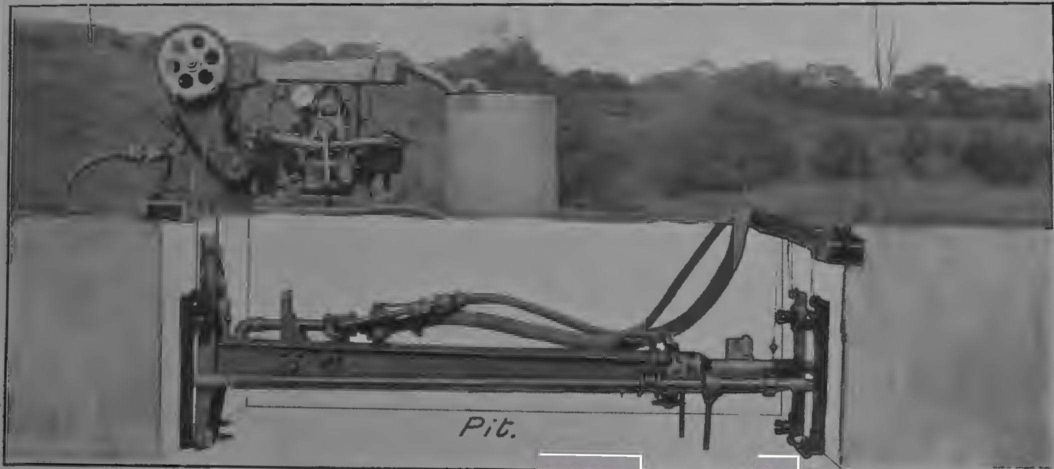


FIG. 1.—GENERAL VIEW OF APPARATUS AND SECTIONAL ELEVATION THROUGH PIT.

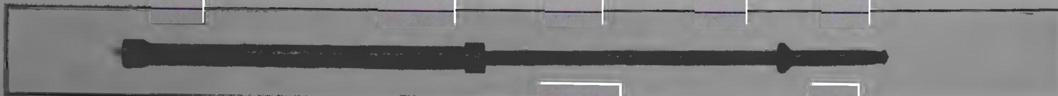


FIG. 2.—PILOT-HEAD.

Plate 16.

WOMBAT BORER.

FIG. 1.—CALYX BIT FOR HARD SOIL.

FIG. 2.—SPIRAL AUGER FOR SOFT AND MEDIUM SOILS.

USE OF GUN-COTTON.

Fig. 1.

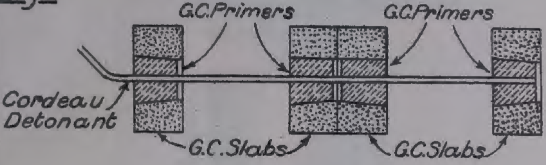


Fig. 2.

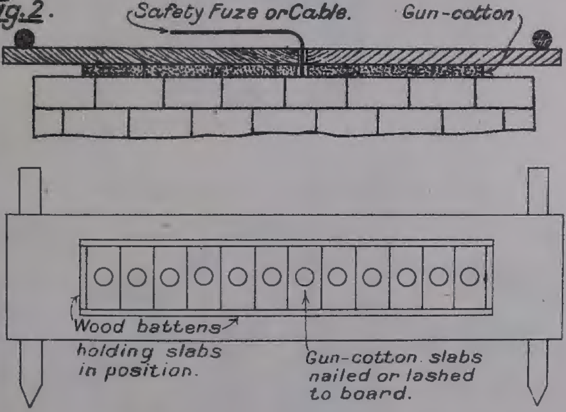
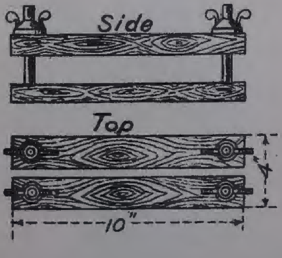


Fig. 3.



Malby & Sons Lith.

USE OF DYNAMITE.

PAN WARMING DYNAMITE.

Fig. 1.

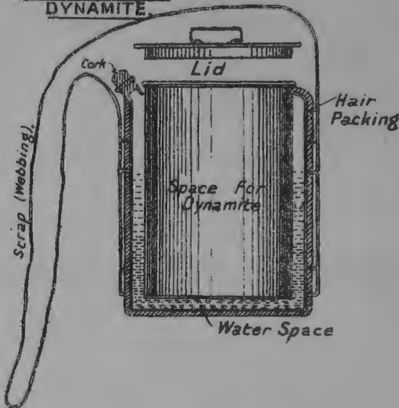


Fig. 2.

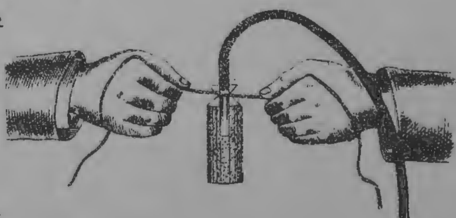


Fig. 3.

PORTABLE CHARGES.

Fig. 1. 25-lb. Ammonal Tin.

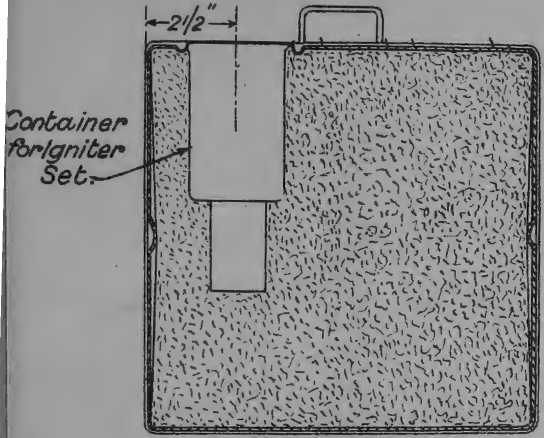
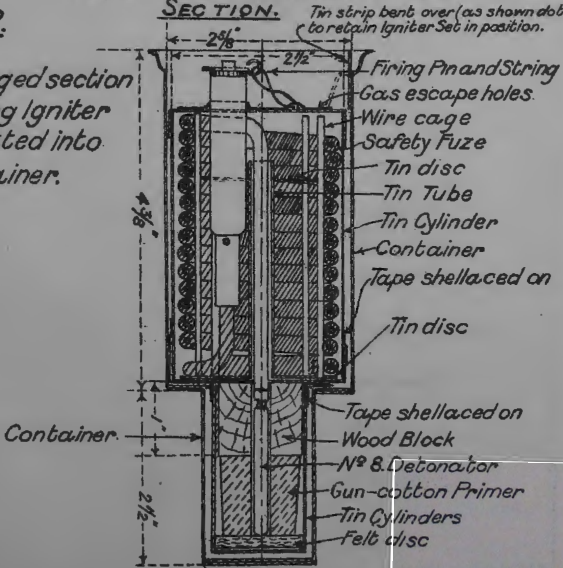


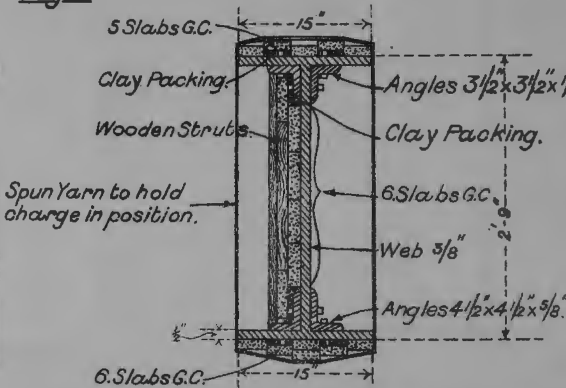
Fig. 2.

Enlarged section showing Igniter Set fitted into Container.



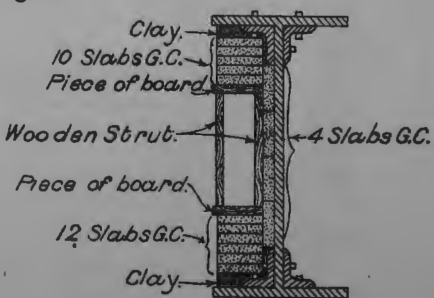
DEMOLITION OF GIRDERS.

Fig. 1.



Thickness of rivet heads ½" throughout.

Fig. 2.



Dimensions of Girder as in Fig. 1.

Malby & Sons, Lith.

DEMOLITION OF GIRDER BRIDGES.

Fig. 1.

Fig. 2.

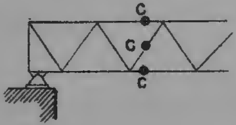


Fig. 3.

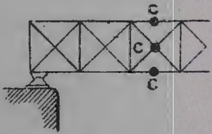
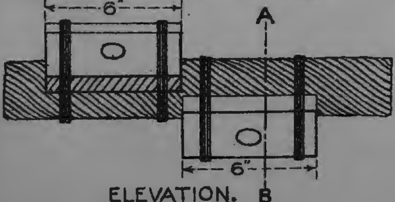
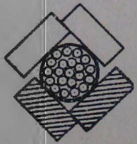


Fig. 4.

Fig. 5. CUTTING STEEL CABLE.



ELEVATION.



SECTION ON A.B.

Malby & Sons Lith.

Plate 23.

DEMOLITION OF MASONRY BRIDGES.

Fig. 1.

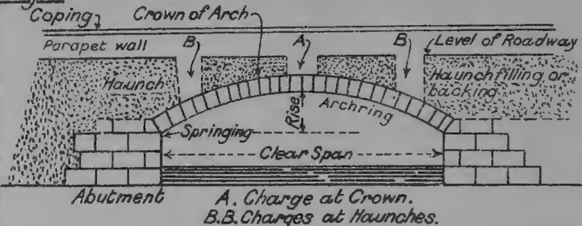


Fig. 2.

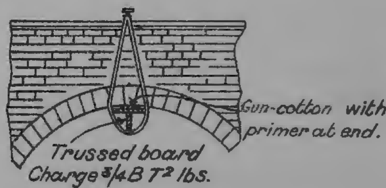
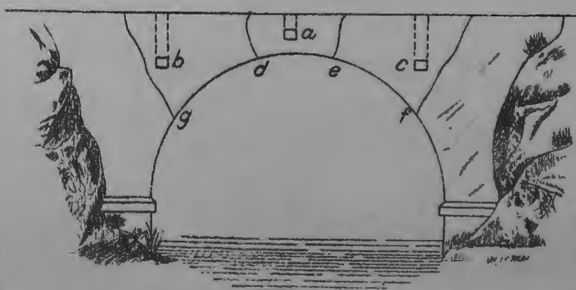


Fig. 3.



Malby & Sons Lith

TIMBER DEMOLITIONS.

Fig. 1.

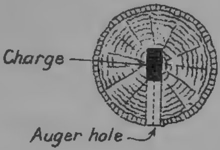


Fig. 2.

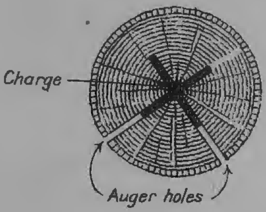
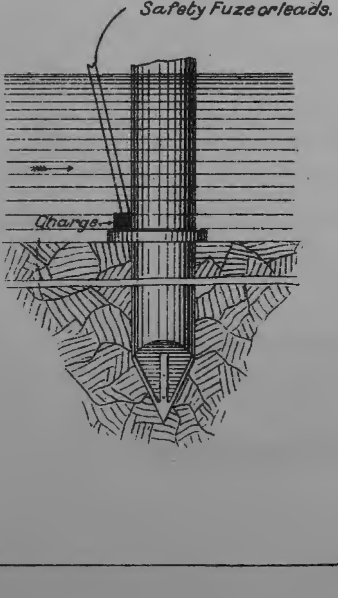


Fig. 3.

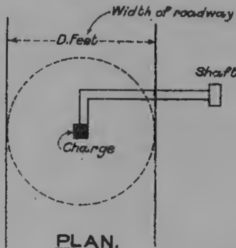


Malby & Sons. Lith

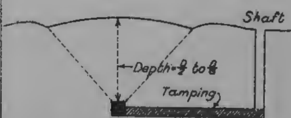
MINED CHARGES.

ROADS AND BRIDGES.

Fig. 1. ROADS, ETC:



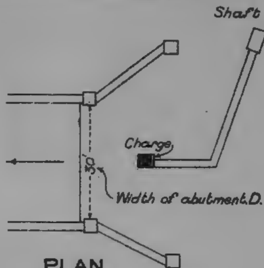
PLAN.



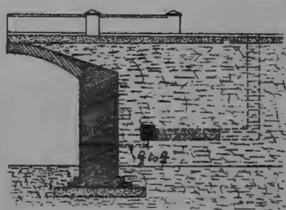
Charge for soft and medium soil = $\frac{D^3}{100}$ (Increased by 50 per cent, for roads with concrete foundations or heavy soling).

SECTION.

Fig. 2. BRIDGE ABUTMENTS.

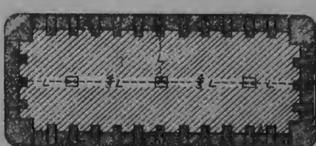


PLAN.



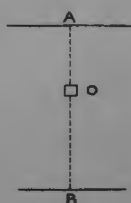
SECTION.

Fig. 3. PIERS.



Concrete and rubble filling

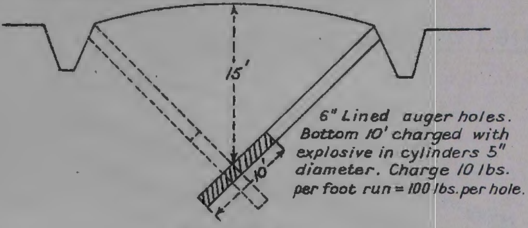
Fig. 4.



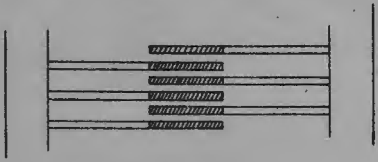
Malby & Sons Lith

ROAD CRATERS.

Fig. 1. MINED CHARGE LAID IN AUGER HOLES.

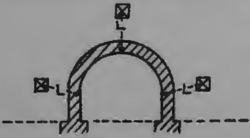


SECTION.

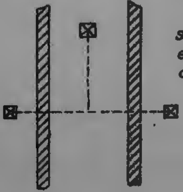


PLAN.

Fig. 2. DEMOLITION OF A TUNNEL IN ROCK.



SECTION.



NOTE.

The distance L should be approximately equal to half the width of the tunnel.

PLAN.

Malby & Sons, Lith.

DEMOLITION OF RAILWAYS.

FIG. 1. *Demolition of Heavy Steel Rail.*

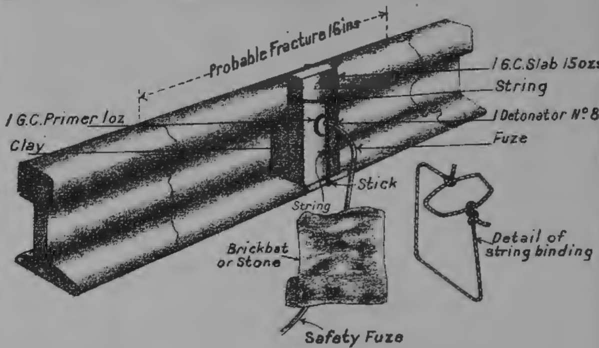


FIG. 2. *Points.*

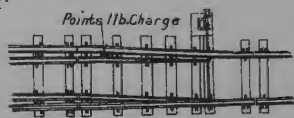


FIG. 3. *Crossings.*

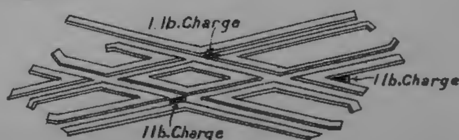
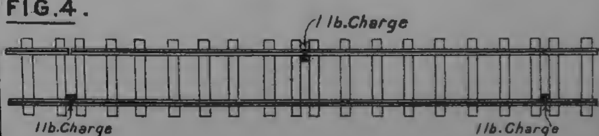
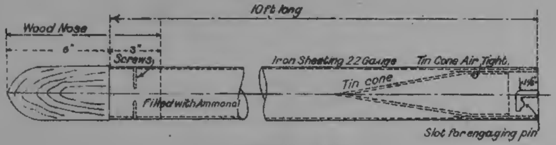


FIG. 4.

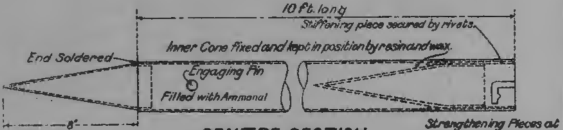


Malby & Sons Lith.

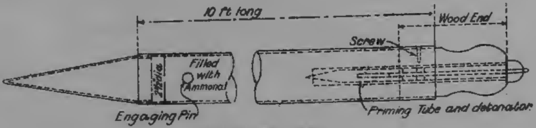
BANGALORE TORPEDO.



LEADING END.

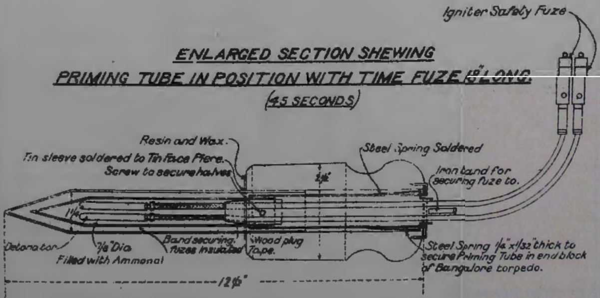


CENTRE SECTION.



TRAILING END.

ENLARGED SECTION SHEWING
PRIMING TUBE IN POSITION WITH TIME FUZE 18" LONG.
(45 SECONDS)



Malby & Sons Lith.

CONTACT MINES.

Fig. 1.

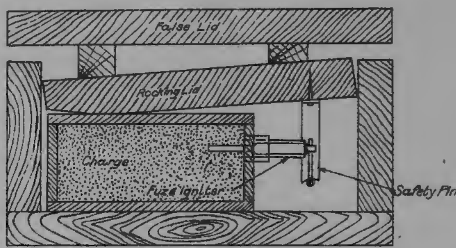
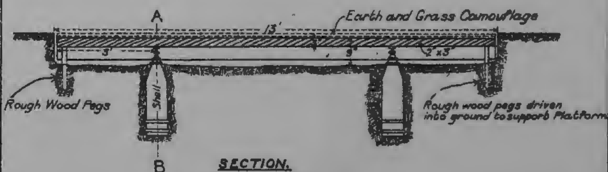
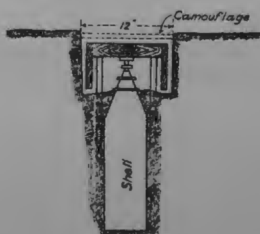


Fig. 2.



SECTION.

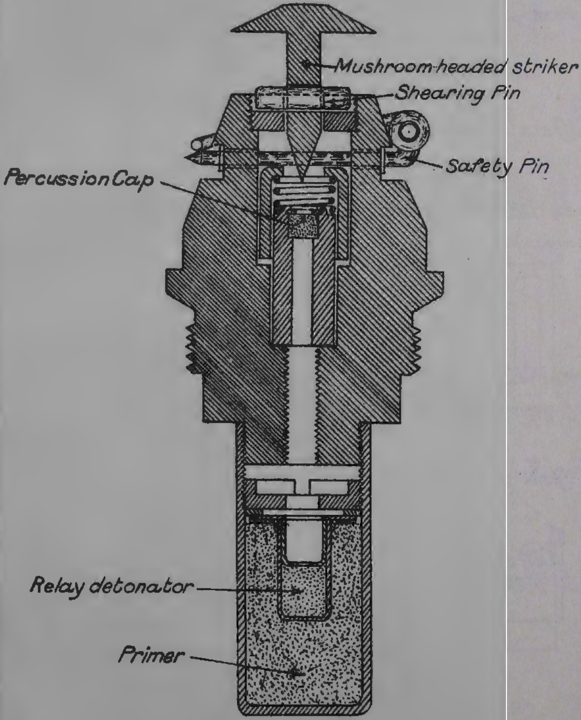
Fig. 3.



SECTION A.B.

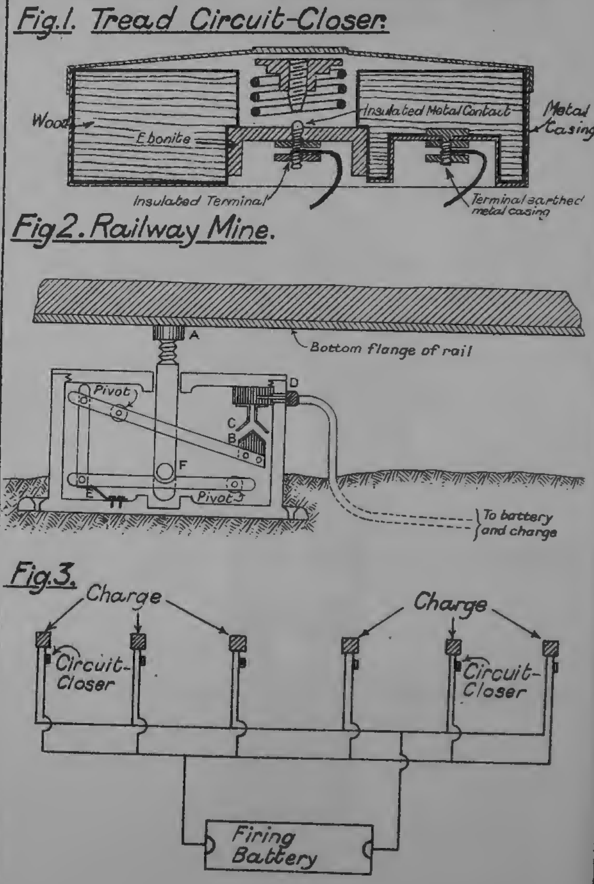
3377
Maltby & Sons. Lith

FUZE FOR SHELL CONTACT MINE.



Malby & Sons Lith.

ELECTRO-CONTACT LAND MINES.



8917

Malby & Sons, Lith.

MINE FIELDS.

Fig. 1.

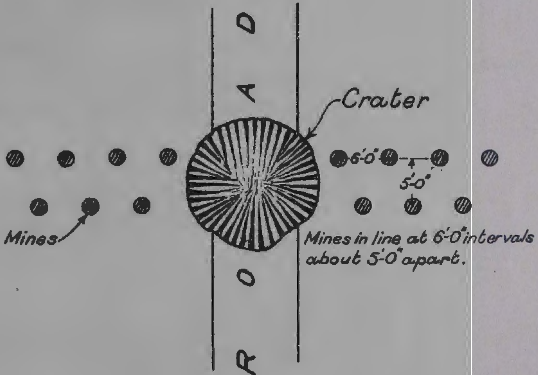
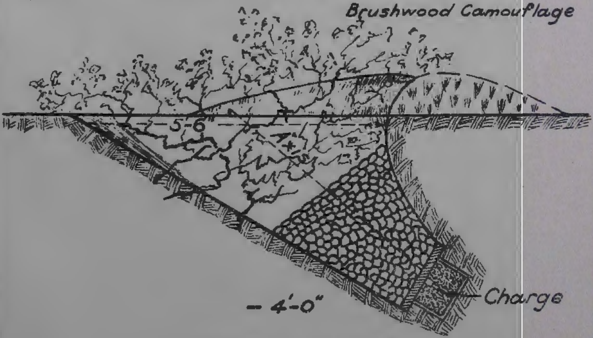


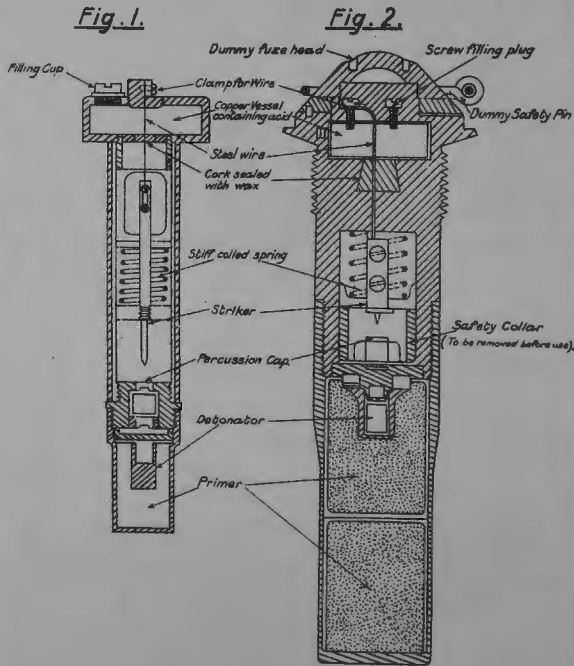
Fig. 2. FOUGASSE.



SECTIONAL ELEVATION.

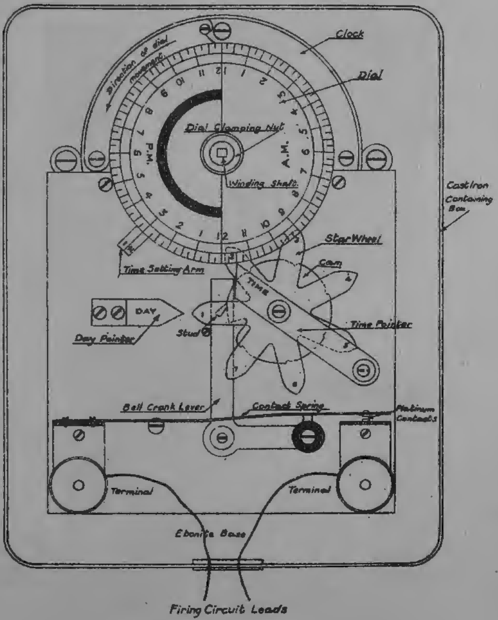
Malby & Sons Lith.

DELAY ACTION DEVICES.



Malby & Sons, Lith

VENNER TIME SWITCH.



HAND-BORING TOOLS.

Fig. 1.

3" Hole steel boring-bar 3½' long.

Fig. 2.

Fig. 3.

Fig. 4. 14-lb. Sledge Hammer.

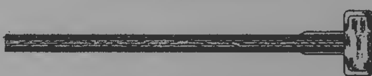


Fig. 5. Miners' Scraper.

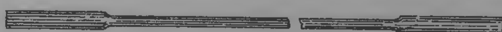
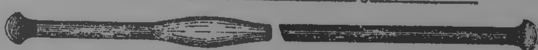


Fig. 6. Steel jumping bar with swelling on stock.



3977

DRILLING MACHINES.

Fig. 1.

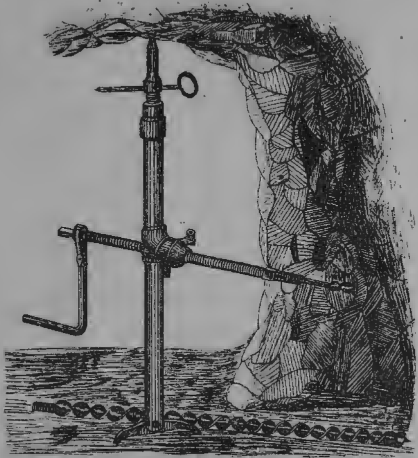
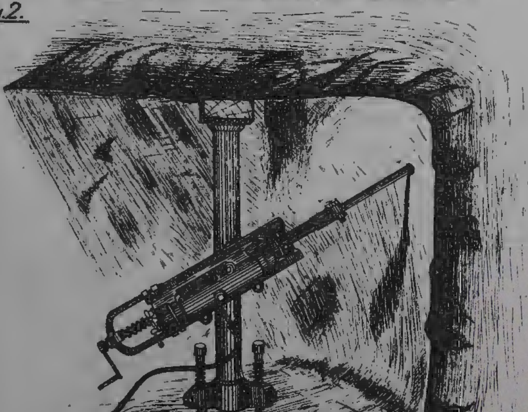


Fig. 2.



1977

Malby & Sons, Lith.

Plate 37

INGERSOLL — SERGEANT DRILL.

LONGITUDINAL SECTION

A — Cylinder.
B — Main Valve.
C — Auxiliary Valve.
D — Piston.
E — Extension of Piston.
F — Rifled Bar.
G — Nut for Rifled Bar.
H — Pawl of Ratchet.
I — Ratchet.
J — Crank Handle.
K — Shank of Drill-bit.
L — Chuck
M — Spigot.

Fig. 1.

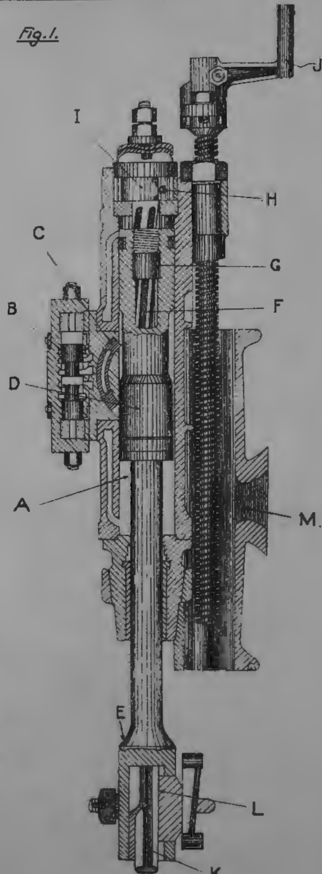
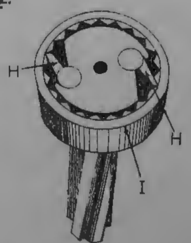


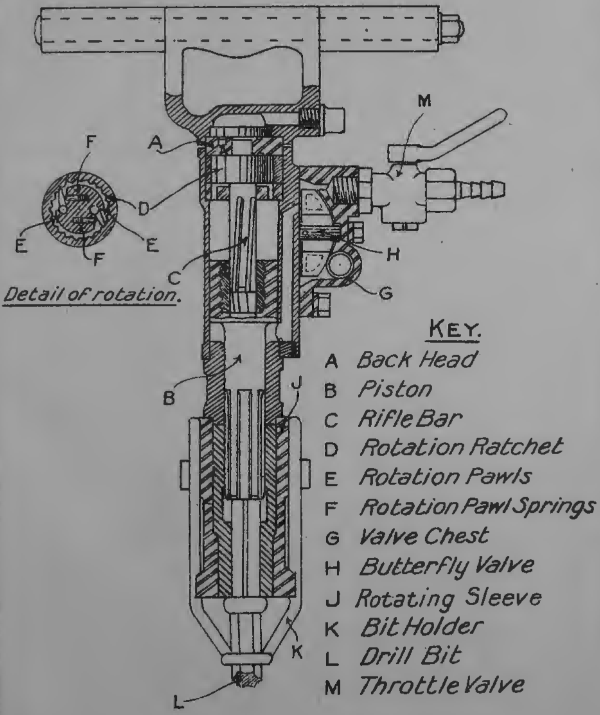
Fig. 2.



DETAIL OF RATCHET
I. — Ratchet.
H.H.—Pawls.

BUTTERFLY JACK-HAMMER DRILL.

INGERSOLL-RAND COY.



Malby & Sons, Lith.

MOUNTINGS FOR MACHINE DRILLS.

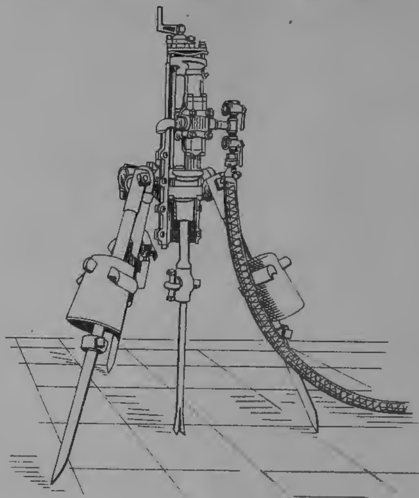


FIG. I. TRIPOD MOUNTING.

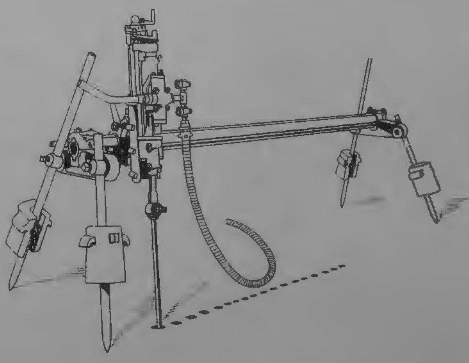


FIG. 2. QUARRY BAR MOUNTING.

3977.

PORTABLE COMPRESSOR PLANT.

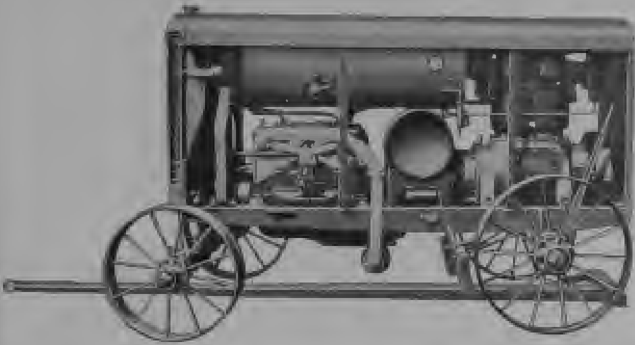


Fig. 1.

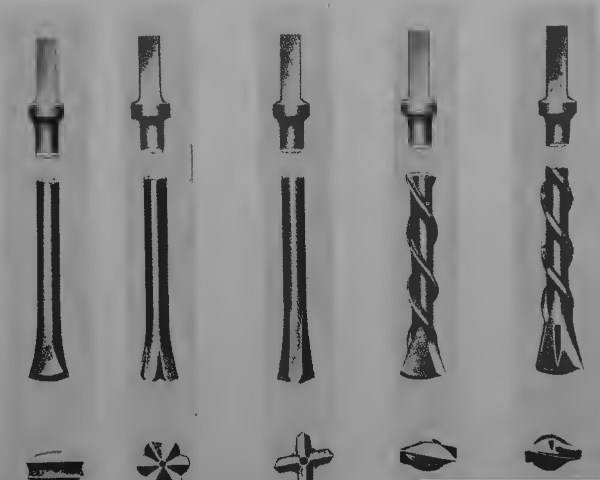


Fig. 2.—Bits showing Cutting Edges.

Fig. 1 reproduced by Permission of The Ingersoll-Rand Co., Ltd., 165, Queen Victoria Street, London, E.C.4.

POSITION OF BORE-HOLES.

Fig. 1.

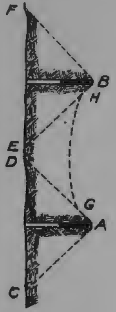
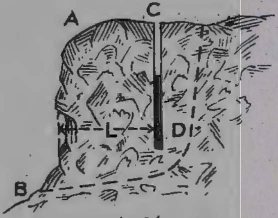


Fig. 2.



C D = 1 to 3/4 A B
L = 3/4 to 2/3 C D

Fig. 3.

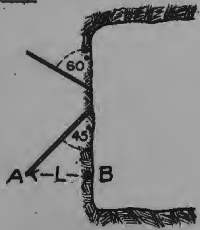


Fig. 4.

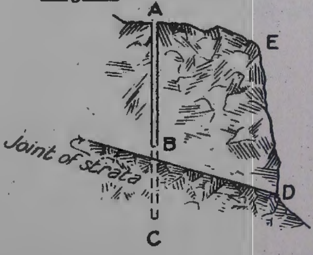
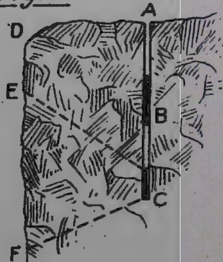


Fig. 5.

Fig. 6.



Malby&Sons, Lith.

POSITION OF BORE-HOLES (Cont^d).

Fig. 1.

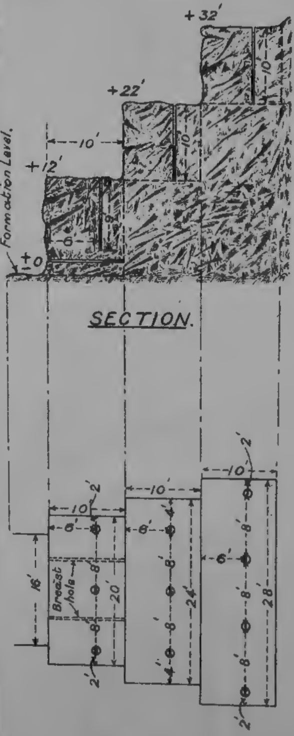


Fig. 2.

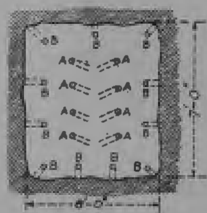
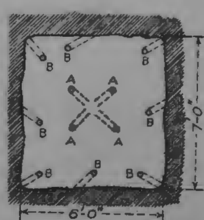


Fig. 3.



Malby & Sons Lith.

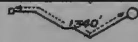
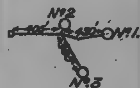
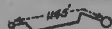
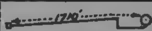
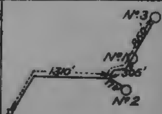
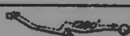
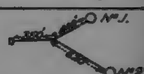
OFFENSIVE MINES MESSINES RIDGE.

3977.

Malby & Sons, Lith.

Plate 44.

OFFENSIVE MINES MESSINES RIDGE – SUMMARY OF DATA.

Name of mine.	Time taken to construct. Months.	Depth of charge. Feet.	Charge of H.E. Lbs.	Radius of destruction Feet.	Length of gallery Feet.	Diagram of mines.
Hill 60 N° 1	11	90	53,500	142·5	870+240	
" " N° 2	14	100	70,000	190	870+510	
St Eloi.	9½	125	95,600	165	1340	
Hollandscheschuur Farm N° 1	6	60	34,200	171·5	405+420	
" N° 2	7	55	14,900	107·5	405+65	
" N° 3	8	55	17,500	100·5	405+395	
Petit Bois N° 1	8	57	30,000	208·5	1810+210	
" N° 2	7½	70	30,000	187·5	1810+260	
Maedelstede Farm.	9	100	94,000	197·5	1610	
Peckham.	7	70	87,000	165	1145	
Spanbroekmolen.	6	88	91,000	215	1710	
Kruisstraat N° 1.	15	57	49,500	197·5	1310+305	
" N° 2	6½	62	30,000	183·5	1310+170	
" N° 3.	7½	50	30,000	168	1310+850	
Ontario Farm	4½	103	60,000	110	1290	
Trench 127 N° 1	4	75	36,000	116	770+250	
" N° 2	4½	76	50,000	171	770+585	
Trench 122 N° 1.	3	60	20,000	181·5	350+440	
" N° 2.	4	75	40,000	178	350+620	

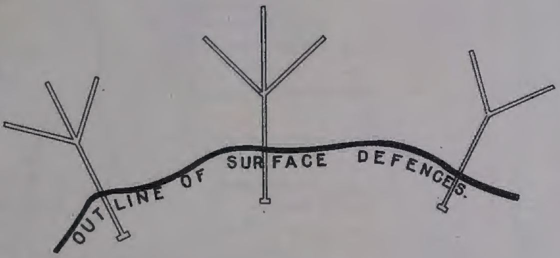
9977 19527. 4815/245

Malby & Sons, Lith

PROTECTIVE SYSTEM.

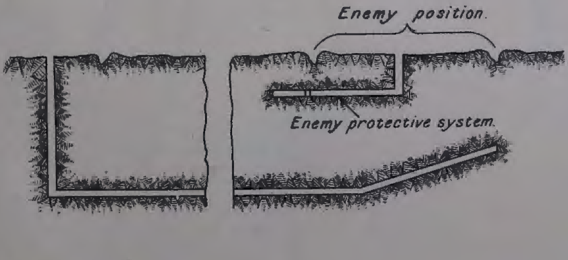
(HERRING-BONE TYPE.)

Fig. 1.



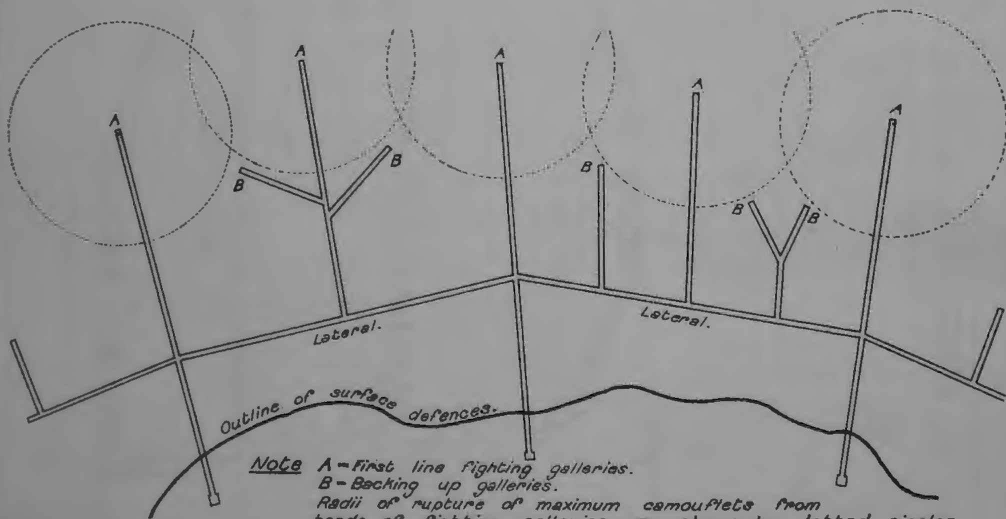
DEEP OFFENSIVE MINING.

Fig. 2.



Malby & Sons, Lith.

DIAGRAM OF A FIGHTING SYSTEM.



Note A – First line fighting galleries.
B – Backing up galleries.
Radii of rupture of maximum camouflets from heads of fighting galleries are shown by dotted circles.

3977 19587 4818/245

Malby & Sons Lith.

INFLUENCE OF SURFACE FEATURES.

Fig. 1.

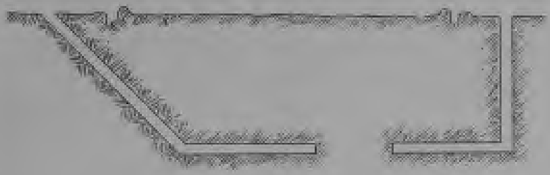
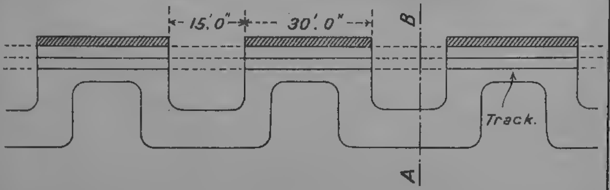
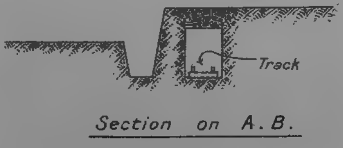


Fig. 2.

Fig. 3. CONCEALED TRACK.





Section on A. B.

Malby & Sons, Lith.

Plate 48

WATER CONDITIONS.

Fig. 1. Water level in chalk.

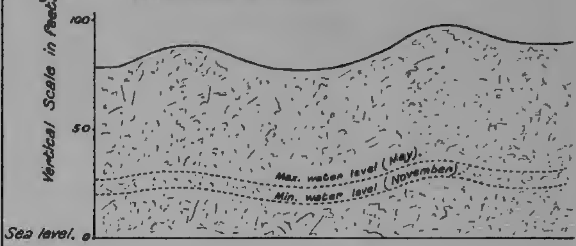


Fig. 2. Water under pressure.

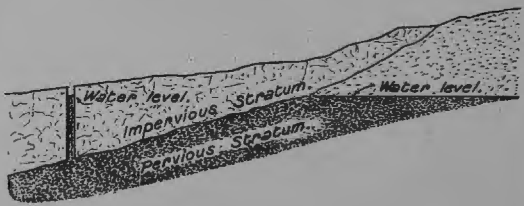
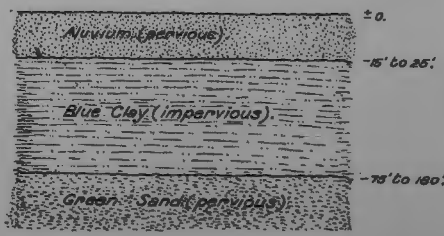


Fig. 3.

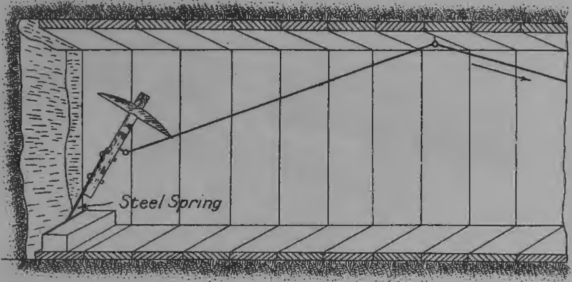


8977

Malby & Sons, Lith.

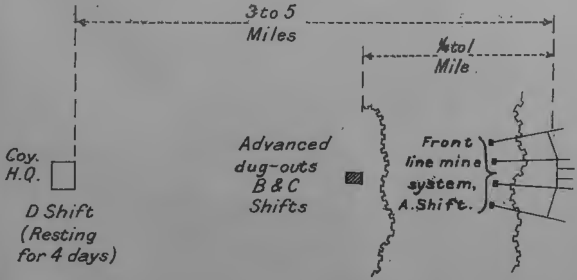
DUMMY PICK.

Fig. 1.



ORGANIZATION OF RELIEFS.

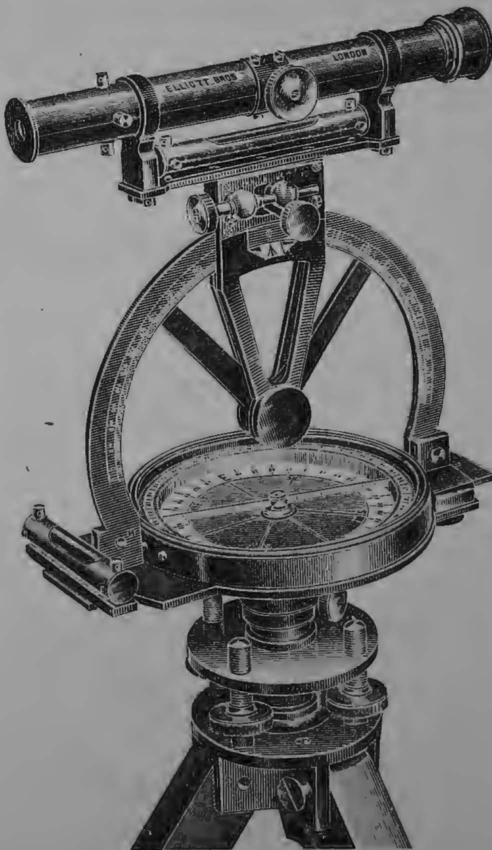
Fig. 2.



Malby & Sons, Lith.

Plate 50.

MINERS' DIAL.



9977

GALLERY SETTS.

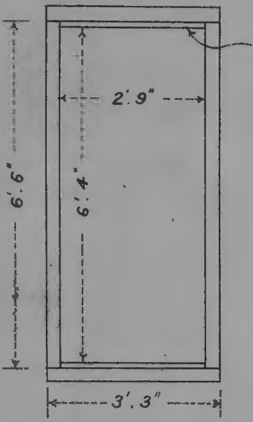


Fig. 1.

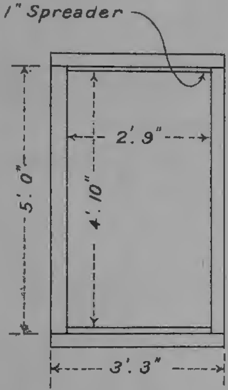


Fig. 2.

Cases, 7 to 11 ins. wide

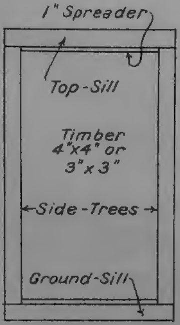


Fig. 3.

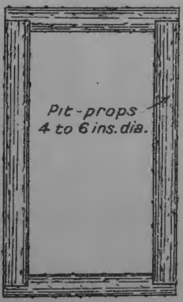


Fig. 4.

Frames.

Malby & Sons, Lith.

TIMBERING.

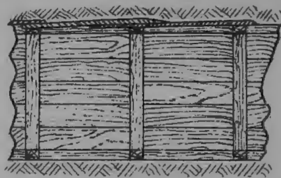


Fig. 1. Frames and sheeting.

Fig. 2. Gallery in rock.

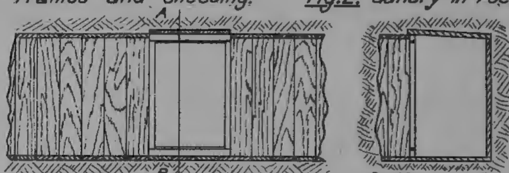


Fig. 3. Cases (close-timbering); showing also method of breaking out one gallery from another.

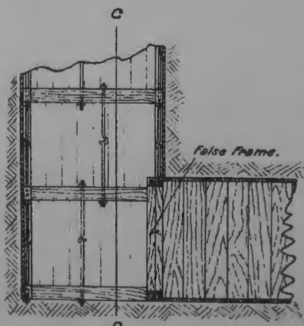


Fig. 4. Breaking out from shaft.

Fig. 5. Section on C.D.

9977

Malby & Sons, Lith.

MINING TOOLS.

Fig. 1.

Grafting Tool.

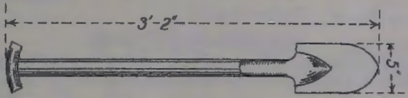


Fig. 2.

Pick.

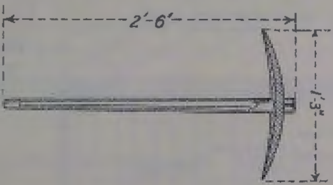


Fig. 3.

Push-Pick.

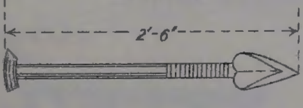
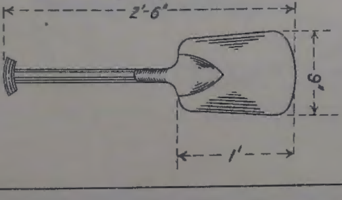


Fig. 4.

Shovel.



Malby & Sons, Lith

SPILING.

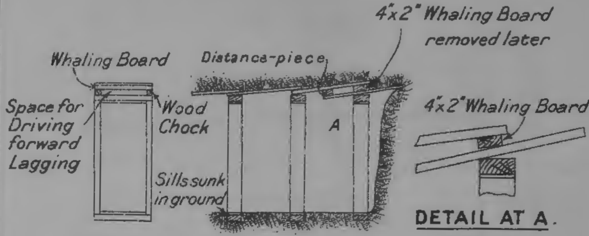


Fig. 1. Without Intermediate Sett.

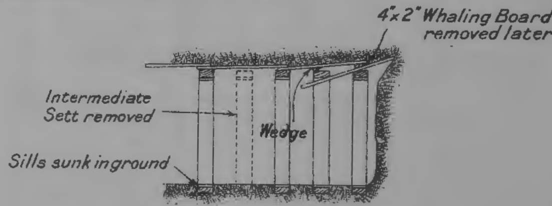


Fig. 2. With Intermediate Sett.

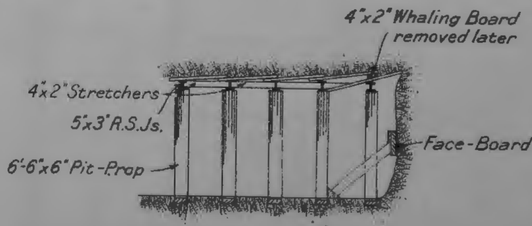
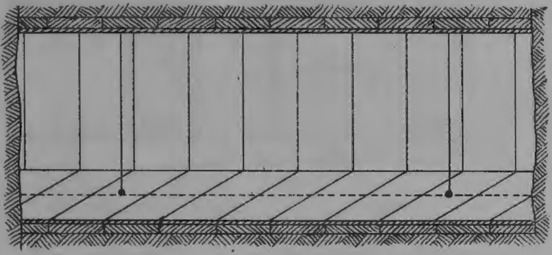


Fig. 3. With Pit-Props & R.S.Js.

Malby & Sons, Lith

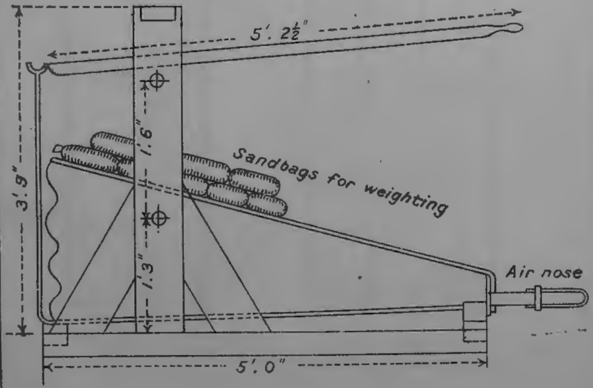
VERIFYING DIRECTION.

Fig. 1.



INSTALLATION OF BELLOWS.

Fig. 2.



Malby & Sons, Lith

Plate 56.

TYPE DESIGN OF DEEP SHAFT.

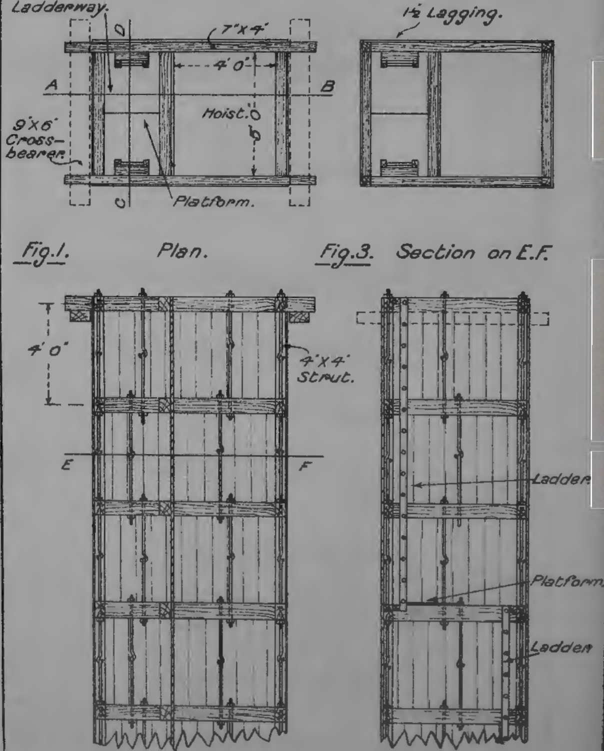


Fig. 2. Section on A.B. (Ladders not shown.)

Fig. 4. Section on C.D.

9977

Malby & Sons, Lith.

SHAFTS.

Fig. 1.

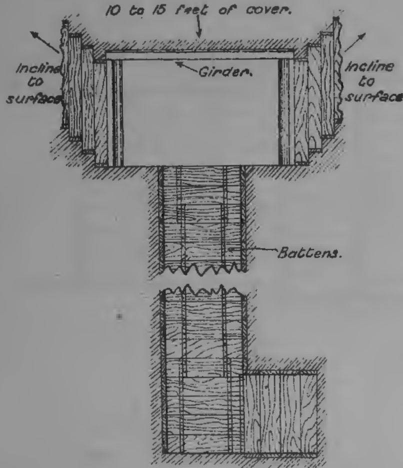
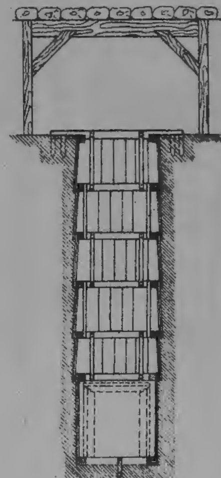


Fig. 2.



METHOD OF SINKING BY SPILING.

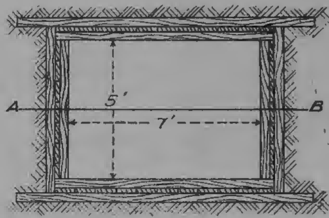


Fig. 1. PLAN OF COLLAR SETT.

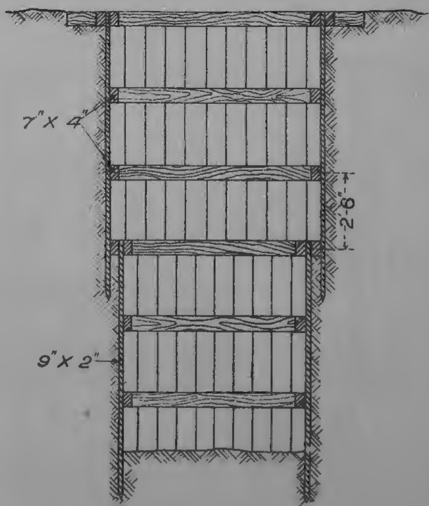
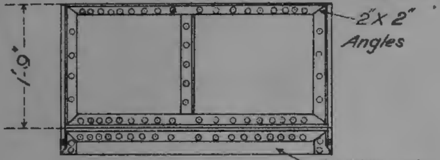


Fig. 2. SECTION ON A.B.

977 (9527 4815/245

Malby & Sons Lith

STEEL TUBBING.



Section on B.B.

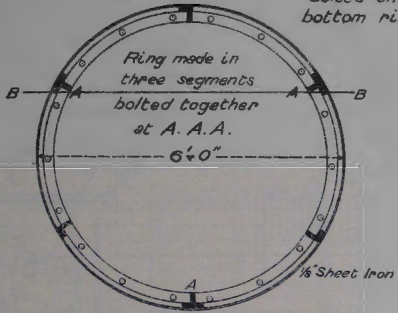


Fig. 1. Plan

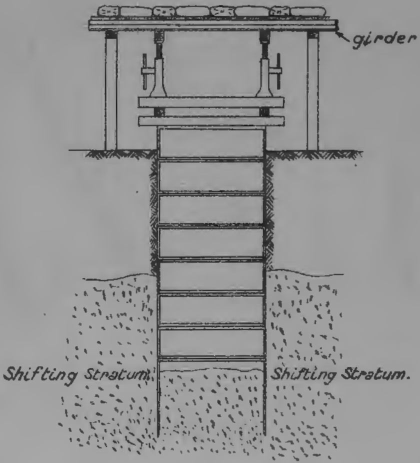


Fig. 2. Method of Sinking

Plate 59.

Malby & Sons Lith.

Plate 60.

INCLINES.

Fig. 1.

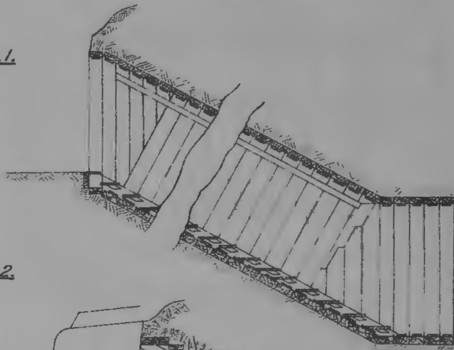


Fig. 2.

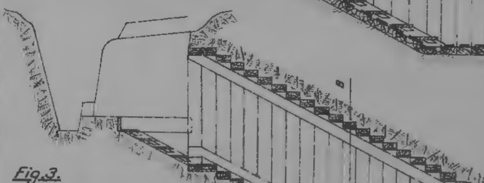


Fig. 3.

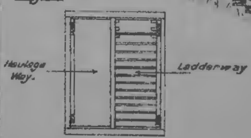
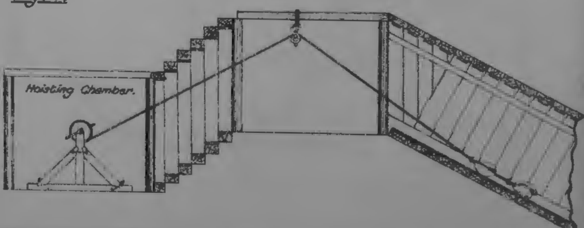


Fig. 4.

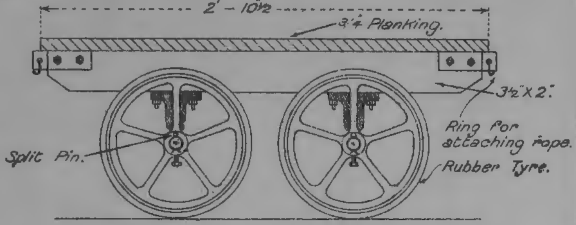


9977

Malby & Sons Lith.

MINERS' TRUCK.

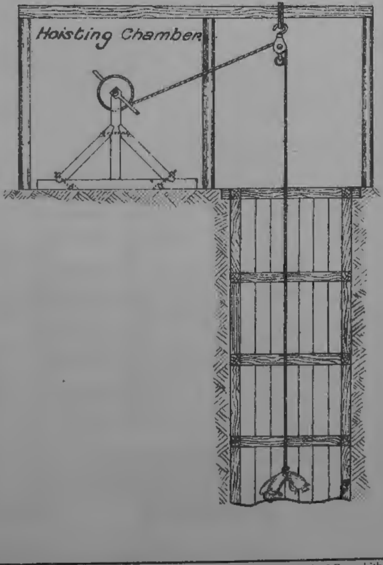
Fig. 1.



Diameter of wheels exclusive of rubber tyres 8½ inches.
" " inclusive " " " 10 inches.

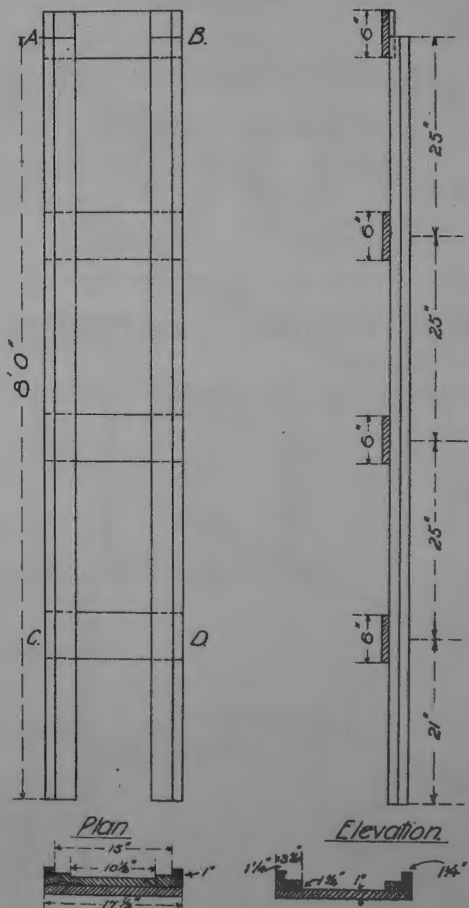
Fig. 2. DIRECT HOISTING.
by hand.

Fig. 3. HOISTING.
with windlass.



Malby & Sons. Lith

WOODEN MINE TRACK.



Plan

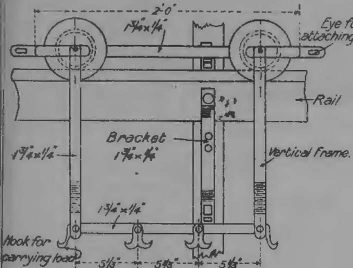
Elevation.

Section A-B.

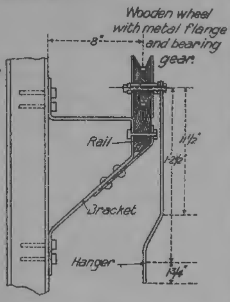
Section C-D.

Malby & Sons. Lith.

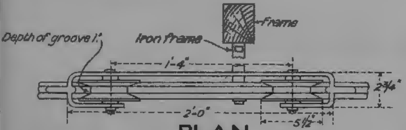
MONO-RAIL HAULAGE.



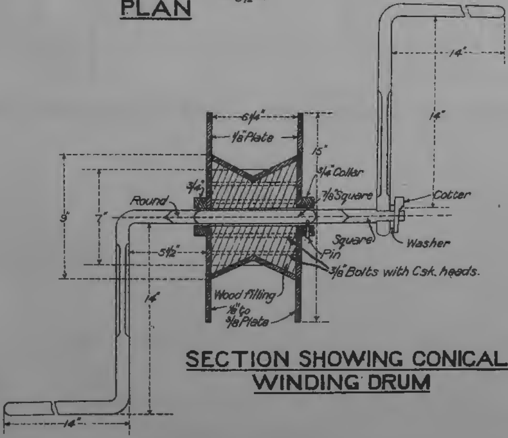
ELEVATION



SECTION



PLAN



SECTION SHOWING CONICAL WINDING DRUM

Malby & Sons, Lith.

WINDLASS FOR SHAFTS.

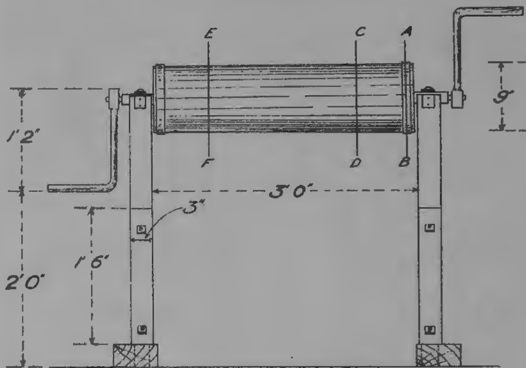


Fig. 1. Front Elevation.

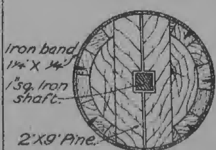


Fig. 2. Enlarged Section thro. A. B.

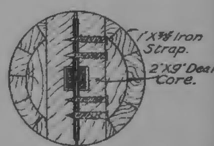


Fig. 3. Enlarged Section thro. C. D.

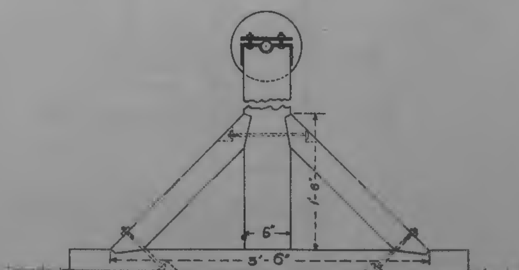
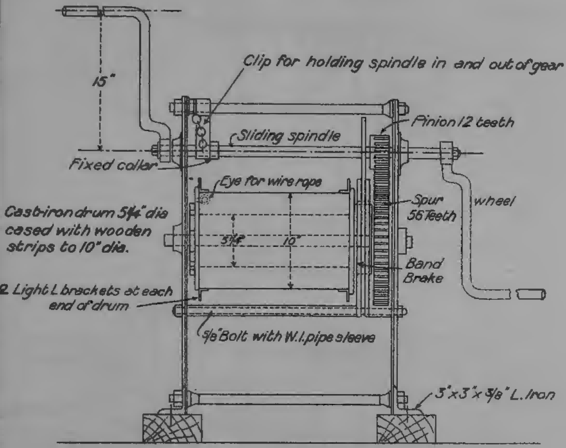


Fig. 4. Side Elevation.

Malby & Sons Lith.

GEARED WINCH.

Fig. 1.

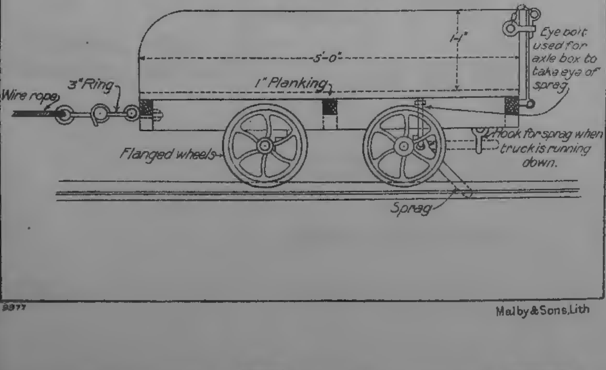


Front Elevation.

Fig. 2.

MINERS' TRUCK.

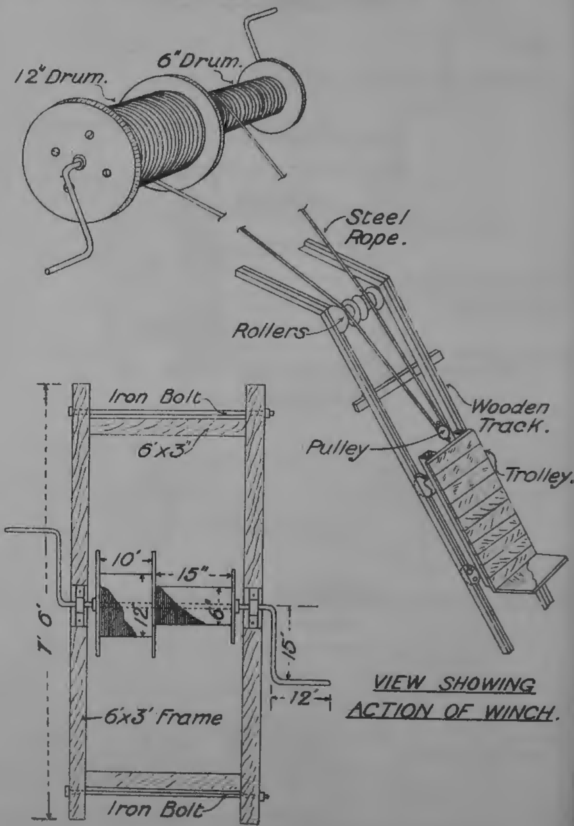
Adapted for hauling.



3377
Malby & Sons, Lith

Plate 66.

DIFFERENTIAL DOUBLE DRUM WINCH.



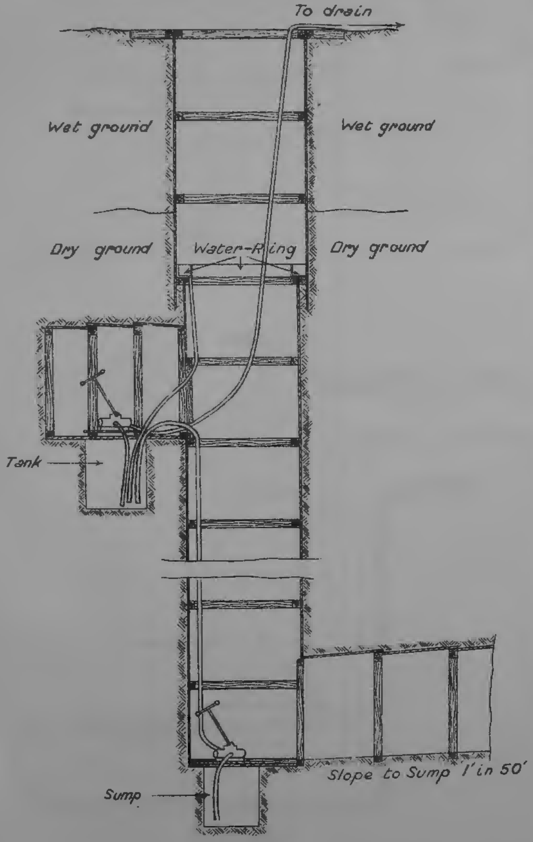
VIEW SHOWING ACTION OF WINCH.

FRONT ELEVATION OF WINCH.

9977

Malby & Sons Lith

PUMPING SCHEME WITH WATER-RING.

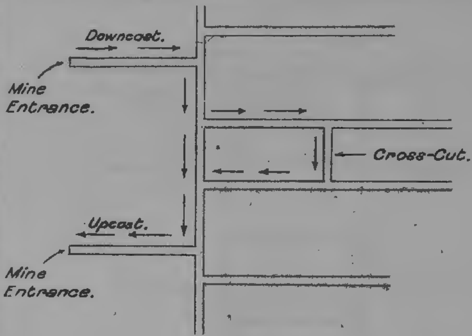


Malby & Sons, Lith

Plate 68.

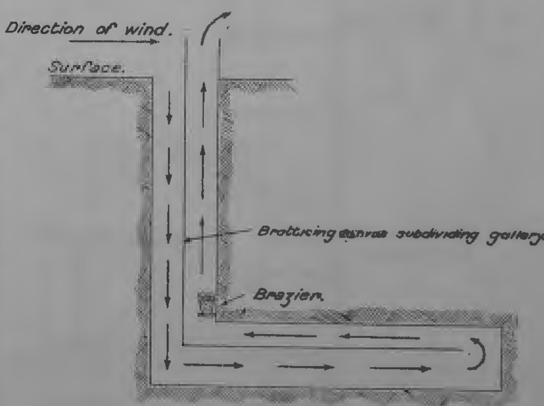
NATURAL VENTILATION.

Fig.1. *Air currents in a mine system with lateral.*



Plan.

Fig.2. *Bratticing.*



Section.

9977

Malby & Sons Lith

HOLMAN AIR-PUMP.

Reproduced by Permission of Messrs. Holman Bros., London, E.C. 2.

TYPE OF REGULATOR GAS DOOR IN MINE.

Scale ½" = 1 Foot.

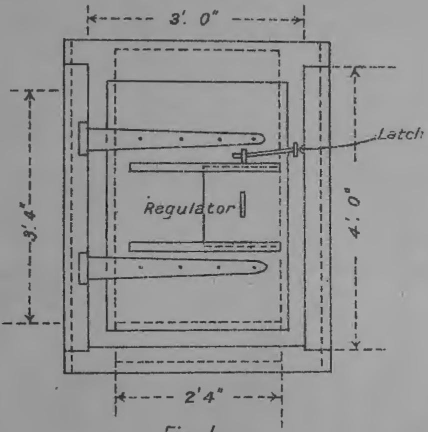
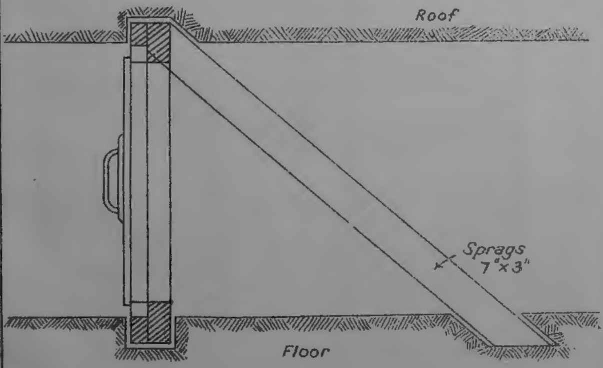


Fig. 1.



Opening of Doorway, 3'.4" high × 2'.4" wide.

Fig. 2.

Malby & Sons, Lith.

MINERS' ELECTRIC SAFETY LAMP.

(THOR ELECTRIC SAFETY LAMP Co.)

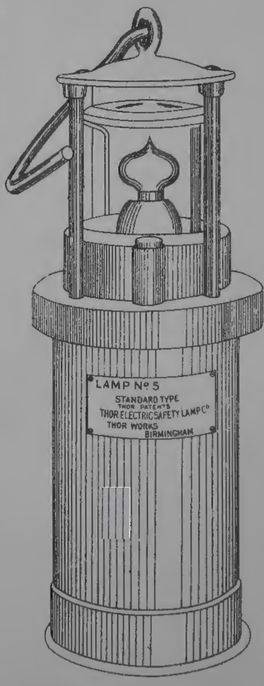


FIG. 1. GENERAL VIEW.

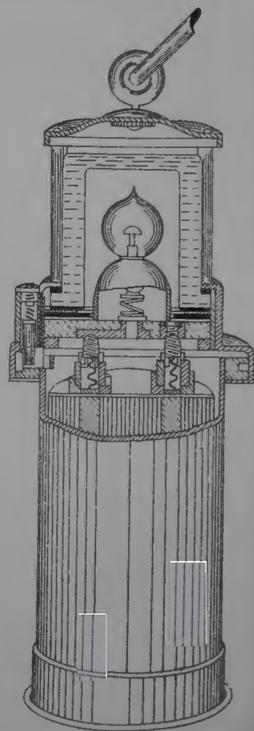


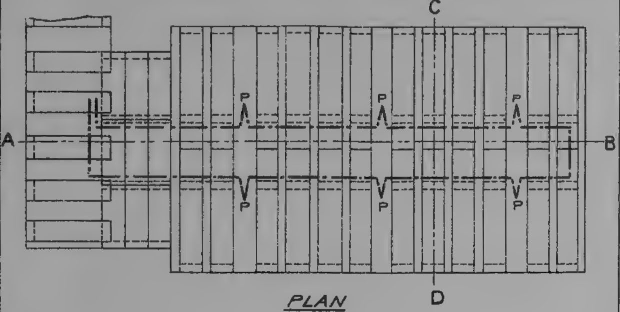
FIG. 2. SECTION
SHOWING WORKING PARTS.

8077

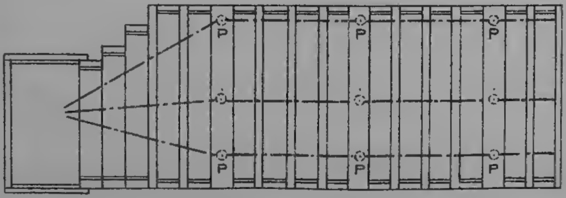
Reproduced by Permission of the Thor Electric Safety Lamp Coy. Ltd.

Malby & Sons Lith.

STANDARD MINE CHAMBER FOR LARGE CHARGES.



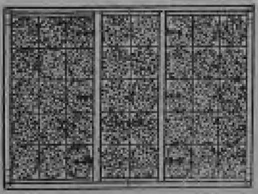
PLAN



SECTIONAL ELEVATION ALONG A.B.

P = Points of detonation.

—·—·—·— Denotes leads.



SECTION. C.D.

Malby & Sons Lith.

ANALYSIS OF THE EFFECTS OF MINE CHARGES.

Fig. 1.

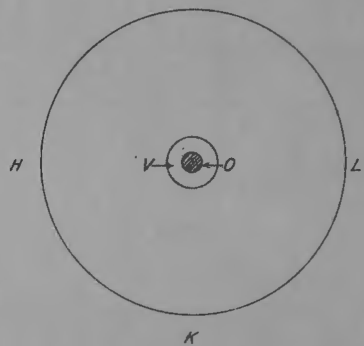
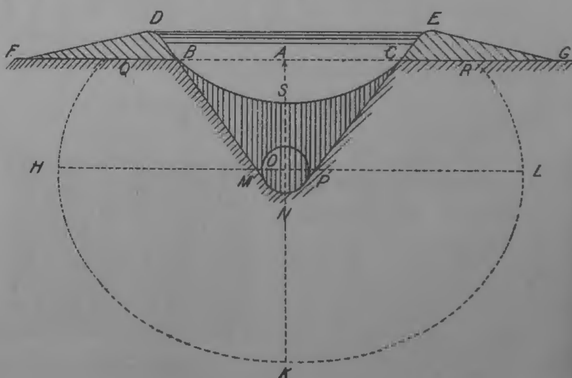


Fig. 2.



9977

Malby & Sons Lith.

Fig. 1.—Front View.

Fig. 2.—Back View.

Plate 75.

MINE STRETCHER.

Fig. 1.—Showing skids for running on Gallery Floors.

Fig. 2.—Use in Gallery.

ARTIFICIAL RESPIRATION

(Schaefer's Method),

USED IN CONJUNCTION WITH THE

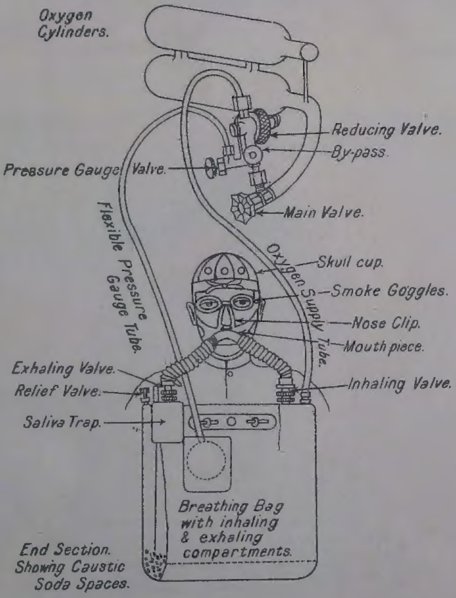
NOVITA OXYGEN REVIVING APPARATUS.

FIG. 1.

FIG. 2.

Reproduced by Permission of Messrs. [illegible] Gorm[illegible] and Co.

DIAGRAMMATIC VIEW OF THE "PROTO" MINE RESCUE APPARATUS.



Malby & Sons, Lith.

LISTENING INSTRUMENTS.

Fig. 1. Water-Bottle.

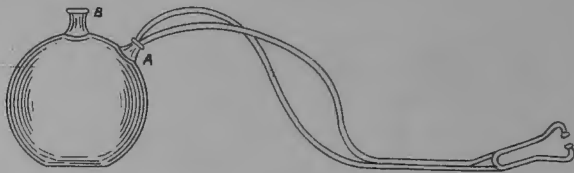
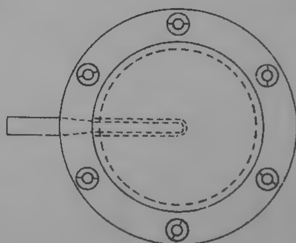
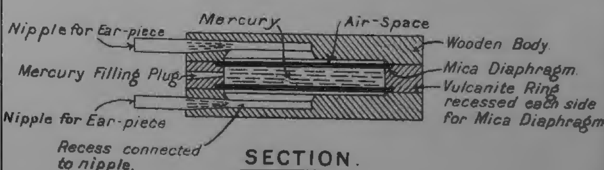


Fig. 2. Details of Geophone.



PLAN.



SECTION.

8977

Malby & Sons, Lith.

METHOD OF USING GEOPHONE.

FIG. 1.—GEOPHONE SET.

FIG. 2.—GEOPHONE IN USE.

FINDING DIRECTION OF SOUND WITH GEOPHONE.

FIG. 1

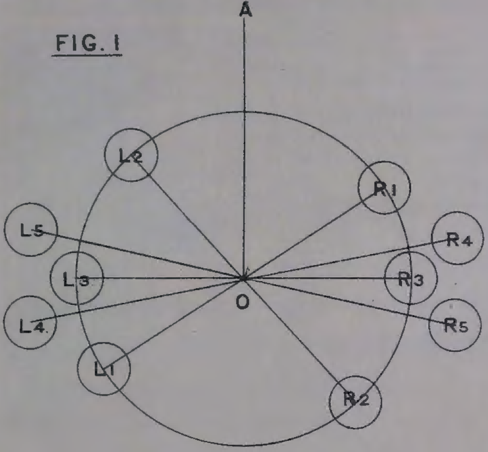
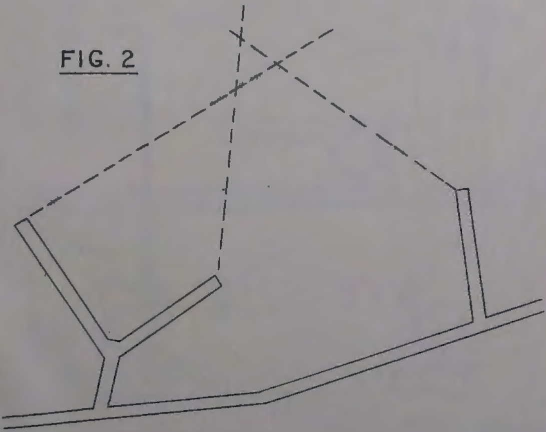


FIG. 2



Malby & Sons, Lith.

Plate 81.

THE SEISMOPHONE.

Fig 1. Detector

Brass Box –
Bottom A.B. – cover C.D.
Mass M. Isolated from box by two rings of solid rubber.
R_1-R_2-R_3-R_4
Microphone E_1 E_2
Terminals H_1 H_2

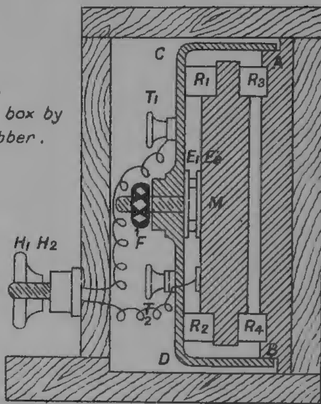


Fig. 2

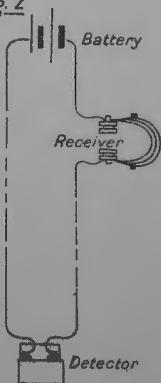
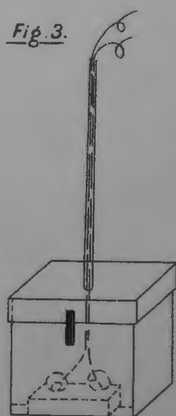
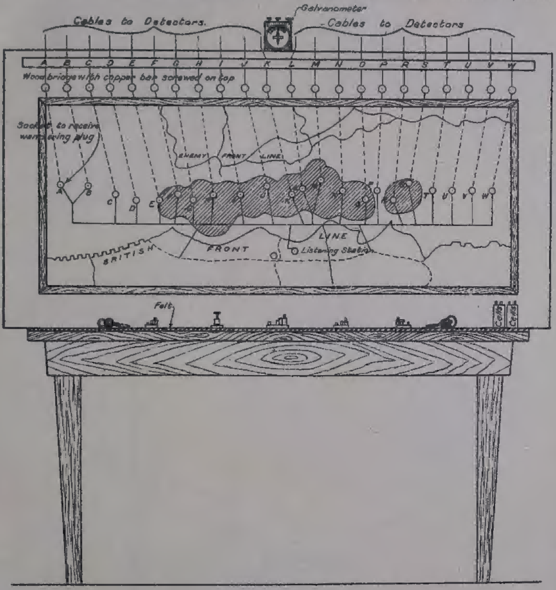


Fig. 3.

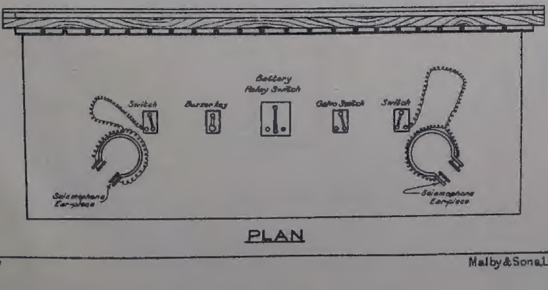


Malby & Sons, Lith.

CENTRAL LISTENING STATION TABLE & SWITCHBOARD.



ELEVATION

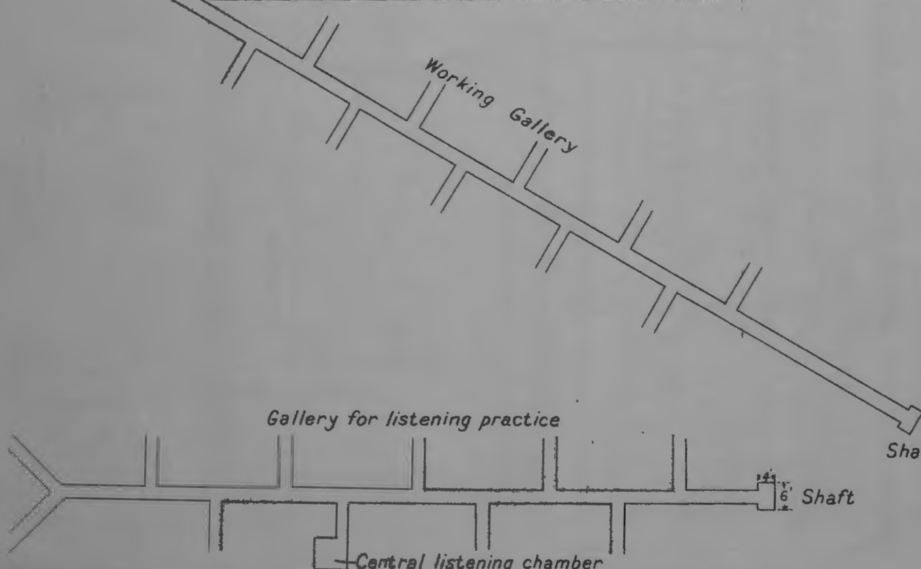


PLAN

 Malby & Sons Lith.

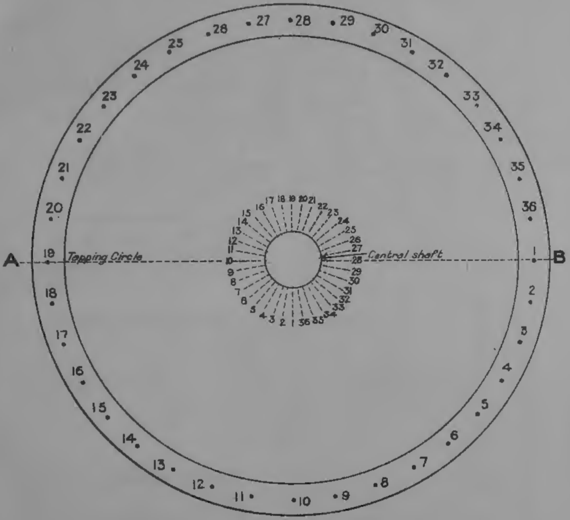
Plate 83

PRACTICE LISTENING GALLERY.

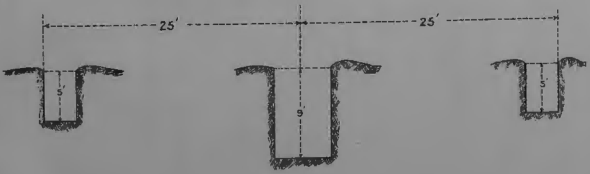


Malby & Sons, Lith.

LISTENING CIRCLE.



PLAN



SECTION A.B.

9877

Malby & Sons, Lith.

DUG-OUTS TO ACCOMMODATE 600 MEN.

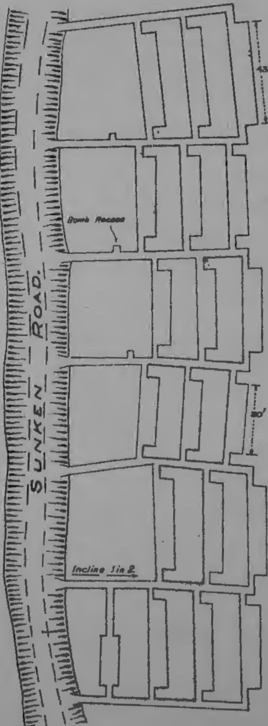


Fig. 1. Plan.

Schedule of Dimensions.

Chambers. 9' Wide. 6'-6" High.
Galleries & Entrances. 3'-6" Wide. 6'-6" High.

Fig. 2. Typical Section.

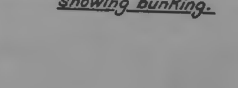


Fig. 3. Plan of dug-out showing bunking.

9977

Malby & Sons, Lith.

DUG-OUT CONSTRUCTION.

Fig. 1. Breaking-away chamber from gallery.

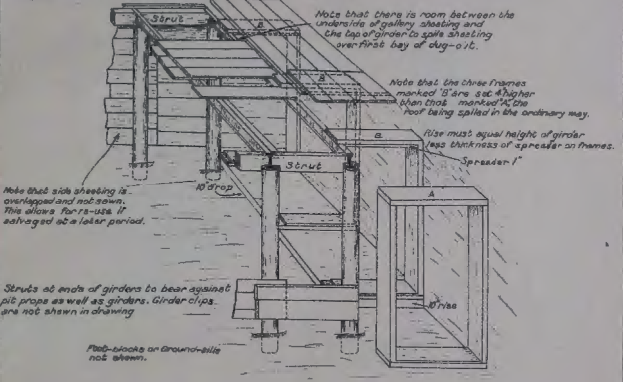
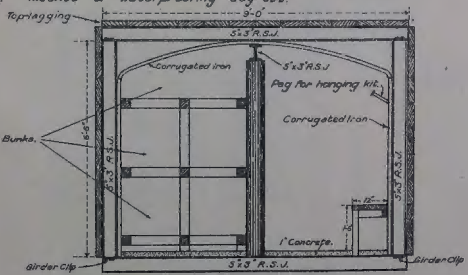


Fig. 2. Method of waterproofing dug-out.



 Malby & Sons Lith.

TYPES OF GIRDER CLIPS.

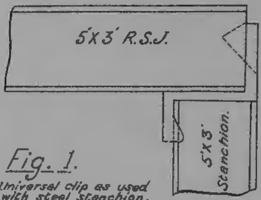


Fig. 1.

Universal clip as used with steel stanchion.

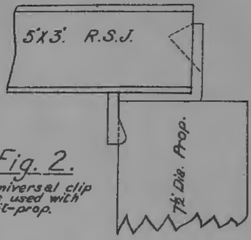
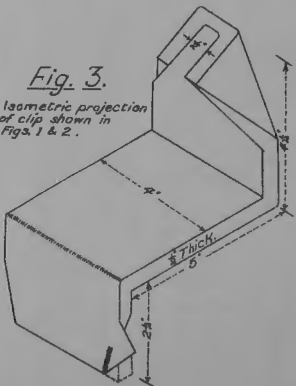


Fig. 2.

Universal clip as used with pit-prop.

Fig. 3.

Isometric projection of clip shown in Figs. 1 & 2.



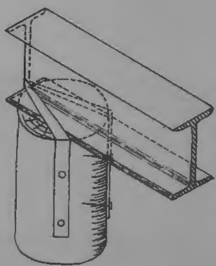


Fig. 4.

Hairpin clip

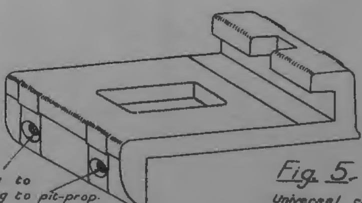


Fig. 5.

Universal clip-alternative design.

8877

Malby & Sons Lith.

EXCAVATION OF CHAMBERS.

Fig. 1. Without pilot-gallery.

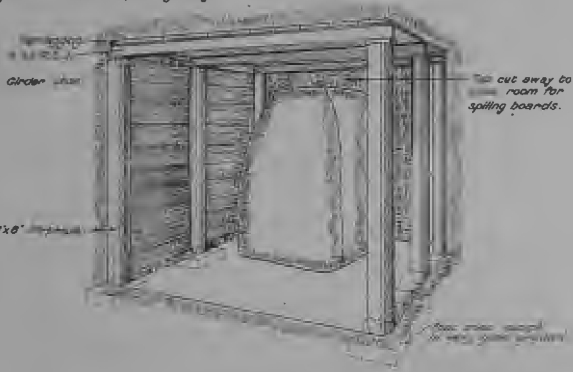
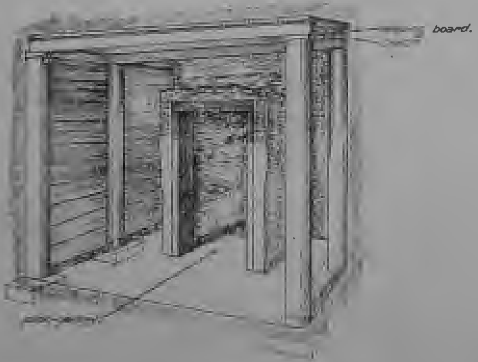


Fig. 2. With pilot-gallery.

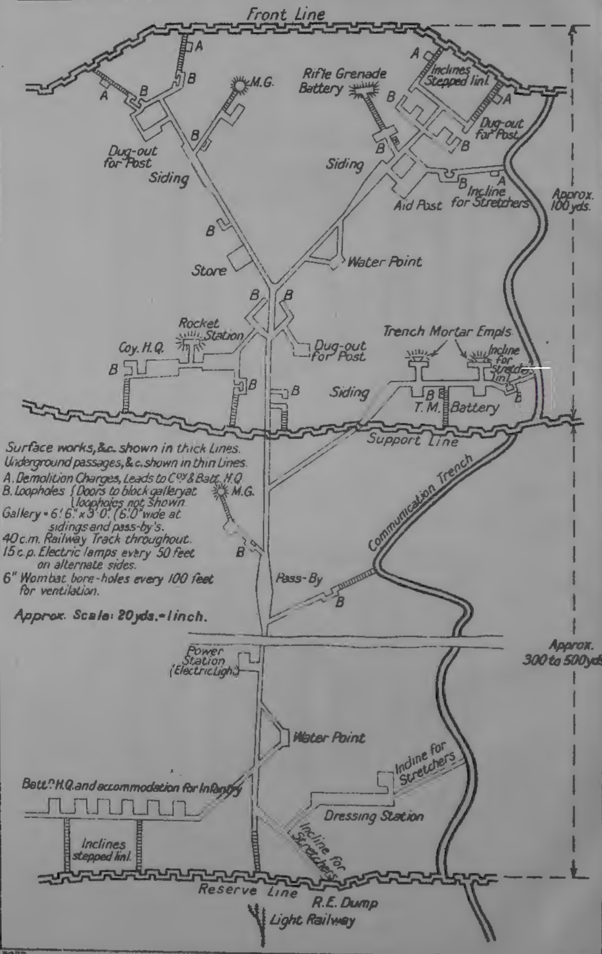


Malby & Sons, Lith.

Plate 89.

SUB-WAYS.

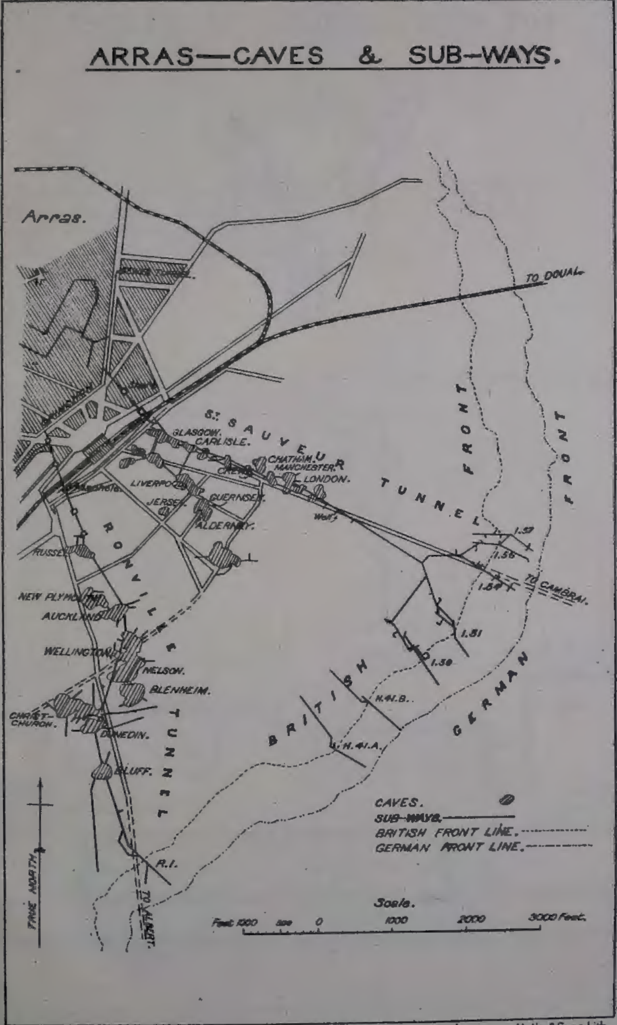
TYPICAL ARRANGEMENT OF GALLERIES AND ACCESSORY DUG-OUTS.



8972

Lith

ARRAS—CAVES & SUB-WAYS.



9977

Malby & Sons, Lith.

SUB-WAYS — DETAILS OF DESIGN.

Fig. 1. Defence of Sub-way

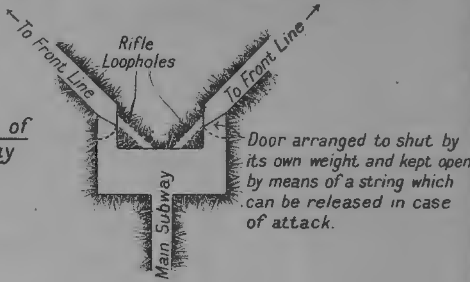


Fig. 2. Expanded Metal Guard for Light

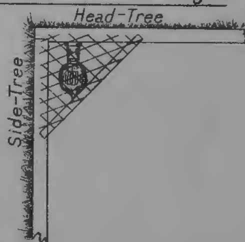
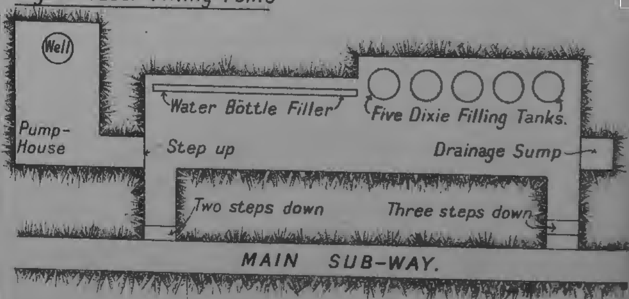


Fig. 3. Water Filling Point



Malby & Sons,

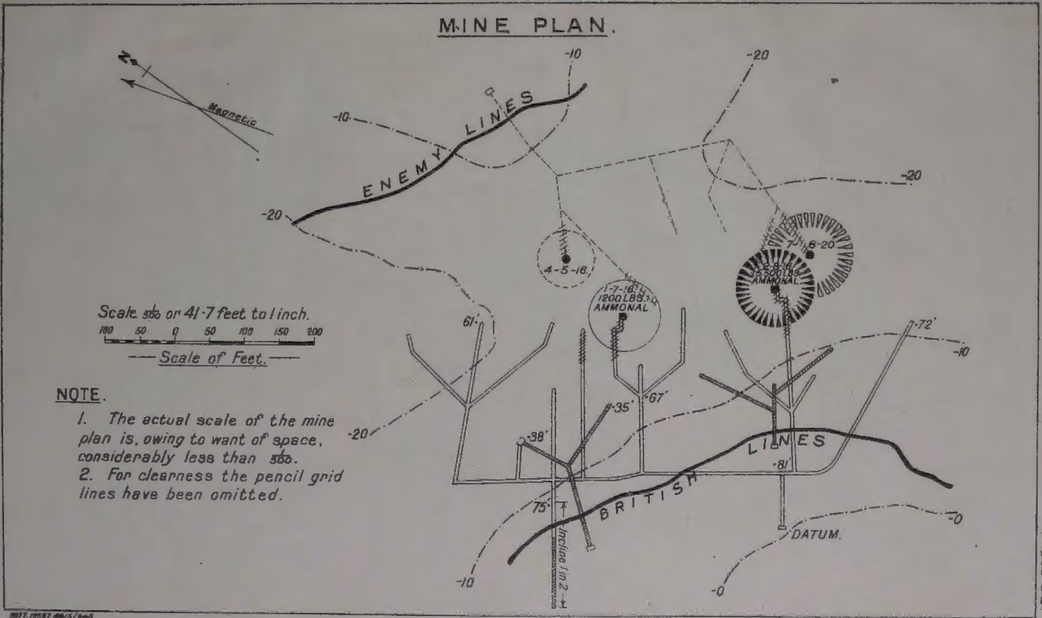


Plate 92.

3877.10527.4615/246.
Malby & Sons. Lith.

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

Examination Papers—*continued.*

Admission to Staff Colleges at Camberley and Quetta. Report and Examiner's Remarks. Feb.–Mar. 1921. 2*s.* (1*s.* 10*d.*); Feb.–Mar. 1922. 2*s.* 6*d.* (2*s.* 3*d.*)

FAMILY ALLOWANCE.

See PAY FOR SOLDIERS AND SEPARATION ALLOWANCE.

FIELD ALLOWANCE to the Commander of an Army and to the Commander of an Army Corps or Group of Divisions; **Promotion of Lieutenants** of the Army Veterinary Corps, Special Reserve, and Territorial Force; **Bounty to Soldiers.** Special Army Order, June 23, 1916. 1*d.* (2*d.*)

FIELD ALMANAC. 1918. 1*d.* (2*d.*)

FIELD SERVICE MANUALS:—

Ammunition Column. Divisional. New Armies. 1915. 3*d.* (3*d.*)
Artillery. Heavy (B.L. 60-pr.) Battery and Ammunition Column. Expeditionary Force. 1916. 3*d.* (3*d.*)
Ditto. Horse. Brigade. 13-pr. Q.F. 1908. 3*d.* (3*d.*)
Cavalry Regiment. Expeditionary Force. 1913. 3*d.* (3*d.*)
Engineers. 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.*)
Signal Service. Signal Company (Cable). Expeditionary Force. 1913. 3*d.* (3*d.*)
Ditto. Ditto. (Divisional). Expeditionary Force. 1915. 3*d.* (3*d.*)

FIELD SERVICE POCKET BOOK. 1914. (Reprinted, with Amendments, 1916). 1*s.* (11*d.*); Addendum No. 1. Shortened Form of Service for the Burial of the Dead. 1*d.* (2*d.*)

FIELD SERVICE REGULATIONS:—

Part II. Organisation and Administration. 1920. 1*s.* (10*d.*)
Ditto. Amendments, April 1915. 1*d.* (1*d.*)
Ditto. Addendum, Jan. 1917, for the Guidance of Troops operating in France and Belgium, Duties and Responsibilities of the Quartermaster-General, the Director-General of Transportation, and the General Officer Commanding Lines of Communication Area. 1*d.* (1*d.*)
Ditto. Additions and Corrections, March 1917. Duties and Responsibilities of the Engineer-in-Chief, and of Chief Engineers, &c. 1*d.* (2*d.*)

FIELD WORKS (All Arms). Manual. 1922. (Provisional). 2*s.* (2*s.*)

FINANCIAL INSTRUCTIONS IN RELATION TO ARMY ACCOUNTS. 1910. Reprinted, with Amendments to Oct. 1, 1917. *(Out of print)*

FIRE MANUAL. ARMY. 1918. 2*d.* (3*d.*)

FOOD. ANALYSES AND ENERGY VALUES OF. 6*s.* (4*s.* 10*d.*)

FOREIGN LANGUAGES. STUDY OF. Regulations. 1922. 3*d.* (4*d.*)

FOREIGN PRESS. Supplements to the Daily Review of the:—

Economic. Fortnightly, commencing with that of Aug. 20, 1918, to Aug. 12, 1919. Each 6*d.* (6*d.*)
Medical. (Compiled by the Medical Research Committee.) Monthly, commencing with that of June, 1918, to April, 1919. Each 1*s.* (10*d.*)
Political. Vol. 7. Weekly from Aug. 9, 1919:—
Section 1. Central Europe. 6*d.* (6*d.*) *(Out of print)*
Ditto 2. East and North-East Europe. 6*d.* (6*d.*) *(Out of print)*
Ditto 4. Western Europe. 6*d.* (6*d.*) *(Out of print)*
Ditto 5. America and the Pacific. 6*d.* (6*d.*) *(Out of print)*

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

Foreign Press—*continued.*

Reconstruction. Fortnightly, commencing with that of Aug. 13, 1918, to July 30, 1919. Each 6*d.* (6*d.*)

Technical. Fortnightly, commencing with that of May 28, 1918, to Aug. 19, 1919. Each 6*d.* (6*d.*)

Index to the Economic and Reconstruction Supplements, May to Nov. 1918. 1*s.* (11*d.*)

Index to the Medical Supplement. Vol. I. Jan. to Dec. 1918. 1*s.* (10*d.*)
Ditto. Vol. II. Jan. to April 1919. 1*s.* (10*d.*)

Index to the Technical Supplement, Vol. I, July to Dec. 1918. 6*d.* (6*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.*)

FRANCE. DISABLED AND DISCHARGED SOLDIERS IN. *See* DISABLED.

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.* (20*s.* 9*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.* (20*s.* 9*d.*)

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 4*s.* 8*d.*)

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

Section.

1. Events in July. Plan. 3*s.* (2*s.* 6*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.* 9*d.*)
10. Investment of Paris. Capture of Toul and Strassburg. 6*s.* (5*s.* 1*d.*)
11. Events before Paris, and at other points of Theatre of War in Western France until end of October. 5*s.* 3*d.* (4*s.* 5*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.* 10*d.*)
13. Occurrences on Theatre of War in Central France up to Re-occupation of Orleans by the Germans. 6*s.* (5*s.*)
14. Measures for Investment of Paris up to middle of December. 4*s.* (3*s.* 5*d.*)
15. Measures for protecting the Investment of Paris and Occurrences before French Capital to commencement of 1871. 2*s.* 6*d.* (2*s.* 1*d.*)

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

Franco-German War—*continued.*

Section

16. Proceedings of Second Army from commencement of 1871 until the Armistice. 3s. 6d. (3s.)

17. Proceedings of First Army from commencement of 1871 until the Armistice. 3s. (2s. 6d.)

18. Occurrences on South-eastern Theatre of War up to middle of Jan. 1871. Events before Paris from commencement of 1871 to the Armistice. 8s. (6s. 9d.)

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. 13s. 6d. (10s. 1d.)

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. 5s. (4s. 3d.)

Analytical Index. 1s. 6d. (1s. 4d.)

Plans—

4. Battle of Colombey-Nouilly. 3d. (5d.)

5A. Battle of Vionville—Mars la Tour. Position of Contending Forces at Noon. 3d. (5d.)

5B. Battle of Vionville—Mars la Tour. Position of Contending Forces from 4 to 5 p.m. 3d. (5d.)

9A. Battle of Sedan. Position of Contending Forces towards Noon. 3d. (4d.)

9B. Battle of Sedan. Position of the Germans in the afternoon shortly before the end of the struggle. 3d. (4d.)

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. 1d. (2d.)

FUNDS, ASSOCIATIONS, SOCIETIES, &c., for the Assistance of Serving and Ex-Service Officers, Men, Women and their Dependants. 1922. 6d. (6d.)

GERMAN ARMY. Cavalry. Drill Regulations. 1909. 3d. (4d.)
Ditto. Electric Light and Power Work. Notes on. 1920 1s. 6d. (1s. 2d.)
Ditto. Foot Artillery. Drill Regulations. Part IV. THE FIGHT. 1909. 3d. (5d.)
Ditto. Manœuvres Regulations. 1908. 3d. (5d.)

GERMAN CONSTITUTION, The. (Edition without Notes.) 1920. 6d. (6d.)

GERMANY. The Campaign of 1866 in:—

With 22 Plans in portfolio. 1872. (Reprinted 1907). 6s. (5s. 6d.)
Moltke's Projects for. 1s. (1s.)
Moltke's Correspondence during. Précis. With 4 Plans. 1s. (1s.)

GUERNSEY AND ALDERNEY ROYAL MILITIA. Regulations With the Militia Laws relating to the Islands. Provisional. 3s. (2s. 6d.)

GUNS. Handbooks for:—

·303-inch Hotchkiss Machine. Provisional. 6d. (7d.)
·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). 9d. (9d.); Addenda. 1d. (2d.); Amendments. ½d. (1d.)

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

Guns—*continued.*

2·75-inch B.L. Mule Equipment. 3*s.* 6*d.* (2*s.* 11*d.*)
Stokes 3-inch Trench Mortar M.L. Land Service. 1919. 1*s.* 6*d.* (1*s.* 4*d.*)
3·7-inch Q.F. Mountain Howitzer. Mark I. 1921. 3*s.* (2*s.* 6*d.*)
4·5-inch Q.F. Howitzer. Addenda and Corrigenda No. 3. 6*d.* (6*d.*)
6-inch B.L., Mark XIX, Gun on Travelling Carriage. Land Service. 1920. 4*s.* (3*s.* 4*d.*)
6-inch B.L. 26-cwt. Mark-I Howitzer on Mark I Travelling Carriage. Land Service. 1919. 3*s.* (2*s.* 7*d.*)
6-inch M.L. Trench Mortars, Marks I, II and III. Land Service. 1920. 1*s.* (11*d.*)
8-inch B.L. Howitzer, Marks VI–VIII. 7*s.* (5*s.* 7*d.*)
9·2-inch B.L. Howitzer. Marks I and II. 1920. 3*s.* (2*s.* 7*d.*) Amendments No. 2, Sept. 1922. 3*d.* (3½*d.*)
6-pr. Q.F. Guns on Casement Mountings. 1920. 2*s.* 6*d.* (2*s.* 1*d.*)
18-pr. Q.F. Gun, Marks I, I*, II and II*, on Carriages, Field, Mark I. Land Service. 1921. 2*s.* 6*d.* (2*s.* 2*d.*) Amendments No. 1. Sept. 1922. *Gratis.*
Do. on Carriages, Field, Marks I*, I** and II. Land Service.
18-pr. Q.F. Gun, Mark IV, on Carriages, Field, Marks III, IIIT, III*, and IV. Land Service. 1921. 5*s.* (4*s.* 1*d.*) Amendments (Nos. I and II). Each 1*d.* (2*d.*)
60-pr. B.L. Marks I to I** Guns, on Marks I and III Field Carriages. Land Service. 1921. 6*s.* 6*d.* (5*s.* 2*d.*) Amendments No. 1. July 1922. 1*d.* (1½*d.*)
60-pr. B.L. Marks II and II* Guns, on Mark IV Field Carriage. 10*s.* 6*d.* (8*s.* 2*d.*); Amendments No. 1. 2*d.* (2½*d.*) Amendments No. 2 2*d.* (2½*d.*)

GUNS. DRILL for:—

2·75-inch B.L. Gun, Converted Mark I, and Mark I. Carriage, Mark I. 1*s.* (10*d.*)
3·7-inch Q.F. Howitzer, Mark I. Carriage, Mark I. 1*s.* (10*d.*)
4·5-inch Q.F. Howitzer, Marks I and II. Carriage, Mark I. 6*d.* (6*d.*) Amendments, Feb. 1922. 1*d.* (2*d.*)
6-inch B.L. Gun, Mark XIX. Carriages, Marks VIII and VIIIA. 1*s.* (10*d.*)
6-inch B.L. 26-cwt. Howitzer, Mark I. Carriage, Mark I. 4*d.* (5*d.*)
9·2-inch B.L. Howitzer, Mark II. Carriage, Siege, Mark II. 9*d.* (8*d.*)
18-pr. Q.F. Gun, Marks I and II. Carriage, Mark I. 6*d.* (6*d.*)
18-pr. Q.F. Gun, Marks I to II. Carriages, Marks I** to II (with Supplement for Mark I Carriage). 6*d.* (6*d.*)
18-pr. Q.F., Mark IV. Carriages, Marks III and III**. 4*d.* (4*d.*)
60-pr. B.L., Marks I–I**. Carriages, Marks I and III. 6*d.* (6*d.*)
M.L. Stokes 3-inch Trench Mortar Equipments. Land Service. 1919 (1920.) 1*s.* 6*d.* (1*s.* 2*d.*)
6-inch B.L., Marks VII and VII* Guns on Carriages, Garrison C.P., Mark II. Land Service. 1922. 6*d.* (6*d.*)
8-inch B.L. Howitzer, Marks VII, VII*, VII**, and VIII. Carriages, Marks VII and VIIA. 9*d.* (8*d.*)

See also MACHINE GUNS; MUSKETRY REGULATIONS, Part I; and RIFLE, ROSS MAGAZINE.

HEALTH OF THE ARMY. REPORT FOR THE YEAR, 1914, ON THE. 10*s.* (7*s.* 4*d.*)

HISTORICAL RECORDS OF THE BRITISH ARMY:—

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

(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.* (2*d.*) In one volume. 5*s.* (4*s.* 9*d.*)

Ditto. The Scots Guards. 1*d.* (1*d.*)

Ditto. The 6th (Inniskilling) Dragoons. (*Out of print.*) 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 Scottish Borderers.
- The Lancashire Fusiliers.
- The Leicestershire Regiment.
- The Loyal North Lancashire Regiment.
- The Northamptonshire Regiment.
- The Oxfordshire and Buckinghamshire 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 Welch Fusiliers.
- The South Staffordshire Regiment.
- The Suffolk Regiment.
- The Welch Regiment.
- The Worcestershire Regiment.

HISTORY OF THE GREAT WAR. *See* WAR.

HORSE. FIELD, PACK, MEDIUM, AND HEAVY ARTILLERY. Instructions for Practice. (Including Movable Armament.) Feb.1921. 3*d.* (3*d.*)

HORSES. ARMY. Notes on the Feeding, Management, and Issue of. 1916. 1*d.* (2*d.*) *See also* ANIMAL MANAGEMENT.

HOSPITALS. MILITARY FAMILIES'. Nursing Staff Regulations. Dec., 1909. 1*d.* (1*d.*)
See also NURSING SERVICE *and* TERRITORIAL FORCE.

HOSTILITIES WITHOUT DECLARATION OF WAR FROM 1700 TO 1870. 2*s.* (1*s.* 7*d.*)

HYGIENE. Manual of Elementary Military. *Reprinted* (1921.) 1*s.* (1*s.* 1*d.*)

HYGIENE. Manual of Military. 1921. 1*s.* (1*s.* 1*d.*)
See also PHYSIOLOGY *and* SCHOOLS.

INDIAN EMPIRE. THE. (Amended 1921 Version.) A Short Review and some Hints for the use of Soldiers proceeding to India. 6*d.* (6*d.*)

INFANTRY TRAINING. (4-Company Organization.) 1914. (Reprinted, 1916. 6*d.* (7*d.*)
Ditto. Amendments, July, Aug. 1916 ; Dec. 1918. Each 1*d.* (2*d.*)

INFANTRY TRAINING. Vol. I. Training. 1922. Provisional. 1*s.* (11½*d.*)
Ditto. Vol. 2. War. Provisional. 1921. 1*s.* 6*d.* (1*s.* 3*d.*)

INJURIES AND DISEASES OF WAR. Manual based on experience of the present Campaign in France. Jan. 1918. 9*d.* (9*d.*)

INSTITUTES. Garrison and Regimental. Rules for the Management of. 1916. 1*d.* (2*d.*)

ITALIAN CAVALRY TRAINING REGULATIONS. 1911. Training for Marches, Tactics of Minor Units, and Training of Patrols. Translated. 4*d.* (4*d.*)

JAMAICA. Standing Orders. 1912. 1*s.* (11*d.*)

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

JERSEY. ROYAL MILITIA OF THE ISLAND OF. Regulations. 1914. With the Jersey Militia Law, 1905. 1*s*. 3*d*. (1*s*. 2*d*.)

KING'S REGULATIONS AND ORDERS FOR THE ARMY. 1912. (Reprinted, with Amendments published in Army Orders up to Aug. 1, 1914). (*Reprinted* 1918.) 1*s*. 6*d*. (1*s*. 8*d*.); Amendments published in Army Orders between Sept. 1, 1914 and Aug. 1, 1916. 1*d*. (2*d*.); Amendments published in Army Orders between Sept. 1, 1916 and March 1, 1918. 1*d*. (2*d*.); Amendments published in Army Orders between March 1, 1918 and April 30, 1920. 3*d*. (5*d*.); Amendments published in Army Orders, March 1920. 2*d*. (3*d*.); Amendments, May 1920. 1*d*. (2*d*.) Reprint of the Amendments published in Army Orders between May 1, 1920, and July 31, 1921. 6*d*. (6*d*.); Amendments, Jan. 1921. 1*d*. (2*d*.); Nov. 1921. 1*d*. (2*d*.); Mar. 1922. 1*d*. (2*d*.); Aug. 1922. 3*d*. (3½*d*.)

KIT PLATES:—

Artillery. Royal—

6. Garrison. Kit laid out for Inspection. 1909. 2*d*. (3*d*.)

10. Ditto. Kit in Barrack Room. 1909. 2*d*. (3*d*.)

Cavalry. 1891. 1*d*. (2*d*.)

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*. (2*d*.)
2. Dismounted. Full Kit laid out for Inspection in Barrack Room. 1914. 1*d*. (2*d*.)
4. Mounted N.C.O. or Driver and Field Troop Sapper. Full Kit laid out for Inspection in Barrack Room. 1910. 1*d*. (2*d*.)
5. Mounted. Detail of Shelf and Bedding. 1910. 1*d*. 2*d*.)
6. Driver, with pair of Horses. Field Kit laid out for Inspection on Parade, including Articles carried in Valise on Baggage Wagon. 1915. 1*d*. (2*d*.)

Infantry. Highland. 1884. 1*d*. (2*d*.)

Medical Corps. Royal Army. Kit in Barrack Room. 1913. 2*d*. (3*d*.)

Ordnance Corps. Army. For guidance at Marching Order and Kit Inspections. 2*d*. (3*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*. (6*d*.)

LAW. Military. Manual of. 1914. (*Reprinted* 1917.) 3*s*. 6*d*. (3*s*. 8*d*.) Ditto, Amendments, May 1919. 1*d*. (2*d*.)

MACHINE-GUN COMPANY TRAINING:—

Infantry. 1917. Provisional. To be read in conjunction with Infantry Training and Musketry Regulations. 6*d*. (6*d*.)

MACHINE GUNS AND SMALL ARMS, ·303-inch. Nomenclature of Parts, Stripping, Assembling, Action, Jams, Missfires, Failures, and Inspection of. Revised Edition. 1917. 6*d*. (7*d*.)

MACHINE GUN TRAINING, 1921. Provisional. 1*s*. 6*d*. (1*s*. 8*d*.)

MAGAZINE REGULATIONS. 1922. 1*s*. 6*d*. (1*s*. 7½*d*.)

MAGAZINES AND CARE OF WAR MATÉRIEL. Regulations for. 1913. (Reprinted, with Amendments published in Army Orders up to March 31, 1917). 1*s*. 6*d*. (1*s*. 8*d*.)

MALARIA. OBSERVATIONS ON, by Medical Officers of the Army and Others. (*With Plates and Diagrams.*) 1920. 6*s*. (6*s*. 1*d*.)

MAPPING FROM AIR PHOTOGRAPHS. 1*s*. (1*s*. 2*d*.)

MAP READING AND FIELD SKETCHING. Manual. 1921. 3*s*. (2*s* 8*d*.) *See also* PROTRACTOR.

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

MEDICAL CORPS. Royal Army. (*See also* TERRITORIAL FORCE):—
Admission to. Regulations for. Jan. 1921. 2*d.* (3*d.*)
Standing Orders. 1914. 1*s.* (1*s.*)
Ditto. Supplement 1920. 2*d.* (3*d.*); Amendment, July 1920. 1*d.* (1½*d.*)
Training. 1911. 9*d.* (11*d.*)
Ditto. Reprint of Chap. XXII, with Amendments Stretcher Exercises. July 1922. 2*d.* (2½*d.*)

MEDICAL DEPARTMENT. Army. Index to Appendices of Reports from 1859 to 1896. 3*d.* (5*d.*)

MEDICAL DISEASES in the Tropical and Sub-Tropical War Areas. *See* DISEASES.

MEDICAL HISTORY. *See* WAR

MEDICAL SERVICE. Army:—
Regulations. 1906. (Reprinted, with Amendments up to Sept. 30, 1914). 4*d.* (7*d.*)
Ditto. Amendments, July, 1920. 1*d.* (2*d.*)
Ditto. Amendments, Feb. 1922. 1*d.* (2*d.*)
Ditto. Amendment, Mar. 1922. 1*d.* (2*d.*)
Ditto. Amendment, Appendix No. 14, Sept. 1922. 1*d.* (1½*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.* 8*d.*)

MEDICAL SERVICES. Advisory Board for Army. The Treatment of Venereal Disease and Scabies First Report. 1904. 1*s.* 6*d.* (1*s.* 5*d.*); Second Report. 1905. 2*s.* (1*s.* 8*d.*); Third Report. 1905. 1*s.* (10*d.*); Final Report. 1906 (*out of print*).

MEDICAL SERVICES OF FOREIGN ARMIES. Handbook of Part I. FRANCE. 6*d.* (6*d.*); Part II. GERMANY. 6*d.* (7*d.*); Part III. AUSTRIA-HUNGARY. 6*d.* (7*d.*); Part IV. RUSSIA. 6*d.* (6*d.*); Part V. ITALY. 6*d.* (6*d.*); Part VI. THE NETHERLANDS AND BELGIUM. 1911. 6*d.* (6*d.*)

MEKOMETER Handbook. 1911. 6*d.* (7*d.*)

MESOPOTAMIA:—
Report for the Army Council on. By Sir John P. Hewett, G.C.S.I., K.C.B. (*With Map*). 1919. 1*s.* 6*d.* (1*s.* 5*d.*)
Some Impressions of, in 1919. By Sir John P. Hewett, G.C.S.I., K.C.B. 1920. 9*d.* (9*d.*)

MILITARY AND OTHER TERMS. *See* SCHOOLS.

MILITARY LANDS ACTS, 1892 to 1903. Byelaws. *See* ARTILLERY AND RIFLE RANGES ACT, &c.

MINE RESCUE WORK ON THE WESTERN FRONT. 5*s.* (4*s.*)

MOUNTED TROOPS (DIVISIONAL) TRAINING. June 1915. Provisional. 1*d.* (2*d.*)

MUSKETRY REGULATIONS:—
Part 1. 1909. (Reprinted, with Amendments, 1914). 1*s.* 6*d.* (1*s.* 5*d.*)
Ditto. Amendments, Nov. 1915. 1*d.* (2*d.*)
Ditto. Amendments, July 1916. Enfield 1914 Pattern Rifle. 1*d.* (2*d.*)
Ditto. Addendum No. 2, Dec. 1916. Hotchkiss Gun and Lewis Gun Courses. 1*d.* (2*d.*)
Ditto. Addendum No. 4, April 1917. Annual General Musketry Course and Musketry Course for Transport Workers' Battalions. 1*d.* (1*d.*)
Ditto. Addendum No. 5. Bayonet Training. (*In the press*)
Ditto. Addendum No. 6, Feb. 1920. Light Guns (Lewis and Hotchkiss Guns) and Table L (Provisional), 1920. 2*d.* (2*d.*)
Ditto. Addendum No. 7, March 1921. 2*d.* (2*d.*)
Ditto. Appendix A. 1*d.* (1*d.*)

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

Musketry Regulations—*continued.*

Part I. Appendix IV, April 1922. T.A. Rifle Course. 1*d.* (1½*d.*)
Ditto. Appendix A to Addendum No. 6. 1*d.* (2*d.*)
Ditto. Appendix B to Addendum No. 6. 1*d.* (1*d.*)
Ditto. Addendum No. 3, Feb. 1921. Instructional Course for Webley Pistol. 2*d.* (2*d.*); Amendments. 1*d.* (2*d.*)
Ditto. Addendum No. 7, April 1920. Musketry Courses (Provisional), 1920. Tables A, B, and C. Amendments to Part I, Chap. VI. 2*d.* (2*d.*)
Ditto and Vickers' Machine Gun Handbook. Amendments, June 1916 Range Tables for Vickers' Guns for Mark VII. Ammunition. 1*d.* (1*d.*)
Part II. Rifle Ranges and Musketry Appliances. 1910. (Reprinted, with Amendments to Oct. 31, 1914). 4*d.* (5*d.*)
Ditto. Amendments, Feb. 1921. 1*d.* (2*d.*)
See also MACHINE GUN COMPANY TRAINING.

NIGHT OPERATIONS. Elementary Training in. 1911. 1*d.* (2*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. Feb. 1921. 2*d.* (2*d.*)
See also HOSPITALS *and* TERRITORIAL FORCE.

OFFICERS DIED IN THE GREAT WAR, 1914-19:—
Part I. Old and New Armies. Part II. Territorial Forces. 7*s.* 6*d.* (6*s.* 1*d.*)

OFFICERS TRAINING CORPS:—
Regulations. 1921. 1*s.* (11*d.*); Amendment, June 1922. 2*d.* (2½*d.*)
Special A.O., March 16, 1908. 1*d.* (2*d.*)
Junior Division. Instructions for the Annual Camps. 1921. 6*d.* (6*d.*)
Report on the Examination for Certificate "A" held in March 1920, for Cadets of the Junior and Senior Division. 1*s.* (1*s.*)

ORANGE FREE STATE Topographical Survey, 1905–1911. Report on the 10*s.* (8*s.*)

ORDNANCE COLLEGE. *See also* ARTILLERY COLLEGE:—
Advanced Classes. Reports on:—
Up to the 33rd. Each 1*s.* (9*d.*)
34th. 6*d.* (6*d.*)
35th. 1*s.* (1*s.*)
36th and later. *See* ARTILLERY COLLEGE.
Artificers. Military. Handbook for. 10th Edition. 1915. 9*d.* (9*d.*)
Ordnance Courses. Reports on:—
Up to the 16th. Each 1*s.* (9*d.*)
17th. 9*d.* (8*d.*)
18th. 1*s.* 6*d.* (1*s.* 4*d.*)
19th. 1*s.* 6*d.* (1*s.* 4*d.*)
Regulations. 1907. 2*d.* (3*d.*)

ORDNANCE CORPS. Army. Standing Orders. 1922 (Provisional.) 6*d.* (6*d.*)

ORDNANCE MANUAL (WAR). 1914. 6*d.* (6*d.*)

ORDNANCE. SERVICE. Treatise on. Seventh edition. 1908. With volume of plates. 7*s.* 6*d.* (6*s.* 8*d.*) Amendments. June 1909. Dec. 1910. Dec. 1912. Each 1*d.* (2*d.*); Ditto. Dec. 1909, Dec. 1911. Each 2*d.* (4*d.*)

ORDNANCE SERVICES. ARMY. Regulations:—
Part I. 1912. (Reprinted, with Amendments up to July 1, 1915). 6*d.* (7*d.*)
Ditto. Amendments, Jan. 1918. Appendix XII. Extract from the Regulations for Magazines, &c. 1*d.* (2*d.*)
Ditto. Amendments, Jan. 1918. Appendix XX. 1*d.* (2*d.*)
Ditto. Sept. 1920. 1*d.* (2*d.*)

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

Ordnance Services, &c.—*continued.*

Part II. 1914. Instructions for Laboratories and Laboratory Operations, Examination of Explosives and Ordnance. (Reprinted, with Amendments published in Army Orders up to and including Dec. 1, 1916). 1*s.* 6*d.* (1*s.* 6*d.*)

Ditto. (Separately.) Amendments, Dec. 1916. (Including Appendices XI., XIV., and XV., as amended in the Regulations). 2*d.* (2*d.*)

Ditto. Amendments, Aug., Oct. 1917. Each 1*d.* (2*d.*)

Ditto. Pamphlet No. 7, Land Service Cordite Regulations. 6*d.* (6*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.* (4*s.* 4*d.*)

PAY. ALLOTMENTS OF. *See* SEPARATION ALLOWANCE.

PAY, Appointment, Promotion, and Non-Effective Pay of the Army. Royal Warrant, 1922. 2*s.* (1*s.* 9*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. June 1918. 2*d.* (3*d.*)
See also TERRITORIAL FORCE.

PAY OF OFFICERS and Allowance for Officers' Children. Royal Warrant, Jan. 25, 1918; with the Army Council's Instructions thereon, and Regulations. (Special Army Order, Jan. 26, 1918). 1*d.* (2*d.*)

PHYSICAL EXAMINATION OF RECRUITS. Instructions for the. 2*d.* (3*d.*)

PHYSICAL TRAINING. Manual of. (Reprint 1908 with Amendments published in Army Orders to Dec. 1, 1914). 9*d.* (1*s.*)

PHYSIOLOGY, Elementary, in its relation to Hygiene. Feb. 1919. 2*d.* (3*d.*)
See also HYGIENE *and* SCHOOLS.

PLACE NAMES OCCURRING ON FOREIGN MAPS. Rules for the Transliteration of. 1919. 1*s.* 6*d.* (1*s.* 2*d.*)

PORTABLE SUB-TARGET (Mark I.), and How to Use it. 1911. (Reprinted, with Amendments, 1914.) 1*d.* (2*d.*)

POSTAL SERVICES. Manual of Army. War. 1913. (Reprinted, with Amendments, 1915). 3*d.* (4*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.* 10*d.*)

PROMOTION OF LIEUTENANTS of the Army Veterinary Corps, Special Reserve, and Territorial Forces. *See* FIELD ALLOWANCE.

PROTRACTOR. SERVICE. For use in Map Reading Classes. 1*d.* (2*d.*)
See also MAP READING.

PUBLICATIONS (RECENT) OF MILITARY INTEREST. List of. Quarterly. Nos. 1 to 8 (except 1, 3, 5 and 6 *out of print*). 2*d.* (2*d.*) each. Nos. 9 to 17. 4*d.* (4*d.*) each. *Continued by* THE ARMY REVIEW.

RAILWAY DISTANCES. Ireland. Handbook of. Third edition. 1884. 7*s.* 6*d.* (6*s.*)

RAILWAY MANUAL (WAR). 1911. (Reprinted, with Amendments, 1914). 6*d.* (6*d.*)

RANGE FINDER. Handbooks:—

Infantry. No. 1. (Marindin). 1913. 3*d.* (5*d.*)

Ditto. No. 2. (Barr and Stroud). 31·5-inches base. 1916. 6*d.* (7*d.*)

RANGES, MINIATURE CARTRIDGE. (*Reprinted from* THE ARMY REVIEW, January 1914). 3*d.* (4*d.*)

RANGETAKERS. Instructions for the Training of, with the Artillery Range-finder. 1*d.* (2*d.*)

RANGING. Examples of. *See* ARTILLERY, TRAINING, FIELD.

RATIONS. ARMY. Their Bearing on the Efficiency of the Soldier. By D. Noël Paton, M.D., F.R.S., Professor of Physiology, University of Glasgow. 3*d.* (5*d.*)

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

RECRUITING FOR THE REGULAR ARMY AND THE SPECIAL RESERVE. Regulations. 1912. (Reprinted, with Amendments to Aug. 31, 1914). 6*d.* (6*d.*)

RECRUITS' TABLE CARD. Feb. 1922. 4*d.* (5*d.*)

REMOUNT REGULATIONS. 1913. 3*d.* (5*d.*)

RESEARCH DEPARTMENT, WOOLWICH:—

Reports—

35. Influence of Chromium on Steel. 7*s.* 6*d.* (5*s.* 11*d.*)
45. Effect of Overstrain on the Elastic Properties of Steel. 2*s.* (1*s.* 7*d.*)
46. Vent Sealing Tubes. Part I. Results of Investigation into the Causes of Failure by Splitting on Firing. (*Out of print.*)
48. Heat Treatment of Carbon Gun Steels. 6*s.* 6*d.* (5*s.* 1*d.*)
49. Heat Treatment of Nickel Gun Steel. (*In the press*)
51. Properties of some Chromium Steels. 3*s.* (2*s.* 5*d.*)
52. Coolidge Radiator Tube. Investigation into the Behaviour of the. 1*s.* 6*d.* (1*s.* 3*d.*)

RESERVE (*See also* SPECIAL RESERVE *and* TERRITORIAL FORCE):—

Army Reserve. Class 1. Regulations. Jan. 1922. 1*d.* (2*d.*)

Ditto. Amendments. June 1913. 1*d.* (2*d.*)

National Reserve. Regulations. 1913. Provisional. 1*d.* (2*d.*)

REVIEW OF NEW ORDERS, DECORATIONS AND GALLANTRY MEDALS, &c. (Revised, Nov. 1920.) 3*d.* (4*d.*)

RIFLE. ENFIELD 1914 PATTERN. *See* MUSKETRY REGULATIONS, Part 1.

RIFLE. ROSS MAGAZINE ·303-inch, Mark IIIB. Handbook of the 1915. (Reprinted, with Amendments, 1917). 1*d.* (2*d.*)

RIFLES, &c. Notes on the Cleaning of. 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. 8*d.* (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.* 8*d.*); Part II. From the Battle of the Ya-lu to Liao-yang, exclusive. 1908. 5*s.* (4*s.* 4*d.*); Part III. The Siege of Port Arthur. 1909. 4*s.* 6*d.* (3*s.* 10*d.*); Part IV. Liao-yang. 1910. 4*s.* (3*s.* 7*d.*) Part V. Sha Ho. 1911. 4*s.* 6*d.* (4*s.* 2*d.*)

Official History (Naval and Military). Vol. I. To August 24, 1904. With case of Maps. 1910. 15*s.* (12*s.* 6*d.*); Vol. II. Liao-yang, the Sha-ho, Port Arthur. With case of Maps. 1912. 15*s.* (12*s.* 9*d.*); Vol. III San-de-pu, Mukden, the Sea of Japan. With case of maps. 1921. 70*s.* (54*s.*)

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.* (18*s.*)

SALISBURY PLAIN. Standing Orders applicable to all Troops Encamped on Salisbury Plain, and applicable generally to Troops Quartered at Bulford. 1921. 3*s.* (2*s.* 5*d.*)

SANITATION IN ITS APPLICATION TO MILITARY LIFE. Manual of. 6*d.* (6*d.*)

SCABIES. *See* MEDICAL SERVICE.

SCHOOLS. Army:—

Annual Reports on. 1911–12; 1912–13. Each 1*s.* (1*s.*)

Military and other Terms, and Words which Occur in Orders. Lists of. 1914. (*Reprinted* 1918.) 8*d.* (5*d.*)

Physiology. Elementary. Handbook. 1901. 1*d.* (2*d.*)

See also HYGIENE; PHYSIOLOGY; *and (below)* SCHOOL HYGIENE.

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

Schools. Army—*continued.*
Regulations. 1911. 4*d.* (4*d.*)
School Hygiene. Handbook of. For Teachers. 1907. 6*d.* (7*d.*)
See also HYGIENE; PHYSIOLOGY; *and* (*above*) PHYSIOLOGY.
Singing in.—Regulations for Teaching. 1911. (*Reprinted* 1915). 1*d.* (2*d.*)
Standing Orders for Inspectors, Examiners, and Teachers. 1910. 6*d.* (6*d.*)

SCOUTS. Training and Use of. Lecture by Col. F. C. Carter. 1905. 2*d.* (3*d.*)

SCREWS. Provision of. Standard Leading. For Screw-cutting Lathes. Report of Committee. 1905. 1*s.* (1*s.*)

SEPARATION ALLOWANCE, ALLOTMENTS OF PAY, AND FAMILY ALLOWANCE. ARMY Regulations for the issue of. 1918. 6*d.* (6*d.*)
See also FAMILY ALLOWANCE *and* PAY FOR SOLDIERS.

SERVICE CORPS. ARMY:—
Regimental Standing Orders. 1911. (*Out of print*); Amendments. 1*d.* (2*d.*)
A.S.C. Memorandum No. 25. 1*d.* (2*d.*)
Soldiers' Pay Schedule. (Reprinted, with Amendments to April, 1919.) 1*s.* 6*d.* (1*s.* 5*d.*)
Training. Part I. 1909. (Reprinted, with Amendments, 1915). 9*d.* (10*d.*)
Ditto. Part II. Supplies. 1909. (Reprinted, 1914, with new Appendix XII.) 1*s.* 3*d.* (1*s.* 5*d.*)
Ditto. Part III. Animal Transport. 1922. 2*s.* 6*d.* (2*s.* 3*d.*)
Ditto. Part IV. Mechanical Transport. (*Out of print*)
Ditto. Part IVB. The Motor Cycle. 1922. 1*s.* 6*d.* (1*s.* 3½*d.*)

SEVASTOPOL. Siege of. 1854–55. 3 vols., with Case of Maps and Plans. Half Morocco, £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. The latest development of. Practical Treatment of. 1906. 6*d.* (5*d.*)

SHOEBURYNESS GARRISON. Standing Orders. 1913. 1*s.* 6*d.* (1*s.* 3*d.*)

SIEGE OPERATIONS in the Campaign against France, 1870–71. (*Von Tiedemann.*) Translated. 4*s.* 6*d.* (3*s.* 11*d.*)

SIGNAL SERVICE. THE ARMY. 1*d.* (2*d.*)

SIGNAL SERVICE. ARMY. Manual of—WAR. Provisional. 1914. 2*d.* (3*d.*)

SIGNAL TRAINING:—
Part I. 1919. Visual Telegraphy. 1*s.* (1*s.*)
Part II. Provisional. 2*s.* (1*s.* 8*d.*)
Part IV. Provisional. Line Telegraphy and Telephony. 2*s.* (1*s.* 9*d.*)
Part VI. 1918. Procedure. 1*s.* (11*d.*)
Part VII. Signal Organization. 6*d.* (7*d.*)
Vol. III. Pamphlet, No. 1. Telephone, Portable, D, Mark III. 1*d.* (1½*d.*)
Ditto. No. 2. Heliograph, 5-inch, Mark V. 2*d.* (2½*d.*)

SOLDIERS, DISABLED AND DISCHARGED, IN FRANCE. *See* DISABLED.

SOLDIERS WHO DIED IN THE GREAT WAR, 1914–19:—
Part 1. Household Cavalry and Cavalry of the Line (including Yeomanry and Imperial Camel Corps). 5*s.* (3*s.* 11*d.*)
Part 2. Royal Horse and Royal Field Artillery, Regulars and Territorial Force (including Honourable Artillery Company Batteries). 15*s.* (12*s.*)

Or separately—
Section 1. A to C. 2*s.* 6*d.* (2*s.*)
Section 2. D to H. 2*s.* 6*d.* (2*s.*)
Section 3. I to N. 2*s.* 6*d.* (2*s.*)
Section 4. O to S. 2*s.* 6*d.* (2*s.*)
Section 5. T to Y. 2*s.* 6*d.* (2*s.*)
Section 6. Royal Horse and Royal Field Artillery, Territorial Force, (including Honourable Artillery Company Batteries). 2*s.* 6*d.* (2*s.*)

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

Soldiers who died in the Great War, 1914-1919—*continued.*

Part 3. Royal Garrison Artillery. 7*s.* 6*d.* (6*s.*)
Part 4. Corps of Royal Engineers. 7*s.* 6*d.* (6*s.* 1*d.*)
Part 5. Foot Guards (including Guards' Machine Gun Regiment). 7*s.* 6*d.* (5*s.* 11*d.*)
Part 6. The Royal Scots (Lothian Regiment). 7*s.* 6*d.* (5*s.* 11*d.*)
Part 7. The Queen's (Royal West Surrey Regiment). 5*s.* (3*s.* 11*d.*)
Part 8. The Buffs (East Kent Regiment). 5*s.* (3*s.* 11*d.*)
Part 9. The King's Own (Royal Lancaster Regiment). 5*s.* (3*s.* 11*d.*)
Part 10. The Northumberland Fusiliers. 7*s.* 6*d.* (6*s.*)
Part 11. The Royal Warwickshire Regiment. 7*s.* 6*d.* (5*s.* 11*d.*)
Part 12. The Royal Fusiliers (City of London Regiment). 7*s.* 6*d.* (5*s.* 11*d.*
Part 13. The King's (Liverpool Regiment). 7*s.* 6*d.* (5*s.* 11*d.*)
Part 14. The Norfolk Regiment. 5*s.* (3*s.* 11*d.*)
Part 15. The Lincolnshire Regiment. 5*s.* (3*s.* 11*d.*)
Part 16. The Devonshire Regiment. 5*s.* (3*s.* 11*d.*)
Part 17. The Suffolk Regiment. 5*s.* (3*s.* 11*d.*)
Part 18. Prince Albert's (Somerset Light Infantry). 2*s.* 6*d.* (2*s.*)
Part 19. The Prince of Wales' Own (West Yorkshire Regiment). 7*s.* 6*d.* (5*s.* 10*d.*)
Part 20. The East Yorkshire Regiment. 5*s.* (3*s.* 11*d.*)
Part 21. The Bedfordshire Regiment. 5*s.* (3*s.* 11*d.*)
Part 22. The Leicestershire Regiment. 5*s.* (3*s.* 11*d.*)
Part 23. Royal Irish Regiment. 2*s.* 6*d.* (2*s.*)
Part 24. Alexandra, Princess of Wales's Own (Yorkshire Regiment). 5*s.* (3*s.* 11*d.*)
Part 25. The Lancashire Fusiliers. 7*s.* 6*d.* (5*s.* 11*d.*)
Part 26. The Royal Scots Fusiliers. 5*s.* (3*s.* 11*d.*)
Part 27. The Cheshire Regiment. 5*s.* (3*s.* 11*d.*)
Part 28. The Royal Welch Fusiliers. 5*s.* (3*s.* 11*d.*)
Part 29. The South Wales Borderers. 5*s.* (3*s.* 11*d.*)
Part 30. The King's Own Scottish Borderers. 5*s.* (3*s.* 11*d.*)
Part 31. The Cameronians (Scottish Rifles). 5*s.* (3*s.* 11*d.*)
Part 32. The Royal Inniskilling Fusiliers. 5*s.* (3*s.* 11*d.*)
Part 33. The Gloucestershire Regiment. 5*s.* (3*s.* 11*d.*)
Part 34. The Worcestershire Regiment. 5*s.* (3*s.* 11*d.*)
Part 35. The East Lancashire Regiment. 5*s.* (3*s.* 11*d.*)
Part 36. The East Surrey Regiment. 5*s.* (3*s.* 11*d.*)
Part 37. The Duke of Cornwall's Light Infantry. 2*s.* 6*d.* (2*s.*)
Part 38. The Duke of Wellington's (West Riding Regiment). 5*s.* (3*s.* 11*d.*)
Part 39. The Border Regiment. 5*s.* (3*s.* 11*d.*)
Part 40. The Royal Sussex Regiment. 5*s.* (3*s.* 11*d.*)
Part 41. The Hampshire Regiment. 5*s.* (3*s.* 11*d.*)
Part 42. The South Staffordshire Regiment. 5*s.* (3*s.* 11*d.*)
Part 43. The Dorsetshire Regiment. 2*s.* 6*d.* (2*s.*)
Part 44. The Prince of Wales's Volunteers (South Lancashire Regiment). 5*s.* (3*s.* 11*d.*)
Part 45. The Welch Regiment. 5*s.* (3*s.* 11*d.*)
Part 46. The Black Watch (Royal Highlanders). 5*s.* (3*s.* 11*d.*)
Part 47. The Oxfordshire and Buckinghamshire Light Infantry. 5*s.* (3*s.* 11*d.*)
Part 48. The Essex Regiment. 5*s.* (3*s.* 11*d.*)
Part 49. The Sherwood Foresters (Nottinghamshire and Derbyshire Regiment). 7*s.* 6*d.* (5*s.* 11*d.*)
Part 50. The Loyal North Lancashire Regiment. 5*s.* (3*s.* 11*d.*)
Part 51. The Northamptonshire Regiment. 5*s.* (3*s.* 11*d.*)
Part 52. The Princess Charlotte of Wales' (Royal Berkshire Regiment). 5*s.* (3*s.* 11*d.*)
Part 53. The Queen's Own (Royal West Kent Regiment). 5*s.* (3*s.* 11*d.*)
Part 55. The King's (Shropshire Light Infantry). 2*s.* 6*d.* (2*s.*)
Part 56. The Duke of Cambridge's Own (Middlesex Regiment). 7*s.* 6*d.* (5*s.* 11*d.*)
Part 57. The King's Royal Rifle Corps. 7*s.* 6*d.* (5*s.* 11*d.*)
Part 58. The Duke of Edinburgh's (Wiltshire Regiment). 2*s.* 6*d.* (2*s.*)

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

Soldiers who died in the Great War, 1914–1919—*continued*

Part 59. The Manchester Regiment. 7*s.* 6*d.* (6*s.*)
Part 60. The Prince of Wales's (North Staffordshire Regiment). 5*s.* (3*s.* 11*d.*)
Part 61. The York and Lancaster Regiment. 5*s.* (3*s.* 11*d.*)
Part 62. The Durham Light Infantry. 7*s.* 6*d.* (6*s.*)
Part 63. The Highland Light Infantry. 5*s.* (4*s.*)
Part 64. Seaforth Highlanders (Ross-shire Buffs, the Duke of Albany's). 5*s.* (3*s.* 11*d.*)
Part 65. The Gordon Highlanders. 5*s.* (3*s.* 11*d.*)
Part 66. The Queen's Own (Cameron Highlanders). 5*s.* (3*s.* 11*d.*)
Part 67. The Royal Irish Rifles. 5*s.* (3*s.* 11*d.*)
Part 68. Princess Victoria's (Royal Irish Fusiliers). 2*s.* 6*d.* (2*s.*)
Part 69. The Connaught Rangers. 2*s.* 6*d.* (2*s.*)
Part 70. Princess Louise's (Argyll and Sutherland Highlanders) 5*s.* (3*s.* 11*d.*)
Part 71. The Prince of Wales's Leinster Regiment (Royal Canadians). 2*s.* 6*d.* (2*s.*)
Part 72. The Royal Munster Fusiliers. 2*s.* 6*d.* (2*s.*)
Part 73. The Royal Dublin Fusiliers. 2*s.* 6*d.* (2*s.*)
Part 74. The Rifle Brigade (the Prince Consort's Own). 7*s.* 6*d.* (5*s.* 11*d.*)
Part 75. Machine Gun, Tank Corps. 7*s.* 6*d.* (5*s.* 11*d.*)
Part 76. The Honourable Artillery Company (Infantry) The London Regiment, Inns of Court Officers Training Corps. *In one Volume.* 15*s.* (12*s.*)

Or in separate parts:—

Section 1. 1st (City of London) Battn. (Royal Fusiliers). 1*s.* (11*d.*)
Section 2. 2nd (City of London) Battn. (Royal Fusiliers); 3rd (City of London) Battn. (Royal Fusiliers). 1*s.* (11*d.*)
Section 3. 4th (City of London) Battn. (Royal Fusiliers); 29th (City of London) Battn. (Royal Fusiliers); 30th (City of London) Battn. (Royal Fusiliers); Honourable Artillery Company (Infantry); Inns of Court Officers Training Corps. 1*s.* (11*d.*)
Section 4. 6th (City of London) Battn. (Rifles). 1*s.* (11*d.*)
Section 5. 9th (County of London) Battn. (Queen Victoria's Rifles). 1*s.* (11*d.*)
Section 6. 11th (County of London) Battn. (Finsbury Rifles); 12th (County of London) Battn. (The Rangers). 1*s.* (11*d.*)
Section 7. 13th (County of London) Battn. (Princess Louise's Kensington Battn.); 15th (County of London) Battn. (Prince of Wales's Own Civil Service Rifles). 1*s.* (11*d.*)
Section 8. 16th (County of London) Battn. (Queen's Westminster Rifles) 31st, 32nd, and 34th Battalions. 1*s.* (11*d.*)
Section 9. 5th (City of London) Battn. (London Rifle Brigade). 1*s.* (11*d.*)
Section 10. 8th (City of London) Battn. (Post Office Rifles); 10th (County of London) Battn. (Hackney). 1*s.* (11*d.*)
Section 11. 17th (County of London) Battn. (Poplar and Stepney Rifles); 25th (County of London) Battn. (Cyclists); 28th (County of London) Battn. (Artists' Rifles); 33rd Battn. 1*s.* (11*d.*)
Section 12. 7th (City of London) Battn.; 19th (County of London) Battn. (St Pancras). 1*s.* (11*d.*)
Section 13. 20th (County of London) Battn. (Blackheath and Woolwich). 1*s.* (11*d.*)
Section 14. 21st (County of London) Battn. (1st Surrey Rifles); 23rd (County of London) Battn. 1*s.* (11*d.*)
Section 15. 22nd (County of London) Battn. (The Queen's); 24th (County of London) Battn. (The Queen's). 1*s.* (11*d.*)
Section 16. 14th (County of London) Battn. (The London Scottish); 18th (County of London) Battn. (London Irish Rifles) 1*s.* (11*d.*)

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

TRANSPORT. MECHANICAL:—
Heavy Pontoon Bridge for use by. 1914. Provisional 2*d.* (3*d.*)
Regulations for the Appointment of Inspectors of. 1*d.* (2*d.*)

TRANSPORT. PACK. Notes on. (Reprinted with Amendments, 1916). 1*d.* (2*d.*)

TROOPS. *See* MOUNTED *and* NUMBER.

TRUMPET AND BUGLE SOUNDS for the Army. With Instructions for the Training of Trumpeters and Buglers. 1914. 9*d.* (10*d.*)
Ditto, Amendments, July 1917. 1*d.* (2*d.*)

TYPE EXERCISES. *See* SCHOOLS.

TYPHOID (ANTI-) COMMITTEE. Report. 1912. 2*s.* 6*d.* (2*s.* 2*d.*)

TYPHOID (ANTI-) INOCULATION COMMITTEE. Report on Blood Changes following Typhoid Inoculation. 1905. 1*s.* 6*d.* (1*s.* 4*d.*)

URDU-ENGLISH PRIMER. For the use of Colonial Artillery 1899. 15*s.* (11*s.* 5*d.*)

VALISE EQUIPMENT. Instructions for Fitting:—
Bandolier pattern. 1903. 2*d.* (2*d.*)
See also EQUIPMENT

VALPARAISO. The Capture of, in 1891. 1*s.* (11*d.*)

VENEREAL DISEASE. *See* MEDICAL SERVICES.

VETERINARY CORPS. Royal Army. Standing Orders. 1920. 6*d.* (6*d.*)

VETERINARY MANUAL (WAR). 1915. 1*d.* (1*d.*)

VETERINARY SERVICES. Army. Regulations. 1906. (Reprinted, with Amendments to Dec. 31, 1917). 3*d.* (3*d.*)

VOLUNTARY AID. *See* TERRITORIAL FORCE.

VOLUNTEER ACTS, 1863, 1869, 1895, 1897, and 1900, except where repealed. Reprint of: Extracts from Regulation of the Forces Acts 1871 and 1881, and Reserve Forces Acts 1890; and Order in Council of February 5, 1872. 1*d.* (2*d.*)

VOLUNTEER LIST. Oct. 1919. 1*s.* 6*d.* (1*s.* 4*d.*)

WAR GRAVES COMMISSION. IMPERIAL:—
War Graves. How the Cemeteries abroad will be Designed. Report Nov. 14, 1918, by Lieut.-Colonel Sir Frederic Kenyon, K.C.B., Director of the British Museum. 3*d.* (4*d.*)
The Graves of the Fallen. Descriptive Account, by Mr. Rudyard Kipling, of the Work of the Commission; Illustrations, by Mr. Douglas Macpherson, showing the Cemeteries and Memorials as they will appear when completed. 6*d.* (6*d.*)

WAR OF 1914–20:—
Despatches (Naval and Military) relating to Operations in the War:—
I. Sept., Oct., and Nov. 1914. With List of Honours and Rewards Conferred. (*Reprinted* 1921.) 1*s.* 6*d.* (1*s.* 4*d.*)
II. Nov. 1914 to June 1915. With Names of Officers Mentioned, and Awards of the Victoria Cross. 5*d.* (6*d.*)
III. July to Oct. 1915. With names of Officers and Men mentioned, and Awards of the Victoria Cross. 3*d.* (5*d.*)
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.* (4*d.*)
V. Jan. to April 1916. With Names of Officers and Men mentioned and Awards of the Victoria Cross. 6*d.* (8*d.*)
VI. May to Dec. 1916. With Names of Officers and Men Awarded the Victoria Cross. 1*s.* (1*s.* 1*d.*)
VII. Dec. 1916 to July 1917. With Names of Officers and Men Awarded the Victoria Cross. 9*d.* (10*d.*)
VIII. July 1917 to June 1918. With Names of Officers and Men Awarded the Victoria Cross. 1*s.* (1*s.* 5*d.*)

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

War of 1914–1920—*continued.*

IX. July to Dec. 1918. With Names of Officers and Men Awarded the Victoria Cross. 1*s.* (11*d.*)

X. Jan. 1919 to Jan. 1920. With Names of Officers and Men Awarded the Victoria Cross. 2*s.* (1*s.* 11*d.*)

History of the War:—

Medical Services:—

General History. Vol. I. 21*s.* (16*s.* 9*d.*)

Diseases of the War Vol. I 21*s.* (16*s.* 9*d.*)

Surgery of the War. Vol. I. 25*s.* (19*s.* 9*d.*)

Military Effort of the British Empire during the Great War Statistics of the. 10*s.* 6*d.* (9*s.* 2*d.*)

Parliament's Vote of Thanks to the Forces. Speeches delivered in the Houses of Parliament, Westminster, on Oct. 29, 1917. 1*d.* (1*d.*)

WAR OFFICE LIST, AND ADMINISTRATIVE DIRECTORY FOR THE BRITISH ARMY. 1922. *Sold by Harrison & Sons, Ltd.,* 44–47, *St. Martin's Lane, W.C.* 2. 30*s. net.*

WATER SUPPLY MANUAL. 1*s.* 6*d.* (1*s.* 5*d.*)

WOMEN'S WAR WORK in Maintaining the Industries and Export Trade of the United Kingdom. Information officially compiled for the use of Recruiting Officers, Military Representatives, and Tribunals. Sept. 1916. Illustrated. 1*s.* (1*s.*)

WORKS MANUAL. (WAR.) 1913. Provisional. 4*d.* (4*d.*); Appendix I. 1914. 1*d.* (1*d.*)

WOUNDS OF WAR. General Principles guiding the Treatment of. Conclusions adopted by the Inter-Allied Surgical Conference held in Paris, March and May 1917. 2*d.* (3*d.*)

YEOMANRY AND MOUNTED RIFLE TRAINING. Parts I. and II. 1912. (Reprinted, with Amendments, 1915.) 6*d.* (7*d.*)

ZULU WAR OF 1879. Narrative of the Field Operations connected with the. 1881 (*Reprinted* 1907.) 3*s.* (2*s.* 10*d.*)

Printed under the authority of HIS MAJESTY'S STATIONERY OFFICE
By Harrison & Sons, Ltd., St. Martin's Lane, London, W.C. 2.

(B 15350)T Wt. 19527—4815 6M 5/28 H & S Ltd.