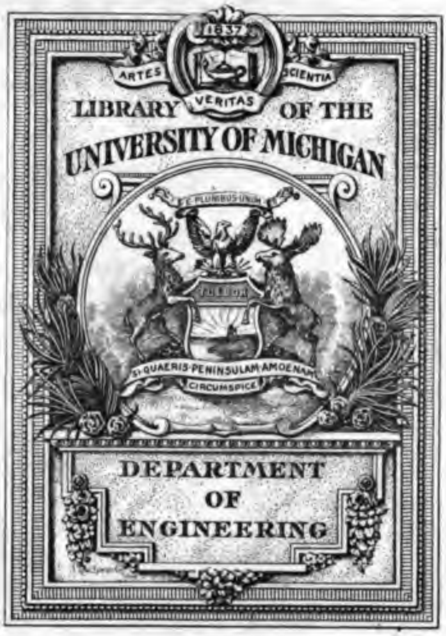
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OF

ENGINEERS AND SHIPBUILDERS.

EDITED BY THE SECRETARY OF THE INSTITUTION.

VOLUME XIII.

THIRTEENTH SESSION, 1896–97.

LONDON AND NEWCASTLE-UPON-TYNE:
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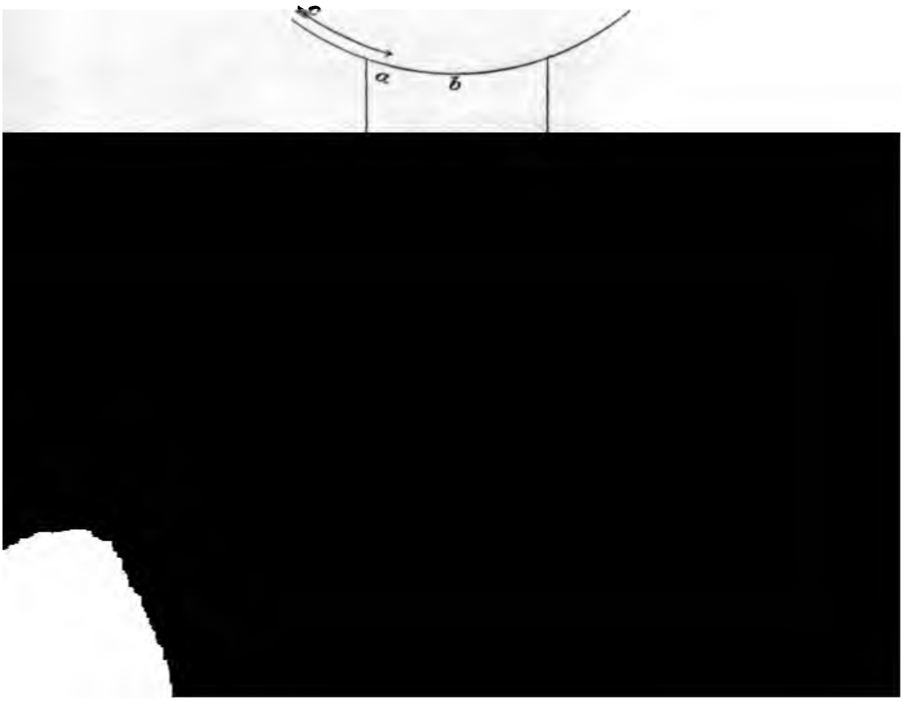
ERRATA.

In headlines on pages 69 to 72 inclusive, *for* "High-pressure Steam Boilers," *read* "Water-gauges for High-pressure Steam Boilers."

Illustration referred to in the last paragraph of page 259.



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NOTE.

Mr. A. E. Sharp's reply to the discussion on his paper on "The Resistance Areas of Transverse Sections" having been received after this volume was compiled, it is not included in the Index, but will be found on pages 273 to 275 at the end of the volume.

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BOOKS AND TRANSACTIONS OF LEARNED SOCIETIES ADDED TO THE LIBRARY.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Vol. XVII., 1896.—The Modern Drop Press. Water Power. Recording Device for Testing Machines. Tests of a Ten Horse-power De Laval Steam Turbine. Experiments on the Friction of Screws. The Proportions of High Speed Engines. Means Adopted for Saving Fuel in a Large Oil Refinery. Some Experiments with the Throttling Calorimeter. The Reliability of Throttling Calorimeters. Effect of Temperature on Strength of Wrought Iron and Steel. Experimental Method of Determining the Effective Centre of the Light Emitted from a Standard Photometric Burner. Some Data relating to Forge Shop Designs. Comparative Test of Steam Boilers with Different Kinds of Coal. Spring Tables. Hollow Steel Forgings. A Study of the Proper Method of Determining the Strength of Pump Cylinders. The Western River Steamboat. The Effect upon the Diagrams of Long Pipe Connections for Steam Engine Indicators. Structural Steel Fly Wheels. A Classification and Catalogue System for an Engineering Library. The Effects of Retarders in Fire Tubes of Steam Boilers. A Hydraulic Dynamometer. Superheated Steam. Experiments with Automatic Mechanical Stokers. Determining Moisture in Coal. New Form of Steam Calorimeter. A Self-cooling Condenser. The Efficiency of a Steam Boiler. What is it? Strength of Cast Iron.

JOURNAL OF AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. VIII., No. 4.—On Crank Shafts. Tests on Riveted Joints. Contract Trial of U.S. "Brooklyn." Marine Boilers, Particularly in Reference to Efficiency of Construction and Higher Steam Pressures (J. R. Fothergill). The Use of Retarders in Fire Tubes of Steam Boilers. Triple Screw Vessels. Vol. IX., No. 1.—A method of determining a Continuous Record of the Performance of a Marine Engine. U.S.S. "Terror." Speed Problem. Crank Shafts. Hollow Steel Forgings. Steel Forgings. Machinery Bearings. The Bearings of the Marine Engine. No. 2.—Electric Plant, Hospital of Insane, Washington. Experiments with an Air Lubricator Journal. Centrifugal Fans. Crank Shafts. Application of the Compound Steam Turbine to Marine Propulsion.

BUREAU OF STEAM ENGINEERING, ANNUAL REPORT, 1896.

BUREAU VERITAS REGISTER OF SHIPPING, 1897.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Vol. X., Part 1.—Penn Yan Waterworks. Effects of Engineering Works on Water Currents. Dry Dock at Kingston. Sewerage of Victoria, B.C. Pneumatic Power applied to Workshops. The Discharge of the St. Lawrence River.

CLEVELAND INSTITUTION OF ENGINEERS, 1895-6, No. 5.—Electric Tramways. No. 6.—The Economical Utilisation of Waste Gases from Blast Furnaces. No. 7.—Excursion to Stockton and Middlesborough Water Works at Hury and Blocklin in Balderadale.

ENGINEERING ASSOCIATION OF NEW SOUTH WALES, Vol. IX., 1893-4.—Some Improvements in Treating Minerals for the Wet Extraction of Gold and Silver. Notes on Hydraulic Power Supply. Bricks and Brickmaking in and around Sydney. Double Ended Screw Ferry Steamers.

ENGINEERS AND SHIPBUILDERS IN SCOTLAND, Vol. XXXIX., 1895-96.—The Extension of Loch Katrine Water Works. A New Departure in Steam Engine Economy. Propeller Diagrams. Period of Rolling of Vessels as an Index of Stability. Comparison of Systems of Mechanical Draught. Cast Iron Segments for Railway and other Tunnels. Tunnelling in Soft Material. Rates of Speed and Rates of Freight. Recovery of Tar and Ammonia from Blast Furnace Gases. The Manufacture of Welded Iron and Steel Pipes. Nickel Steel.

GENIO CIVILE, 1896, Anno XXXIV., Fas. 6, 7, 8, 9, and 10.—Papers on Civil Engineering and Public Works. Fas. 11 and 12; Anno XXXV., Fas. 1 and 2.—Interesting Papers on Civil Engineering.

GERMAN LLOYD'S REGISTER OF SHIPPING, 1897.

CIVIL ENGINEERS, Vol. CXXV., 1895-96, Part 3.—Littoral Drift. The Lixiviation of Silver Ores. The Thermal Efficiency of Steam Engines. The Tampico Harbour Works, Mexico. Vol. CXXVI., 1895-96, Part 4.—The Thirlmere Works for the Water Supply of Manchester. The Vyoning Works for the Water Supply of Liverpool. American and English Methods of Manufacturing Steel Plates. The Magnetic Testing of Iron and Steel. Magnetic Data of Iron and Steel. Physical Experiments in relation to Engineering. Vol. CXXVII., Part 1, 1896-7.—The Tower Bridge. The Bacterial Purification of Water. Tipping and Screening Coal. Surface Plant at Kirkby Colliery. Part 2.—Steel Skeleton Construction in Chicago. Superheated Steam Engine Trials. The Diversion of the Penyar Tunnel. Swing Bridge at Selby. The Wagga-Wagga Timber Bridge, N.S.W. Railway Steam Ferries in Denmark. The Mush-Kaf-Bolan Railway. Vol. CXXVIII., 1896–97, Part 2.—Steel Skeleton Construction in Chicago. Superheated Steam Engine Trials. The Diversion of Penyar. The Penyar Tunnel. Swing Bridge at Selby. The Wagga-Wagga Timber Yard. Railway Steam Ferries in Denmark. The Mush-Kaf-Bolan Railway, Baluchistan. The Construction of a Lock and Weir in the River Darenth. Dimensions of Channels for Surface Drainage. Garbage Disposal at St. Louis, Mi., U.S.A. Experiments on a Two Stage Air Compressor. Equiangular Prisms. A New Form of Extensometer. Transverse Strength of Large Beams of Yellow Pine Timber. Mineral Resources of the Argentine Republic.

Preliminary Tests of the Strength of Copper. No. 1, 1896.—Telemeters and Range Finders for Naval and other Purposes. Calculation of Horse-Power for Marine Propulsion. No. 2, 1896.—Notes on Steam Superheating. Steel Steam Pipes and Fittings.

NAVAL ARCHITECTS, 1896, Vol. XXXVII.—The amplitude of Rolling on a Non-synchronous Wave. On Wood and Copper Sheathing for Steel Ships. The M.G. Meter. On the utility of Calculating the whole External Volume of Ships, and Constructing the Complete Scale of Solidity, from the points of view of "Stability," "Tonnage," and "Loadline." On Steam Vessels of Light Scantlings, for special purposes of trade. On Coupling Boilers of different systems. The Cost of Warships. On Water-tube Boilers. The Neclaussi Water-tube Boiler.

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INGENIEURS CIVILS DE FRANCE, Anno XLIX., No. 7.—Sur le pottement des fluides centres les surfaces solides. Note sur l'Acetylene. Mesure de la resistance a l'asure de quelque alleayes de cuiver. La navigation sous-marine. No. 8.—La Traction Electrique des chemins defer. No. 9.—Les Tramways d'traction mecanique et notamment avec moteurs a gaz. Theorie du flambaye des pieces elastiques comprimers Transmission de la puissance. Motrice a L'aide de Electricite. No. 10.—Fabrication industrielle du Carbure de Calcium et de

L'acetylene. Compte rendu du Congres des Sables d'Olonne. Le Pont Alexandre III. No. 11.—La Pullman City et la question ouvriere aux Etals-Uries. L'Exposition Nationale Russe de Nijny-Novgorod et industrie Russe. Les forages artesians du Sahara. Annuaire, 1897.—Congres de 1896. Memoires. Nos. 1, 2, 3, and 4 of Bulletin.

Société Industrielle and Scientifique de Marseille, 1895, No. 23.—La turbine à vapeur de Laval. Effets dynamiques dans les explosions de chaudières. Comparaison entre le tramway électrique à fil aérien et le tramway à vapeur, système Serpollet. Les moteurs à pétrole au concours régional d'Arles. L'acétylène appliqué à l'éclairage. Notice sur un projet d'ascenseur pour le Mont-Blanc. L'àviation comparée avec l'aéronef L. Roze. Assainissement urbain.—Système de la surverse, utilisation des anciens égouts à profils défectueux pour l'évacuation des eaux d'orage. Sur un nouveau réactif de l'huile de Colza. 1896, No. 24.—Incendie du navire à vapeur "Comorin." Des rayons de Rœntgen et de leurs applications spécialement médico-chirurgicales. Installation de perforation électrique à la galerie de la mer de la Société de Charbonnages des Bouches-du-Rhône. Traction électrique des tramways par accumulateurs avec récupération. Désargentation électrolytique des plombs argentifères. Tricycle à moteur à essence de pétrole de Dion et Bouton. L'acétylène et ses applications à l'éclairage. Le carbure de calcium. Historique. Fours électriques. Fabrication Industrielle.

Society of Engineers, 1896.—The Mechanics of Horse Haulage. Water Supply of Small Towns. Hydraulic Rotative Engines. Examples of Railway Bridges for Branch Lines. Discharging and Storing Grain. The effect of Admixtures of Kentish Ragstone, etc., upon Portland Cement. The Ultimate Purification of Sewage.

South Wales Institute of Engineers, Vol. XX., 1896, No. 1.—Shaw's Gas Tester. Driving a Long Cross Measure Drift from both Ends. No. 2.—Notes on Machinery Exhibits at the Cardiff Exhibition, 1896. Laying out Pit Bottoms. The Transvaal Coal-field. No. 3.—The Transvaal Coal-field. Laying out Pit Bottoms. No. 4.—Strength of Corrugated Sheets.

United States Naval Institute, Vol. XXII., No. 3.—Composition of the Fleet. The Sea and Sea Power as a Factor in the History of U.S.A. Howe and D'Etaing Telescopic Sights for Guns. Housing Pigeons for Sea Service. Vol. XXIII., No. 1.—Torpedo Boat Policy. International Arbitration. Naval Law and Naval [redacted]

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Engineering, 35 and 36, Bedford Street, Strand, London, W.C.
Engineers' Gazette, Prudential Buildings, Mosley Street, Newcastle-upon-Tyne.
Fairplay, 34, Leadenhall Street, London, E.C.
Indian and Eastern Engineer, 50, Fenchurch Street, London, E.C.
Indian Engineering, Pat. Doyle, Esq., C.E., Star Press, 19, Lall Bazar, Calcutta, British India.
Industries and Iron, 39 and 40, Shoe Lane, London, E.C.
Journal de la Marine le Yacht, 55, Rue de Châteaudun, Paris.
Marine Engineer, 3, Amen Corner, Paternoster Row, London, E.C.
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Shipping World, Effingham House, Arundel Street, London, E.C.
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B.

Bagnall, T. W., The Groves, Winlaton ... ...(F M) Nov. 1893
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Bailey, James, 3, South Avenue, Ryton-on-Tyne ... ... (E) Nov. 1884
Baines, Geo. Henry, Messrs. Central Marine Engineering Co., West Hartlepool ... ... (E) Oct. 1888
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Blumer, Wm., 2, Ashmore Terrace, Stockton Road, Sunderland ... (S) Dec. 1886
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Brankston, R. T., 36, Hawthorn Street, Newcastle-upon-Tyne ... (E) Nov. 1884
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Buchanan, John H., Oswald Chambers, 5, Oswald Street, Glasgow (SUR) Oct. 1888
Buckland, H. B., Baltic Chambers, Quayside, Newcastle-upon-Tyne (E) Nov. 1885
Buckwell, George William, Board of Trade Surveyor's Offices, Custom House Arcade, Liverpool ... ... (SUR) Oct. 1896
Bull, John Catharinus, 29, Bexley Heath, Erith, Kent ... ... (E) Oct. 1892
Bulmer, Frederick Charles, 2, Graingerville North, Newcastle-upon-Tyne ... ... (E) { Graduate, May 1894; Member, Oct. 1895 }
Bulmer, John, 1, Graingerville North, Newcastle-upon-Tyne ... (E) Mar. 1886
Bulmer, John George, 34, Brighton Grove, Newcastle-upon-Tyne (E) May 1894
Burnett, Norman, Watergate Buildings, Newcastle-upon-Tyne ... (E) Oct. 1891
Bush, Montague, c/o Messrs. Ernest Scott, Mountain, & Co., Close Works, Newcastle-upon-Tyne ... ... (EE) Nov. 1896
Bushell, Chas. A., 1, Benton Terrace, Newcastle-upon-Tyne (N A & SUR) Nov. 1893
Butterfield, George, 4, Kayll Road, Sunderland ... ... (S) Nov. 1884

C.

Cama, Nusserwanji Bomanji, Sleater Road, Tardeo, Bombay, British India ... ... (E) Dec. 1888
Cameron, Angus, c/o James Laing, Esq., Deptford Yard, Sunderland (S) Nov. 1892
Campbell, J. Jennings, Bureau Veritas Register of Shipping, 155, Fenchurch Street, London, E.C. ... ... (E) Oct. 1888
Campbell, John M., 4, Winchester Terrace, Newcastle-upon-Tyne (N A) April 1895
Campbell, Thomas, c/o Messrs. Hills Dry Dock Co., Cardiff ... (S) Mar. 1894
Camps, H. E. J., 3, Cambridge Street, Newcastle-upon-Tyne ... (N A) Oct. 1894
Cannell, Frank, Messrs. H. Parry & Son, Lisbon ... ... (E & S) Nov. 1887
Carney, J. H., Stow Park Road, Newport, Monmouth ... ... (E) Mar. 1897
Carruthers, Frank, 9, Battlefield Gardens, Langside, Glasgow ... (E) Nov. 1893
Carstons, Samuel, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark... ... ... (S) Dec. 1887
Casey, James, 10, Philpot Lane, London, E.C. ... ... (E) Nov. 1891
Cay, Arthur, Messrs. Cay, Hall, & Co., Quayside, Newcastle-upon-

[redacted]

ELECTED.

Chisholm, Alexander, 5, Elton Street West, Wallsend-on-Tyne ... (S) Mar. 1893
Christie, C. J. D., Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Christie, J. D., 4, Colbeck Terrace, Tynemouth ... ... (S) Nov. 1884
Churchill, James Dixon, 9, London Street, London, E.C.... ... (E) Oct. 1889
Clague, James Henry, Birkenhead Ironworks, Birkenhead ... ... (S) { Graduate, April 1891 / Member, May 1894 }
Clark, Charles, c/o Messrs. Irvine & Co., West Hartlepool... ... (E) Jan. 1897
Clark, Geo., Southwick Engine Works, Sunderland ... ... (E) Nov. 1884
Clark, George, Jun., Southwick Engine Works, Sunderland ... (E) Feb. 1888
Clark, Henry, Southwick Engine Works, Sunderland ... ... (E) Oct. 1887
Clarke, Harry, 23, West Parade, Newcastle-upon-Tyne ... ... (E) Mar. 1897
Clarke, Henry Trevisa, Deptford Shipyard, Deptford, Sunderland (S) Mar. 1892
Clarke, William Henry, The Hermitage, Gateshead-on-Tyne ... (E) Dec. 1896
Cleghorn, Alexander, Datcha, Scotstounhill, near Glasgow ... (E) Feb. 1897
Cohn, William M., 2, Marine Terrace, North Shields ... ... (S) Nov. 1893
Coleby, James W., 42, Burns Terrace, Willington Quay-on-Tyne ... ... (E) { Graduate, Oct. 1891 / Member, Jan. 1894 }
Coletti, Silvio, 83, Park Road, Newcastle-upon-Tyne ... ... (S) Dec. 1895
Common, John B. A., 51, Mount Stuart Square, Docks, Cardiff ... (E) April 1896
Conràdi, Carl, 8, Toldbodgaden, Christiana, Norway ... ... (E) Nov. 1884
Consiglio, Luigi, 8, Via Paterno, Palermo ... ... (N A) Nov. 1890
Cooper, Nusserwanji Naoroji, Indo-China Mills, Dader, Sivri, Bombay, India ... ... (E) Oct. 1889
Coote, Arthur, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Nov. 1884
Copeman, William C. J., Clifton House, 1, Grosvenor Road, Ilford, Essex ... ... (E) Oct. 1892
Cornish, H. P., Lloyd's Register of Shipping, Hull ... ... (E) Oct. 1888
Couche, Henry Drew, c/o Messrs. Laird Bros., Birkenhead ... (S) Oct. 1891
Courtier-Dutton, W. T., British Corporation Registry of Shipping, 69, St. Vincent Street, Glasgow... ... ... (S SUR) April 1890
Cowan, Robert, 14, Osborne Avenue, South Shields ... ... (E) Dec. 1896
Cowens, William Edward, c/o Messrs. John Abbot & Co., Gateshead-on-Tyne ... ... (E) Dec. 1889
Craggs, Ernest H., Messrs. R. Craggs & Sons, Middlesbrough ... (S) Oct. 1888
Craig, John C., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (E SUR) Oct. 1890
Craig, Robert, Pageland House, Grange Road, West Hartlepool ... (E) Nov. 1892
Crawford, Jas., Bureau Veritas Register of Shipping, 9, Custom House Court, Quayside, Newcastle-upon-Tyne ... (S SUR) Nov. 1886
Crawford, W. A. F., Westminster Chambers, 9, Victoria Street, London, S.W. ... ... (E) Nov. 1884
Crawford, William, 60, Holly Avenue, Newcastle-upon-Tyne ... (E) Dec. 1896
Crofton, Charles, 17, Albany Terrace, Whitley, near Newcastle-upon-Tyne ... ... (E) Nov. 1895
Crookston, John, 72, Mark Lane, London, S.E. ... ... (E) Mar. 1896
Cross, Wm., c/o Messrs. Simpson, Strickland, & Co., Engineers and Yacht Builders, Dartmouth, South Devon ... ... (E) Mar. 1886
Cruddas, W. D., M.P., Messrs. Sir W. G. Armstrong & Co., Elswick, Newcastle-upon-Tyne ... ... (E) Dec. 1884
Cruickshank, Alexander, The Admiralty, Albany Buildings, 47, Victoria Street, London, S.W. ... ...(SUR) Mar. 1892

ELECTED.

Cumming, Alexander, 20, Lorne Terrace, Sunderland ... ... (E) Nov. 1891

Cumming, William, c/o Mrs. Hyslop, The Haven, Beaconsfield Parade, St. Kilda, near Melbourne, Australia ... ... (E) Mar. 1896

Cummins, W. B., Belle Vue, Wormit, Fife ... ... (E) Nov. 1884

Cunliffe, Tom Arthur, 12, Cresswell Terrace, Sunderland ... ... (E) Feb. 1897

D.

Dale, John, 26, Whitehall Terrace, Hylton Road, Sunderland ... (E) Mar. 1897

Dalrymple, Wm., Myrtle Cottage, W. Cleadon, Sunderland ... (E) Dec. 1886

Dalrymple, William, Jun., 8, Amberley Terrace, Sunderland ... (E) Dec. 1895

Daniel, Alfred John, Board of Trade Surveyors' Office, West Hartlepool ... ... (S) Nov. 1893

Darling, W. J., Lloyd's Register of Shipping, Dock Chambers, Barry ... ... (S) April 1887

Darney, John, c/o Messrs. Short Bros., Pallion, Sunderland ... (S) Nov. 1884

Davis, Thos., c/o Miss Watson, Westoe Terrace, South Shields (E) Graduate, Jan. 1891; Member, Mar. 1894

Davy, William, Greenfield Terrace, Ryton-on-Tyne ... ... (E) Oct. 1896

Denny, Archibald, c/o Messrs. W. Denny & Bros., Dumbarton ... (S) Dec. 1891

De Rusett, Edwin W., Warden House, Percy Park Road, Tynemouth ... ... (S) Nov. 1890

Dick, Francis, 6, Gladstone Street, Sunderland ... ... (E) Nov. 1885

Dick, F. W., c/o Messrs. Palmer's Shipbuilding Co., Jarrow-on-Tyne... ... ... (I & S M) Oct. 1891

Dickie, James, 428, Mississippi Street, Potrero, San Francisco, California, U.S.A.... ... ... (S) Mar. 1894

Dickinson, F. T., 23, Park Place W., Sunderland ... (E) Graduate, May 1885; Member, Oct. 1886

Dickinson, James, The Cloisters, Sunderland ... ... (E) Nov. 1884

Dickinson, John, Park House, Sunderland ... ... (E) Nov. 1884

Dickinson, W., Park House, Sunderland ... ... (E) Nov. 1884

Dietze, F. G., Messrs. The Hamburg South American Steam Ship Company, Hamburg ... ... (E) Nov. 1893

Dixon-Brown, L. D., 42, Burdon Terrace, Newcastle-upon-Tyne ... (S) Nov. 1886

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		ELECTED.
Doxford, Albert Ernest, M.A., 1, Grange Crescent, Sunderland... (E)	Graduate, Member,	Oct. 1890, Nov. 1893
Doxford, Charles D., Bainbridge Holme, Tunstall Road, Sunderland (S)		Nov. 1884
Doxford, Robert P., Pallion Engine Works, Sunderland ... ... (E)		Nov. 1884
Doxford, W. Theodore, M.P., Pallion Shipyard, Sunderland ... (S)		Nov. 1884
Drake, William Edward, 7, Rodwell Terrace, Weymouth ... ... (E)		Feb. 1893
Drakenberg, J., 73, Nybrogatan, Stockholm, Sweden ... ... (E)		Feb. 1886
Duckitt, Jno., 4, St. Nicholas' Buildings West, Newcastle-upon-Tyne ... ... (E)		Nov. 1884
Duckitt, John Brentnall, 19, Whitehall Terrace, Sunderland ... ... (E E)	Graduate, Member,	Oct. 1888, April 1895
Dudgeon, F. S., 30, Great St. Helens, London, E.C. ... ... (E)		Feb. 1885
Dugdale, William H., Green Bank, Jarrow-on-Tyne ... ... (S)		Mar. 1894
Duguid, Robert, c/o Messrs. Harland & Wolff, Drawing Office Department, Belfast ... ... (S)		Oct. 1892
Duncan, George Thos., c/o Messrs. Tangyes Limited, 3, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (E)		Nov. 1894
Dunlop, William, 3, Schnieder Terrace, Barrow-in-Furness ... (E)		Mar. 1888
Dyer, Charles M. B., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (E SUR)		Oct. 1892
Dykes, George, Lloyd's Register of Shipping, Steinhoeft 3, Hamburg ... ... (S)		Jan. 1893
Dykes, James, 82, Park Road, Newcastle-upon-Tyne ... ... (E)		May 1885
Dykes, John, Lloyd's Register of Shipping, Oriel Chambers, Liverpool ... ...(SUR)		Oct. 1889

E.

Edmiston, Jas. B., Ivy Cottage, Highfield Road, Walton, Liverpool (E)		Nov. 1886
Edwards, Guy W., 89, Holly Avenue, Newcastle-upon-Tyne ... (E)		Mar. 1897
Edwards, James Harry, Jun., High Docks, South Shields ... ... (S)		Mar. 1893
Eeles, Robert, Queen Street, Newcastle-upon-Tyne ... ... (E)		April 1889
Egan, James, 72, Riviera House, Collingwood Road, West Hartlepool ... ... (E)		Dec. 1893
Elder, Edward, c/o Messrs. J. & G. Thomson, Clydebank, Glasgow ... ... (S)	Graduate, Member,	Nov. 1890, Oct. 1892
Elliott, William D., Hessle, Hull ... ... (E)		Nov. 1894
Ellis, Robert Elwood, Messrs. Cumming & Ellis, Inverkeithing, Fife ... ... (S)		Feb. 1891
English, Thos. (Lieut.-Col.), Hawley, near Dartford, Kent ... (E)		Oct. 1890
Erdtman, Herman, c/o Mr. W. Lindberg's Varf, Stockholm, Sweden ... ... (E)		Nov. 1893
Eshelby, William, 13, Brankingham Terrace, Norton Road, Stockton-on-Tees ... ... (E)		Feb. 1888
Evans, Charles H., c/o Messrs. The Vulcan Shipbuilding and Engineering Co., Stettin, Germany ... ... (E)		Mar. 1891
Evans, Lewis, c/o Ralph Carr, Esq., Maritime Buildings, King Street, Newcastle-upon-Tyne ... ...(SUR)		Dec. 1890
Evans, William, Superintendent Engineer, Caerphilly, near Cardiff (E)		Nov. 1889
Evans, William T., c/o Messrs. John Cory & Sons, Mount Stuart Square, Cardiff ... ... (E)		Mar. 1896

ELECTED.

Ewen, Alex., 22, Albany Terrace, Whitley, near Newcastle-upon-Tyne ... ... (E) { Graduate, Oct. 1891 / Member, Jan. 1894

F.

Fairbairn, James, 54, Amberly Street, Sunderland... (E) { Graduate, May 1885 / Member, April 1895

Farina, A. J., 63, Quayside, Newcastle-upon-Tyne ... ... (E) Nov. 1884

Faruffini, Capt. M. C., c/o Connitato Pei Designa delle Navi Ministero dilla Marina, Rome, Italy ... ... (N A) Dec. 1888

Fenwick, James, B.Sc., C.E., 19, Bridge Street, Sydney, New South Wales ... ... (E) Oct. 1892

Ferrier, Robert M., B.Sc., Durham College of Science, Barras Bridge, Newcastle-upon-Tyne ... ... (E) Nov. 1892

Filley, George Frederick, 5, Park Terrace, Govan, Glasgow ... (S) Nov. 1891

Finch, Herbert K., Colliery Agent, c/o Messrs. Blainscough Colliery Co., Coppull, near Chorley, Lancashire (E) { Graduate, Dec. 1888 / Member, Nov. 1894

Findlay, John Taylor, 14, Nelson Street, Sunderland ... ...(SUR) Feb. 1890

Fish, Thomas Wilson, Lloyd's Register of Shipping, Calcutta, British India ... ...(SUR) May 1892

Fleming, Charles Edward, 71, Elswick Road, Newcastle-upon-Tyne (E) Nov. 1884

Fletcher, Robert, Walker Forge, Walker-on-Tyne ... ...(F M) Dec. 1886

Flohr, Justus, Elisabethstrasse 10, Stettin, Germany ... ... (E) Oct. 1886

Foley, Wm. C. le B., Box 537, Newport News, Virginia, U.S.A. ... ... (S) { Graduate, Nov. 1887 / Member, Oct. 1892

Ford, David, c/o Messrs. J. Boyd & Co., Shanghai, China ... ... (E) May 1891

Ford, John McLaren, 70, Mount Pleasant, Barrow-in-Furness ... (S) Nov. 1896

Forster, Alfred Lindsay, 26, Hotspur Street, Tynemouth (E) { Graduate, Nov. 1891 / Member, Oct. 1895

Forster, William, c/o Messrs. Dixon, Robson, & Co., 2, Collingwood Street, Newcastle-upon-Tyne ... ... (E) Mar. 1890

Foster, Henry, c/o Messrs. Galloway & Co., Knott Mills Ironworks, Manchester ... ... (E) April 1885

Fothergill, J. R., Dock Office, West Hartlepool ... ...(C E) Mar. 1886

Fowell, Ridley, Lloyd's Register of Shipping, Dock Offices, West Hartlepool ... ...(S & E SUR) Feb. 1893

ELECTED.

Gannaway, H. G., 11, Kent Street, Jarrow-on-Tyne ... ... (S) Nov. 1884
Garelli, Fabio, *via* Settembre, Sestro Ponente, Italy ... ... (S) Oct. 1896
Garthwaite, John R., c/o Messrs. R. Ropner & Sons, Stockton-on-Tees (S) May 1889
Gayner, Robt. H., Jun., Beech Holm, Sunderland ... (E) {Graduate, Mar. 1886 / Member, Oct. 1888}
Gearing, Ernest George, Penshurst, Clarence Drive, Harrogate ... (E) Dec. 1892
Geddes, Christopher, 2A, Drury Lane, Water Street, Liverpool ... (E) Oct. 1888
Gibson, David, 18, Wadsworth Avenue, Cardiff ... ... (E) June 1896
Gibson, H., 162, Roker Avenue, Monkwearmouth, Sunderland ... (S) Nov. 1884
Gibson, J. Hamilton, c/o Messrs. Laird Bros., Birkenhead (E) {Graduate, April 1891 / Member, Oct. 1894}
Gibson, W. H., 37, Tatham Street, Sunderland ... ... (E) Nov. 1884
Golledge, William, Royal Agricultural Hall, Islington, London ... ... (E E) {Graduate, Nov. 1891 / Member, Nov. 1896}
Good, Farrant, c/o Messrs. Bute Dry Dock Co., Ltd., Roath Basin, Cardiff ... ... (E) Mar. 1896
Gordon, William James, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Oct. 1887
Gordon, William Leslie, Invermark, Broughty Ferry, N.B. ... (E) April 1893
Graham, William, Ford Lodge, South Hylton, near Sunderland ... (S) Nov. 1884
Graham, William, West House, Tynemouth ... ... (S) Oct. 1891
Graham, William, 30, Hill Street, Jarrow-on-Tyne ... ... (S) April 1893
Graham, William, Primrose Villa, Kingsland Crescent, Barry Docks, South Wales ... ... (E) Nov. 1894
Gravell, John, Bureau Veritas Register of Shipping, 155, Fenchurch Street, London, E.C. ... ... (N A SUR) Nov. 1884
Gray, A., 17, Belgrave Terrace, Newcastle-upon-Tyne ... ... (E) Nov. 1888
Gray, George, 6, Salem Hill South, Sunderland ... ... (E) Feb. 1888
Gray, Harry, Dominion House, 110, Fenchurch Street, London, E.C. ... ... (E) Dec. 1885
Gray, Sir William, Messrs. W. Gray & Co., West Hartlepool (S & E) Oct. 1888
Green, William, 46, Church Street, Barrow-in-Furness ... ... (E) Oct. 1885
Green, W. G., Engine Department, Messrs. Palmer's Iron and Shipbuilding Co., Jarrow-on-Tyne ... ... (E) Nov. 1884
Greenhow, John, 9, Rowell Street, Hartlepool ... ... (S) Oct. 1894
Greig, David William, Messrs. Lymington Shipbuilding Co., Lymington, Hants ... ... (E) Mar. 1891
Grimes, Thomas Benjamin, 45, Eastbourne Grove, South Shields... (E) Mar. 1890
Gross, Felix, Assistant Manager, c/o Messrs. John Brown & Co., Atlas Works, Sheffield ... ... (I & S M) Feb. 1893
Gulston, A., Clayton Park Lodge, Jesmond, Newcastle-upon-Tyne (E) Dec. 1888
Gunn, John, Chairman, Messrs. Mount Stuart Dry Docks Co., Cardiff (*Life Member*) ... ... June 1896

H.

Hake, G. A., 29, Rothbury Terrace, Heaton, Newcastle-upon-Tyne (SUR) Oct. 1888
Hall, Edward, 68, Grange Road West, Jarrow-on-Tyne ... ... (S) Nov. 1885
Hall, J. Percy, Carville, Lawrie Park Road, Sydenham, London, S.E. (E) Oct. 1885
Hall, John W., Messrs. Southampton Royal Mail Steamship Co., Southampton ... ... (S) Oct. 1887

ELECTED.

Hamilton, Robert C., The College, Durham... ... (E) { Graduate, Dec. 1892 / Member, Oct. 1895 }

Hamilton, R. R., c/o Messrs. Maudslay, Sons, & Field, Westminster Bridge Road, Lambeth, London ... ... (E) Nov. 1884

Hammar, Hugo G., Lindholmens, Verkstads Aktreholag, Göteberg, Sweden ... ... (S) Nov. 1890

Harbottle, John, 63, Malvern Street, Newcastle-upon-Tyne ... (E) Oct. 1896

Harding, J. C., Fernville Terrace, West Hartlepool... ... ... (E) Nov. 1884

Harkness, Richard, Grange Road, West Hartlepool ... (S SUR) Nov. 1884

Harlow, F., 8, Benton Terrace, Newcastle-upon-Tyne ... ... (E) Nov. 1884

Harman, Bruce, Messrs. The Linde British Refrigerating Co., 35, Queen Victoria Street, London, E.C. ... ... (E) Oct. 1886

Harper, J. H., 1, Beaumont Street, North Shields ... ... (E) Jan. 1885

Harris, Anthony, Clyde Yacht Club House, Hunter's Quay, Argyleshire... ... ... (E) Mar. 1892

Harrison, Alfred, Scotia Engine Works, Sunderland ... ... (E) Oct. 1889

Harrold, Alexander, 26, Park Road, Newcastle-upon-Tyne ... (E) Nov. 1884

Harrold, F., 140, Cardigan Terrace, Heaton, Newcastle-upon-Tyne (E) Nov. 1888

Harroway, George Mitchell, Philiphaugh, Wallsend-on-Tyne ... (S) Jan. 1896

Harvey, John W. J., 1, Richmond Villa, Chertsey Road, Redland, Bristol ... ... (E) Feb. 1889

Havelock, Michael, 6, Exchange Buildings, King Street, Newcastle-upon-Tyne ... ... (E) Dec. 1887

Hawkins, Charles Gittens, 65, Westmorland Road, Newcastle-upon-Tyne ... . (E) Nov. 1896

Head, Archibald P., 47, Victoria Street, London, S.W. (E) { Graduate, Nov. 1884 / Member, Oct. 1887 }

Headlam, Robert, New Park Terrace, Hartburn Lane, Stockton-on-Tees ... ... (E) Nov. 1886

Heaviside, Arthur West, 7, Grafton Road, Whitley, near Newcastle-upon-Tyne ... ... (E E) Oct. 1896

Heck, John H., Lloyd's Register of Shipping, 3 St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (S SUR) Nov. 1885

Hemphill, Henry, 15, North View, Heaton, Newcastle-upon-Tyne (E) April 1897

Henderson, Alex., c/o Messrs. Empreza, Nacional, De. Nav. D'Vapor, [illegible]

ELECTED.

Hirst, Richard, Lloyd's Register of Shipping, Dock Offices, West Hartlepool ... ... (E SUR) Nov. 1885
Hodge, Rowland F. W., Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne ... ... (S) Dec. 1890
Hogg, Archibald, Norham House, Whitley, Northumberland ... (S) Jan. 1897
Hogg, James, 8, Lovaine Terrace, North Shields ... ... (B F) Nov. 1889
Hodgson, Rich. Bowness, Gordon Street, Workington ... ... (S) Dec. 1896
Hök, Wilhelm, Deptford Shipyard, Sunderland ... ... (S) Oct. 1886
Holbrook, Thomas, 22, St. Hilda Street, Hartlepool ... ... (E) Nov. 1893
Holgate, Charles H., School Close Works, Leeds ... ... (E) Feb. 1895
Hollis, Henry William, Whitworth House, Spennymoor ... ... (I M) Oct. 1891
Holmes, John H., Portland Road, Newcastle-upon-Tyne ... ... (E E) Jan. 1888
Homji, A. C. N., c/o Messrs. Lakhmidas Khimji S. & W. Co., Limited, Fergusson Road, Bombay, India ... ... (E) Nov. 1884
Hongland, Even, Lloyd's Surveyor, Bergen, Norway ... ... (E) Dec. 1896
Hooper, Ernest, 24, Whitehall Terrace, Sunderland ... ... (E) Nov. 1885
Hopkinson, Frank A., c/o Messrs. J. Hopkinson & Co., Huddersfield (E) Dec. 1891
Houston, John, 32, Randolph Street, Sunderland ... ... (E) Nov. 1894
Hunter, George B., Messrs. C. S. Swan, Hunter, & Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
Hunter, J. W., 10, Princess Road, Stockton Road, Sunderland ... (E) May 1885
Hunter, Summers, c/o Messrs. N.E. Marine Engineering Co., Northumberland Engine Works, Wallsend-on-Tyne ... ... (E) Nov. 1885
Hutchinson, C. W., 6, Park Parade, Westmorland Road, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Hutchinson, Wesley, B.A., 6, Park Parade, Westmorland Road, Newcastle-upon-Tyne ... ... (E) Oct. 1891
Hutchison, J., Board of Trade Offices, Middlesbrough ... ...(SUR) Dec. 1891
Hutchison, Thomas Allan, 98, Warwick Street, Heaton, Newcastle-upon-Tyne ... ... (S) Nov. 1891

I.

Inglis, John, c/o Messrs. Hawthorn & Co., Leith ... ... (S) April 1887
Inglis, John, Pointhouse Shipyard, Partick, Glasgow ... (E & S) Oct. 1886
Inman, Douglas S., Fairholm, Heaton, Newcastle-upon-Tyne ... (E) Oct. 1892
Irwin, J. H., Sunderland Engine Works, South Docks, Sunderland (E) Nov. 1884

J.

Jack, William C., Service Subventionné des Correspondances Fluviales au Tonkin, Haiphong, China ... ... (E) Nov. 1894
Jackson, A., Surveyor's Office, Board of Trade, North Shields (E SUR) Nov. 1888
Jackson, Albert S., c/o Messrs. The Baron Hambro' Steamship Co., Ltd., Mount Stuart Square, Cardiff ... ... (E) Mar. 1896
Jackson, William S., Messrs. Gourlay Bros. & Co., Camperdown Shipyard, Dundee... ... ... (S) April 1891
James, M. C., 6, Park Terrace, Gateshead-on-Tyne ... ... (S) Nov. 1884
Jobling, J. C., Blackwall Ironworks, Isle of Dogs, London, E. ... (E) Nov. 1884
Jobling, W. J., 1, Akenside Hill, Newcastle-upon-Tyne ... (E & S O) Nov. 1884
Jobson, H. G., Exchange Buildings, West Hartlepool ... ...(SUR) June 1896

ELECTED.

Johnson, Alexander, 9 Cheltenham Terrace, Heaton, Newcastle-upon-Tyne ... ... (E) Feb. 1893
Johnson, Johan, 7, Vestra Hamngaten, Gothenburg, Sweden ... (S) May 1885
Johnson, T. Allan, Dry Docks, Passage West, Cork ... ... (S) Nov. 1884
Johnstone, William, Lloyd's Register of Shipping, Barrow-in-Furness ... ...(SUR) Nov. 1884
Joicey, Jacob G., Forth Banks West Factory, Newcastle-upon-Tyne (E) Jan. 1889
Jones, Charles, 10, Glynrhondda Street, Cardiff ... ... (E) Mar. 1896
Jones, George, c/o Messrs. W. Gray & Co., West Hartlepool ... (S) Oct. 1888
Jones, Morlais G., 6, Delahay Street, Westminster, London, S.W. (E) Nov. 1887

K.

Keene, H. R., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E) { Graduate, May 1885 / Member, April 1887 }
Kendall, Stonard O., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ...(SUR) Mar. 1891
Kerfoot, James, 45, Rue de Grand Chila, Zurenberg, Antwerp ... (E) Oct. 1892
King, John, 16, Lefroy Street, Newcastle-upon-Tyne (S) { Graduate, Dec. 1890 / Member, Oct. 1892 }
Kirkaldy, John, 40, West India Dock Road, London ... ... (E) Nov. 1885
Kitching, J. F., Clifton Avenue, West Hartlepool ... ... (E) Nov. 1890

L.

Laing, Andrew, c/o Messrs. Wallsend Slipway and Engineering Co., Wallsend-on-Tyne ... ... (E) Oct. 1892
Laing, Arthur, Deptford Shipyard, Sunderland ... ... (S) Nov. 1884
Laing, Hugh, Deptford Shipyard, Sunderland ... ... (N A) April 1897
Laing, John, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Landreth, Cowen, 34, Simonside Terrace, Newcastle-upon-Tyne ... (E) Mar. 1896
Larkin, James, Tyne View, East Jarrow-on-Tyne ... ... (E) Nov. 1884
Lewins, Frank, Rosehill, Willington Quay-on-Tyne ... ... (E) Dec. 1895
Lewis, R. A., Newburn Steel Works, Newburn-on-Tyne ... ... (E) Nov. 1884
Liddell, J., c/o Messrs. Denny & Co., Engine Works, Dumbarton (E) Nov. 1884

M.

		ELECTED.
MacColl, Hector, Strandtown, Belfast	(E)	Dec. 1890
MacColl, Hugo, 12, Victoria Terrace, Newcastle Road, Sunderland	(E)	Nov. 1896
Maccoy, John, 55, Larkspur Terrace, Newcastle-upon-Tyne ...	(E)	Feb. 1886
MacDonald, David R., c/o Messrs. Sir W. G. Armstrong & Co., Walker Shipyard, Newcastle-upon-Tyne	(S)	Nov. 1891
Mace, W., 253, Albert Road, Jarrow-on-Tyne	(E)	Jan. 1886
Macfarlane, Andrew, 18, John Street, Sunderland	(E)	Dec. 1890
MacGregor, John, 2, Michaelston Villas, Barrow-in-Furness ...	(E)	Mar. 1888
MacHaffie, John, 635, Terrace Place, Schenectady, New York, U.S.A.	(E)	Dec. 1885
Mackay, William, 8, Camperdown Cottages, Whiteinch, near Glasgow	(S)	Mar. 1892
Mair, James, Wh. Sc., 65, Linskill Terrace, North Shields ...	(E)	Oct. 1894
Manaira, Guiseppe, 4, Salita S Gerslamo, Genoa, Italy ...	(E & N A)	Nov. 1893
Marlborough, Richard, 44, Muirpark Gardens, Partick, Glasgow...	(S)	Nov. 1884
Marr, James, c/o Messrs. J. L. Thomson & Sons, North Sands Shipyard, Sunderland	(S)	Nov. 1884
Marshall, F. C., 38, Percy Gardens, Tynemouth	(E)	Nov. 1884
Marshall, Frank T., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-upon-Tyne ... ... (E)	Graduate, Member,	Jan. 1885 Oct. 1888
Marshall, R. J., 51, Larkspur Terrace, Jesmond, Newcastle-upon-Tyne...	(E)	Mar. 1887
Mason, George F., Lloyds' Bank Buildings, Mount Stuart Square, Cardiff	(E)	Oct. 1895
Mather, Charles, 44, Warrington Road, Newcastle-upon-Tyne ...	(SUR)	Oct. 1888
Matheson, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne...	(S)	Dec. 1889
Matthews, A., c/o Messrs. Blyth Shipbuilding Co., Blyth... ...	(S)	Nov. 1884
Matthews, Jas., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Forth Banks, Newcastle-upon-Tyne	(E)	Oct. 1886
Maxwell, William Ward, Messrs. H. Charlton & Co., Engineers, Gateshead-on-Tyne	(E)	Dec. 1896
McBride, William, Warren Cement Works Cottages, Hartlepool...	(E)	Dec. 1894
McDougall, Neil, Managing Director, Messrs. British Steam Users' Insurance Society, Ld., 4 & 5, Victoria Buildings, Manchester	(E)	Mar. 1890
McGlashan, Arch., Beechcroft, Clifton Avenue, West Hartlepool	(S)	Nov. 1885
McIlvenna, J. G., c/o Messrs. The Tyne Pontoons and Dry Docks Co., Wallsend-on-Tyne	(S)	Nov. 1884
McKay, Jno., 4, Northumberland Street, Newcastle-upon-Tyne...	(E)	Nov. 1884
McKechnie, James, Messrs. Naval Construction and Armaments Co., Barrow-in-Furness	(E)	April 1896
McKenna, Francis, c/o Messrs. E. F. Wailes & Co., 4, St. Nicholas' Buildings, Newcastle-upon-Tyne ... (E)	Graduate, Member,	Dec. 1890 Dec. 1896
McLaren, Robert M., Flinton Hill, Sunderland	(S)	Nov. 1893
McLaren, William, 16, Rock Park, Rock Ferry, Cheshire	(E)	Oct. 1894
McLean, John H. K., 3, Windsor Terrace, South Shields	(S)	Mar. 1897
McNeil, Thomas Young, 98, Meldon Terrace, Heaton, Newcastle-upon-Tyne	(S)	Oct. 1895
Meagher, H. L., Messrs. Sir W. G. Armstrong & Co., Ltd., Elswick Ordnance Works, Newcastle-upon-Tyne	(E)	Dec. 1896
Meldrum, Michael, Humbledon View, Sunderland	(E)	Dec. 1893

ELECTED.

Mellanby, Alex. Lawson, Fernleigh, Grange Road, West Hartlepool ... ... (E) { Graduate, Dec. 1894 / Member, Oct. 1896

Menzies, Wm., The Side, Newcastle-upon-Tyne ... ... (E) Nov. 1884

Messenger, Thomas, Paris House, Snargate Street, Dover, Kent ... (E) Mar. 1887

Metcalf, Thos., 18, John Street, Sunderland... ... (S) { Graduate, May 1885 / Member, Nov. 1893

Metcalfe, C. S., 24, Croft Avenue, Sunderland ... ... (E) Nov. 1884

Micheli, Pietro, Jun., Via Sottoripu, No. 1, piano nobile, Genoa, Italy ... ... (E & N A) Oct. 1888

Middlemass, Thomas, 3, Albert Place, Norton Road, Stockton-on-Tees ... ... (S) Oct. 1889

Middleton, H., 20, Lynnwood Avenue, Newcastle-upon-Tyne (I & S M) Jan. 1893

Middleton, Robert Alexander, 4, Ashville, Skeigoneil Avenue, Belfast, Ireland ... ... (N A) Oct. 1892

Milburn, Christopher J., Ovingham-on-Tyne ... ... (E) Feb. 1888

Millar, Thos., c/o Messrs. Sir W. G. Armstrong & Co., Walker Shipyard, Walker-on-Tyne ... ... (S) Nov. 1884

Miller, Thomas B., Pier Head Chambers, Cardiff ... (E) { Graduate, Nov. 1886 / Member, Oct. 1888

Mills, John, c/o Messrs. Greenock Steam Shipping Co., Greenock ... ... (E) Feb. 1888

Mills, William, Atlas Works, Bonners Field, Sunderland ... ... (E) Feb. 1890

Milton, J. T., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E SUR) Nov. 1886

Moffatt, James, 7, Murray's Terrace, Belfast, Ireland (E) { Graduate, Dec. 1889 / Member, Oct. 1892

Moffitt, George, 42, Stanley Street, Blyth ... ... (S) Oct. 1888

Moffitt, Robert, 13, Grace Terrace, Sunderland ... ... (E) Dec. 1885

Moody, Thomas V., 7, The Grove, Gosforth, Newcastle-upon-Tyne (E) Dec. 1887

Moore, Frederick, c/o Messrs. Wilson, Sons, & Co., Ld., Bahia ... (E) Oct. 1890

Morch, C. J., 20, Archbold Terrace, Newcastle-upon-Tyne ... (N A) June 1896

Morgan, W. H., 22, Rochdale Street, Wallsend-on-Tyne ... ... (E) Nov. 1884

Morison, D. B., 8, Albion Terrace, Hartlepool ... ... (E) Feb. 1885

Mörk, Peter, 31, Holsteinsgude, Copenhagen ... ... (E) Nov. 1884

Morrison, Robt., 5, Challoner Terrace, South Shields ... ... (E) Nov. 1886

N.

ELECTED.

Nastoupil, John, Chief Engineer, Austro-Hungarian Navy, Marine Casino, Pola, Austria ... ... (E) Nov. 1890
Nevins, William, 28, Brookbank Road, Lewisham, London, S.E.... (E) Mar. 1894
Newitt, Leonard, 20, East Parade, Newcastle-upon-Tyne... ... (E E) Dec. 1887
Newton, Richard, Park Square, West Hartlepool ... ... (E) April 1889
Nicholls, H. E., 25, Churchill Street, Sunderland ... ... (E) Nov. 1893
Nichols, Walter W., 30, Denmark Street, Gateshead-on-Tyne ... (E) May 1895
Nicholson, John S., North View, Mowbray Road, Westoe, South Shields ... ... (E) Nov. 1893
Nicholson, Joseph Cook, Collingwood Street, Newcastle-upon-Tyne (E) Feb. 1897
Nicholson, Walter E., Hebburn Boiler Works, Hebburn-on-Tyne (B B) April 1896
Nicol, John M., 15, Linskill Terrace, North Shields ... ... (E) Nov. 1884
Nicolson, G. C., H.M.S. "Talbot," North America and West Indies Station ... ... (E) { Graduate, Oct. 1885; Member, Oct. 1888 }
Nisbet, John Mowat, c/o M. W. Aisbitt, Esq., 47, Mount Stuart Square, Cardiff ... ... (E) Oct. 1896
Noble, George, 7, Dean Street, Newcastle-upon-Tyne ... ... (E) May 1893
Noble, Harry, Northern Machine Tool Works, Brewery Lane, Felling-on-Tyne ... ... (E) Nov. 1888
Nodder, Joseph, Ash Lea, Crabtree, Sheffield ... ... (F M) May 1893
Norman, W. S., Orchard House, Whitby, near Chester ... ... (E) Nov. 1884
Norton, Harold P., Engineer Corps U.S. Navy, Washington, U.S.A. ... ... (E) Oct. 1890
Noton, F. R., Lloyd's Register of Shipping, Bute Docks, Cardiff (S) Nov. 1884
Nunes, Enrique E., Engineer, Argentine Navy, 433, Calle Ayacucho, Buenos Ayres ... ... (E) April 1891

O.

O'Halloran, Timothy, 205, Avenue du Commerce, Antwerp, Belgium ... ... (E) Jan. 1895
O'Neil, J. J., 2, Erith Terrace, Sunderland ... ... (E) Nov. 1884
Ord, Godfrey C., The Esplanade, Sunderland ... ... (E E) Jan. 1897
Orde, E. L., c/o Messrs. Sir W. G. Armstrong & Co., Walker Shipyard, Newcastle-upon-Tyne ... ... (E) Oct. 1887
Orlando, Chev. Giuseppe, Cantiere Navale, Fratelli Orlando, Leghorn ... ... (N A) Jan. 1893
Orr, John, B.Sc., c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne ... ... (E) Mar. 1897
Orr, Reginald, 18, Bulwer Street, Shepherd's Bush, London, W. ... ... (E) { Graduate, Mar. 1890; Member, Oct. 1892 }
Oxley, G., 39, Norman Terrace, Howdon-on-Tyne ... ... (S) Nov. 1884
Oxton, Walter, 96, Blackpool Street, Burton-on-Trent (E) { Graduate, Dec. 1890; Member, May 1894 }

P.

Pacey, John W., 3, Main Street, Stapenhill, Burton-on-Trent ... (E) Feb. 1888
Parsons, Hon. Charles A., Holeyn Hall, Wylam-on-Tyne... ... (E E) Dec. 1887
Parsons, Harry F., c/o P. Brotherhood, Esq., Belvedere Road, Westminster Bridge, London, S.E. ... ... (E) Dec. 1890

ELECTED.

Pascoe, J. R., Tyrmont, Woodford Green, Essex (*Life Member*) ... (S) Dec. 1889

Patterson, Jas., c/o Messrs. Workman, Clarke, & Co., Queen's Road, Belfast, Ireland ... ... (E) Nov. 1884

Pattison, Jos., 123, Bute Road, Cardiff ... ... (E) Nov. 1884

Paulin, William J., 47, Clarence Crescent, Shieldfield, Newcastle-upon-Tyne ... ... (E) April 1897

Paulson, John, Messrs. The Wm. Cramp & Sons' Ship and Engine Building Co., Philadelphia, U.S.A. ... ... (S) Feb. 1886

Payne, Henry Fernie, c/o Messrs. Henry Fernie & Sons, Rumford Street, Liverpool ... ... (E) Dec. 1895

Peacock, Nicholas B. J., 30, Dingle Road, Tranmere Park, Birkenhead ... ... (E) Oct. 1892

Pendred, L. St. L. ... ... (E) { Graduate, Mar. 1894; Member, Oct. 1895 }

Penney, R. H., Board of Trade Offices, 79, Mark Lane, London, E.C. ... ... (S SUR) Nov. 1884

Pepper, W., 9, West Villas, Oxbridge Lane, Stockton-on-Tees ... (E) Nov. 1888

Petersen, John L., 18, Bellerby Terrace, West Hartlepool... ... (E) Oct. 1888

Petree, James, Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (N A SUR) Oct. 1885

Petrini, Giacomo Luigi, C.E., c/o Messrs. Gio Ansaldo & Co., Sestri-Ponente, Italy ... ... (N A) Nov. 1892

Petterson, Carl Edwin, 7, Vestra Hamngaten, Gothenburg, Sweden (E) Oct. 1891

Philipson, Roland, Tynemouth... ... ... (E) Dec. 1884

Phillips, Walter, 28, Brownhill Road, Catford, London, S.E. (N A & E) Oct. 1886

Phorson, P., Glen Lea, Roker, Sunderland ... ... (S) Nov. 1884

Piaud, Leon, Bureau Veritas, 8, Place de la Bourse, Paris ... ... (N A) Nov. 1888

Piercy, Frank, 1, Bolton Terrace, Newcastle-upon-Tyne ... .. (E) Dec. 1896

Pitt, Frederick William, 15, Wilberforce Terrace, Gateshead-on-Tyne... ... ... (E SUR) Oct. 1890

Plotnicki, E. C., 39, George Road, Wallsend-on-Tyne ... ... (E) Nov. 1886

Poli, Rodolfo, Chioggia, Italy ... ... (N A) Jan. 1890

Pollard, T., 43, Second Avenue, Heaton, Newcastle-upon-Tyne ... (E) Dec. 1896

Potts, Cuthbert Ivan, 6, Rodsley Avenue, Gateshead-on-Tyne ... (E) Oct. 1895

Potts, Matthew, 86, Glen Terrace, Hebburn-on-Tyne ... ... (S) Dec. 1890

Q.

ELECTED.

Quicke, Herbert John, c/o Messrs. Harfield & Co., Blaydon Iron-works, Blaydon-on-Tyne ... ... (E) Feb. 1891

R.

Rae, John, 11, Gray Street, Glasgow, N.B. ... ... (E) April 1886
Ramage, J. T., St. Aubyn's, Bonnington, Edinburgh ... ... (E) April 1887
Ramage, John Anderson, 74, Glen Terrace, Hebburn-on-Tyne ... (S) Oct. 1892
Readhead, Jas., Beach View, South Shields ... ... (S) Nov. 1884
Readhead, John, 4, Salisbury Place, South Shields.. ... ... (E) Mar. 1886
Readhead, R., 28, Sea View Terrace, South Shields ... ... (E) Nov. 1884
Readhead, W. B., South-garth, Westoe, South Shields ... ... (S) Nov. 1886
Reavell, W., c/o P. Brotherhood, Esq., Belvedere Road, Westminster Bridge, London, S.E. ... ... (E) { Graduate, April 1885; Member, Oct. 1887 }
Reed, Joseph, Angerton House, North Shields ... ... (E) Oct. 1889
Reed, J. W., c/o Messrs. Palmer's Shipbuilding and Iron Co., Limited, Engine Works Department, Jarrow-on-Tyne ... (E) Nov. 1884
Reed, Richard, c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne ... ... (S) Oct. 1894
Rennoldson, C., Messrs. J. P. Rennoldson & Sons, South Shields (S) Jan. 1886
Rennoldson, Jos. M., Messrs. J. P. Rennoldson & Sons, South Shields (S) Feb. 1886
Renton, John, 1, Akenside Hill, Newcastle-upon-Tyne ... (M SUR) April 1895
Reynolds, Charles H., c/o Messrs. Sir W. G. Armstrong & Co., Walker-on-Tyne ... ... (S) Mar. 1889
Reynolds, W. G., 4, Ulfra Terrace, South Shields ... ... (E) Oct. 1886
Richardson, Sir Thomas, B.A., M.P., Hartlepool Engine Works, Hartlepool ... ... (E) April 1888
Richardson, Wigham, Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Rickaby, A. A., Bloomfield Engine Works, Sunderland ... ... (E) Mar. 1888
Ridley, J. H., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Riley, J. H., Messrs. Riley Bros., Stockton-on-Tees ... ... (B B) May 1893
Ritson, M., Lloyd's Register of Shipping, 29, Regent Quay, Aberdeen ... ... (E SUR) Nov. 1884
Ritson, S. M., c/o J. H. Hallett, Esq., 123, Bute Docks, Cardiff ... ... (E) { Graduate, Nov. 1887; Member, Nov. 1893 }
Robinson, William, 7, Choppington Street, Newcastle-upon-Tyne ... ... (E) { Graduate, May 1885; Member, April 1888 }
Robson, Arthur, Messrs. J. Blumer & Co., North Dock, Sunderland (S) Dec. 1886
Robson, George, 9, Wellington Terrace, South Shields ... ... (E) Oct. 1889
Robson, George, 140, Aurelian Terrace, South Shields ... ... (E) Feb. 1896
Robson, Geo. Edward, 61, Thornton Street, West Hartlepool ... (S) Nov. 1893
Robson, John H., Grainger Commercial Hotel, Newcastle-upon-Tyne (E) Nov. 1885
Robson, J. M., 4, Abbey Terrace, Gateshead-on-Tyne ... ... (E) Nov. 1884
Robson, M., 23, Zion Terrace, Newcastle Road, Sunderland ... (S) Nov. 1884
Roger, Robert, Stockton Iron Foundry, West Row, Stockton-on-Tees (E) Nov. 1888
Rogers, Herbert M., Redcliffe, Durham Avenue, Bromley, Kent (SUR) April 1889
Rolf, George, Lefroy House, Newcastle-upon-Tyne... ... ... (E E) May 1892
Rolland, Alexander, Villa Ruzic, Susak, Fiume, Hungary... ... (E) Mar. 1892
Roper, Leopold, Palace Chambers, Westminster, London, S.W. ... (N A) Dec. 1896

ELECTED.

Ropner, Robert, Jun., Stockton-on-Tees ... ... (S) Feb. 1886
Rosenthal, James H. Woodville, 97, Eltham Road, Lee, Kent ... (E) Dec. 1896
Roseti, S., 90, Paradise Street, Liverpool ... ... (N A) June 1896
Ross, William, 20, Meadow Side, Dundee ... ... (E) May 1893
Rosser, W. D., Messrs. The Cardiff Pontoon Company, Mount Stuart Square, Cardiff ... ... (S) Nov. 1893
Rowan, Jas., 231, Elliott Street, Glasgow ... ... (E) Nov. 1886
Rowell, G. W., Simla House, New Benwell, Newcastle-upon-Tyne (E) Feb. 1885
Rowell, H. B., Hebburn Hall, Durhamshire ... ... (S) Nov. 1884
Rusden, L., 14, Sanderson Road, Jesmond, Newcastle-upon-Tyne (E) Nov. 1884
Russell, F. Herbert, Scotia Engine Works, Sunderland ... ... (E) Oct. 1891
Rutherford, G., Messrs. Mercantile Pontoon Co., Roath Dock, Cardiff ... ... (S) Oct. 1886
Rutherford, J. T., 2, Umfraville Road, Harringay, London (E) { Graduate, Jan. 1886 / Member, Nov. 1893 }
Ryder, C. L. ... ... (E) Oct. 1886
Ryder, William J. H., Hartford Bridge House, Cramlington, R.S.O. · (E) Oct. 1891

S.

Salmon, P., 5, The Oaks West, Sunderland ... ... (E SUR) Nov. 1884
Sambidge, James, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-upon-Tyne ... ... (E E) Nov. 1891
Sandeman, John Watt, 2, St. Nicholas' Buildings, Newcastle-upon-Tyne... ... ... (E) Oct. 1891
Sanderson, Henry Thomas Barron, Messrs. Sanderson & Co., High Quay, Blyth ... ... (E) Oct. 1891
Sanderson, J., 31, Park Road, Jarrow-on-Tyne ... ... (S) Nov. 1884
Sandison, M., 12, Beech Grove Road, Newcastle-upon-Tyne ... (E) Dec. 1884
Sawyers, John, c/o Messrs. Thos. Wilson, Sons, & Co., Hull ... (E) Oct. 1886
Schaeffer, A. G., 32, Side, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Scotson, Wm., Fair View, Wood Green Road, Wednesbury ... (E) Nov. 1884
Scott, Ernest, Close Engine Works, Newcastle-upon-Tyne ... (E E) Nov. 1884
Scott, James, c/o Messrs. Consett Iron Co., Blackhill, Co. Durham (E) Oct. 1892
Scott, Joseph R., 9, Queen Street, Newcastle-upon-Tyne ... ... (E) Oct. 1887

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ELECTED.

Shaw, Jas., 36, Sandhill, Newcastle-upon-Tyne ... ... (M SUR) Jan. 1885
Sheriff, Thomas, c/o Messrs. Robert Mackill & Co., 29, Waterloo Street, Glasgow ... ... (E) April 1890
Short, J. Y., 49, West Sunniside, Sunderland ... ... (S) Nov. 1884
Short, Jos., 49, West Sunniside, Sunderland... ... . (S) Nov. 1884
Shotton, John W., 32, Mount Stuart Square, Cardiff ... ... (SUR) Nov. 1886
Shute, A. E., 12, Clyde View, Partick, Glasgow ... ... (E) Dec. 1892
Sibun, William, Lloyd's Register of Shipping, Bute Docks, Cardiff (SUR) Mar. 1896
Sim, John Archibald, 1, South Cliffe, Roker, Sunderland ... ... (S) Jan. 1896
Simpson, Edward, Boddie Street, Wallsend-on-Tyne ... ... (S) Dec. 1890
Simpson, Kenneth, 115, Tynemouth Road, Heaton, Newcastle-upon-Tyne ... ... (S) { Graduate, Dec. 1893; Member, Oct. 1895 }
Sinclair, R., c/o Messrs. J. Wildridge & Sinclair, Consulting Engineers, 97, Pitt Street, Sydney, N.S.W., Australia ... (C E) Nov. 1884
Sinton, John K., 26, Sandhill, Newcastle-upon-Tyne ... ... (E) Nov. 1885
Sisson, Wm., Gloucester ... ... (E & N A) Oct. 1888
Sivewright, G. W., 5, Radcliffe Terrace, Hartlepool .. ... (S) Nov. 1886
Skinner, Leslie, Ravensbourne Terrace, South Shields (S) { Graduate, Dec. 1886; Member, Oct. 1891 }
Smith, C. E., Crowesby, Clifton Avenue, West Hartlepool .. (E) Nov. 1888
Smith, Eustace, 5, Queen Street, Newcastle-upon-Tyne ... ... (S) Nov. 1884
Smith, L. Eustace, 22, St. Mary's Place, Newcastle-upon-Tyne... ... . (E) { Graduate, Oct. 1889; Member, Oct. 1892 }
Smith, Thomas, Steam Crane Works, Old Foundry, Rodley, near Leeds (E) Oct. 1888
Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle-upon-Tyne ... ... (E) April 1885
Smith, Wm., 152, Roker Avenue, Sunderland M. ... ... (E) Nov. 1884
Snook, Francis W. G., 83, Park Road, Newcastle-upon-Tyne ... (E) Dec. 1896
Soliani, Nabor, Col., Sotto Direzione Delle Costruzioni Navali del Rº Cantiere di Castellammare di Stabi, Italy ... ... (S) Jan. 1885
Sowter, Isaac G., c/o Messrs. Samuel F. Hodge & Co., Detroit, Michigan, U.S. America .. .. (E) Jan. 1889
Spear, John, c/o Messrs. T. Wilson & Sons, Hull ... ... (E) Oct. 1887
Spearman, Richard, Eachwick House, Dalton, Newcastle-upon-Tyne (E) Feb. 1889
Spence, W. G., c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne (*Life Member*) ... ... (E) Nov. 1884
Spencer, J. W., Newburn Steel Works, Newburn-on-Tyne ... (E) Feb. 1885
Stafford, William, 8, Tyne Vale Terrace, Bensham, Gateshead-on-Tyne ... ... (E) Nov. 1885
Staig, William Andrew, Station Road, Wallsend-on-Tyne ... (E) Feb. 1897
Stansfield, George R., The Grove, Westoe, South Shields ... ... (E) Mar. 1891
Stephen, A. E., Linthouse, Govan, Glasgow ... ... (E & S) June 1896
Stephen, John Murray, Linthouse Engine Works, Govan, Glasgow (E) Oct. 1895
Stephenson, Bernard, 15, St. John's Terrace, Middlesbrough ... (E) Dec. 1896
Stephenson, C., 2, Elm Terrace, The Green, Wallsend-on-Tyne ... (S) Nov. 1884
Stevenson, Wm., 24, Heaton Grove, Heaton, Newcastle-upon-Tyne (E) Nov. 1884
Stewart, James, 31, Lily Avenue, Jesmond, Newcastle-upon-Tyne (E) Oct. 1890
Stirling, Andrew, Jun., 1, Greenvale Terrace, Dumbarton... ... (E) Feb. 1888
Stirzaker, J. C., 16, Grosvenor Place, Newcastle-upon-Tyne ... (E) Nov. 1884
Stoddart, J. E., Lloyd's Register of Shipping, White Lion Court, Cornhill, London, E.C. ... ... (E SUR) Oct. 1888

ELECTED.

Stoddart, Swinton, 24, North Milburn Street, Sunderland (S) { Graduate, May 1885 / Member, Nov. 1892
Stokoe, Thomas W., 55, Northcote Street, South Shields ... ... (S) Dec. 1885
Stone, Wm., 13, Rosslyn Terrace, Sunderland ... ... (S) Nov. 1884
Strong, George Aaron, 87, West Percy Street, North Shields ... (E) Dec. 1889
Stronghair, John W. H., 6, Wallace Terrace, Ryton-on-Tyne ... (E) Nov. 1894
Summers, James, 114, Grange Road West, Middlesbrough ... (E) Mar. 1889
Summersby, Robert Arthur, 4, Otterburn Terrace, Jesmond, Newcastle-upon-Tyne ... ... (E) Oct. 1891
Surtees, Francis V., Westfield, Renfrew ... ... (S) Dec. 1892
Surtees, R., Frame House, Low Teams, Gateshead-on-Tyne ... (E) Nov. 1884
Swan, A. S., Grove House, Gosforth, Newcastle-upon-Tyne ... (S) Nov. 1888
Swan, Charles Sheriton, c/o Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne... ... ... (S) { Graduate, Nov. 1890 / Member, Mar. 1894
Swan, H. F., North Jesmond, Newcastle-upon-Tyne .. ... (S) Nov. 1884
Swinburne, M. W., 117, Park Road, Newcastle-upon-Tyne ... (E) Nov. 1884
Swinburne, T. M., Bewick Road, Gateshead-on-Tyne ... ... (E) Jan. 1885
Swinney, W., 10, Wentworth Terrace, Westoe Lane, South Shields (E) Dec. 1888
Sydserff, Thomas B., Jun., 2, Claremont Villas, Totterdown, Bristol (E) Oct. 1888
Syme, James, Fairfield Works, Govan, Glasgow ... ... (E) Oct. 1892

T.

Tate, Chas. H., 7, Side, Newcastle-upon-Tyne ... ... (N A) Nov. 1884
Taylor, Alexander, Maritime Buildings, King Street, Newcastle-upon-Tyne... ... ... (E) Nov. 1884
Taylor, C. W., South Garth, Westoe, South Shields ... ... (E) April 1885
Taylor, John, 1, St. Alban's Place, Tynemouth ... ... (E) Dec. 1894
Thompson, C. E., Messrs. J. L. Thompson & Sons, North Sands, Sunderland... ... ... (S) Nov. 1884
Thompson, Charles, M.A., 33, Mosley Street, Newcastle-upon-Tyne (E) Feb. 1887
Thompson, Jas., 2, Carlton Terrace, Sunderland ... ... (E) Dec. 1886
Thompson, John Augustus, 12, London Street, Fenchurch Street, London, E.C. ... ... (E & N A) Oct. 1892
Thompson, J. L., North Sands Shipyard, Sunderland ... ... (S) Nov. 1884

ELECTED.

Trewent, F. J., 43, Billiter Buildings, Billiter Street, London, E.C. ... ... (S) Dec. 1884
Trowell, Wm. John, 37, Caroline Street, Jarrow-on-Tyne ... (E) Oct. 1894
Turnbull, Charles, Jun., Hylton Lodge, North Shields ... ... (E E) Oct. 1894
Turner, S. J., 71, Warwick Street, Heaton, Newcastle-upon-Tyne (E) Mar. 1887
Turpie, David Whyte, c/o Messrs. W. Pickersgill & Sons, Southwick, Sunderland ... ... (S) Dec. 1895
Tuxen, Holger, Bureau Veritas Register of Shipping, Custom House Court, Quayside, Newcastle-upon-Tyne ... ... (S) Nov. 1896
Twaddell, James L., 4, St. John's Terrace, Jarrow-on-Tyne ... (S) Oct. 1891
Tweedy, J., Neptune Works, Walker-on-Tyne ... ... (E) Nov. 1884
Twigden, George J., c/o Messrs. Hick Bros., Mount Stuart Square, Cardiff ... ... (E) Jan. 1890
Tyzack, George, Dean Street, South Shields... ... ... (E) April 1888

U.

Ullstrom, Otto, 84, Leadenhall Street, London, E.C. ... ... (S) Nov. 1884
Ulm, John, The Arsenal, Pola, Austria ... ... (E) Nov. 1885

V.

Vianson, N. E., *vià* Corsica 20/5, Genoa, Italy ... ... (E) Dec. 1885
Vick, R. W., Messrs. Furness, Withy & Co., Middleton Shipyard, West Hartlepool ... ... (S) Nov. 1888
Vivet, Leon, 25, Rue de Pornichat, St. Nazaire, France ... ... (N A) Nov. 1892

W.

Wadagaki, Yasuzo, Union Ironworks, San Francisco, California ... (E) Jan. 1891
Wailes, T. W., Mount Stuart Dry Docks, Cardiff ... ... (E & S) Oct. 1887
Wait, Thomas Herbert, Cail's Buildings, Quayside, Newcastle-upon-Tyne ... ...(C E) Dec. 1893
Wake, Tom, 2, Cliff Terrace, Hartlepool ... ... (E) April 1892
Wakeham, John F., 38, King John Street, Heaton, Newcastle-upon-Tyne ... ... (S) { Graduate, Mar. 1893 / Member, Oct. 1895 }
Walker, Archibald, 143, Leith Walk, Leith, N.B. ... ... (E) April 1887
Walker, Henry, 11, Oxford Terrace, Gateshead-on-Tyne ... ... (E E) Feb. 1893
Walker, John, c/o Messrs. R. Stephenson & Co., Limited, South Street, Newcastle-upon-Tyne ... ... (E & S) Nov. 1891
Wallau, J., 68, Coatsworth Road, Gateshead-on-Tyne ... ... (E) Nov. 1884
Walliker, J. F., Lloyd's Register of Shipping, Bute Docks, Cardiff (E) Nov. 1885
Walliker, John George, c/o Messrs. Hodges & Walliker, Barry Docks, South Wales ... ... (E) May 1896
Wallis, Robert, Wh.Sc., Point Pleasant House, Wallsend-on-Tyne (E) April 1891
Walter, Max, Norddeutscher Lloyd, Central Bureau, Bremen ... (S) Feb. 1893
Walton, J. G., 26, Fenchurch Street, London, E.C. ... ... (E) Nov. 1884
Walton, Samuel, 34, Pollard Street, South Shields ... ... (E) Dec. 1893
Warburton, J., 4, Beauclerc Terrace, Sunderland ... ... (S) Nov. 1884
Warburton, John Arthur, 47, Harrogate Street, Sunderland (E) { Graduate, Mar. 1894 / Member, Nov. 1896 }

		Elected
Ward, John, c/o Messrs. W. Denny & Bros., Dumbarton	(S)	Dec. 1891
Ward, Mark M., 76, Church Street, West Hartlepool	(E)	Dec. 1893
Wardale, Henry, 5, Collingwood Terrace, Gateshead-on-Tyne ...	(E)	Feb. 1888
Warden, Thomas M., 21, Windermere Street, Gateshead-on-Tyne	(E)	Oct. 1894
Watson, Thomas Henry, 10, Neville Street, Newcastle-upon-Tyne	(SUR)	Jan. 1896
Watt, Robert B., c/o Messrs. Sir Raylton Dixon & Co., Cleveland Shipyard, Middlesbrough	(S)	April 1888
Watts, Philip, Elswick Shipyard, Newcastle-upon-Tyne	(S)	Nov. 1885
Weidemann, Nils, Det-Norske Veritas, Christiania, Norway ...	(SUR)	Jan. 1892
Weighton, R. L., M.A., Durham College of Science, Barras Bridge, Newcastle-upon-Tyne	(E)	Nov. 1884
Weir, George Dobie, Northumberland Engine Works, Wallsend-on-Tyne	(E)	Oct. 1894
Weir, John, c/o Messrs. J. Scott & Co., Abden Works, Kinghorn, N.B.	(E)	Nov. 1884
Weir, William, c/o Messrs. Wigham Richardson & Co., Walker-on-Tyne	(E)	Nov. 1889
Welton, J. G., 12, Hendon Valley Road, Sunderland	(E)	Nov. 1893
West, Henry H., British and Foreign Chambers, 5, Castle Street, Liverpool	(E & N A)	Oct. 1886
Westgarth, Tom, Messrs. Sir C. Furness, Westgarth, & Co., Middlesbrough	(E)	Oct. 1886
Westmacott, Alfred, Benwell Hill, Newcastle-upon-Tyne	(E)	Graduate, Dec. 1885; Member, Nov. 1892
Westmacott, P. G. B., Benwell Hill, Newcastle-upon-Tyne ...	(E)	Nov. 1884
Wheater, Chas. Busfield, 14, York Street, Newcastle-upon-Tyne ...	(E)	Oct. 1894
White, C., 13, Mosley Street, Newcastle-upon-Tyne	(E)	Nov. 1884
White, Ernest T., 6, Rydal Street, Gateshead-on-Tyne	(E)	Graduate, May 1889; Member, Jan. 1894
White, R. Saxon, Messrs. Sir W. G. Armstrong & Co., Walker Shipyard, Walker-on-Tyne	(S)	Nov. 1884
Whitfield, Thomas, Messrs. Tyne Dock Engineering Co., South Shields	(E)	April 1896
Whittaker, Frederick W., Dockyard, Messrs. Mersey Docks and Harbour Board, Liverpool	(E)	Oct. 1892

[redacted]

		ELECTED.
Withy, H., Middleton Shipyard, West Hartlepool	(S)	Nov. 1884
Wood, Henry Alfred, Oakfield Road, North Ormesby, Middlesbrough-on-Tees	(S)	Dec. 1893
Wood, John Scott, 6, Eslington Terrace, Newcastle-upon-Tyne	(S)	Graduate, Oct. 1891 Member, Oct. 1896
Wood, Joseph, Foundry Manager, Deptford Yard Brass Works, Sunderland	(E)	Mar. 1895
Wortley, Henry B., 23, Bedford Road, Rock Ferry, Birkenhead	(S)	Graduate, Jan. 1886 Member, Nov. 1892
Wray, Thomas W., Board of Trade Offices, Sunderland	(SUR)	Jan. 1895
Wright, R., 5, Hawthorn Terrace, Newcastle-upon-Tyne	(E)	Nov. 1884

Y.

Young, Andrew, Bureau Veritas Register of Shipping, 155, Fenchurch Street, London, E.C.	(S)	Graduate, Feb. 1892 Member, May 1893
Young, J. Denholm, 2A, Tower Chambers, Liverpool	(E)	Oct. 1888
Younger, R., Elmire House, Heaton, Newcastle-upon-Tyne ...	(E)	Nov. 1884

Z.

Zeeman, J. H., 5, Willemsplein, Rotterdam	(S)	Oct. 1889

ASSOCIATES.

A.

Adam, John B., 8, Osborne Terrace, Newcastle-upon-Tyne ...	(O)	Nov. 1893
Anderson, Daniel G., Burnaby Lodge, Ryton-on-Tyne	(A)	Nov. 1893
Armstrong, S., Beaconsfield Street, Hartlepool	(A)	Nov. 1888
Arnott, James, 25, Dean Street, Newcastle-upon-Tyne	(S O)	Oct. 1895

B.

Bacon, William Charles, Chadwick House, West Hartlepool ...	(S O)	Dec. 1890
Ball, Alfred F., 14, Landsdowne Terrace, Gosforth, Newcastle-upon-Tyne	(A)	Nov. 1894
Barklam, George, 167, Dudley Port, Tipton, Staffordshire ...	(A)	April 1888
Barr, John Smith, 16, Broad Chare, Quayside, Newcastle-upon-Tyne...	(A)	Nov. 1893
Barwick, J. S., Ashbrook Grange, Sunderland	(S O)	Nov. 1884
Bell, J. H., Netherhall, Lenzie, Dumbartonshire	(I & S M)	Oct. 1887
Beynon, Thomas, 9, Dean Street, Newcastle-upon-Tyne	(E A)	Oct. 1891
Bigge, C. W., Northern Counties Club, Newcastle-upon-Tyne ...	(A)	Dec. 1889
Bingham, Col. J. E., Manufacturer, West Lea, Sheffield	(M)	Mar. 1895
Bird, William, 8, Latimer Street, Tynemouth	(A)	May 1896
Blacklin, Richard James, Dinsdale House, Brougham Terrace, West Hartlepool	(S O)	Dec. 1890
Briggs, R. S., Moorlands, Sunderland	(S O)	Dec. 1886
Brims, D. N., 4, St. Nicholas' Buildings, Newcastle-upon-Tyne ...	(C)	Nov. 1893

ELECTED.

Brown, Percy Ledger, 1, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (E A) Oct. 1896
Brunton, John, 3, Prior's Terrace, Tynemouth ... ... (S O) Oct. 1886
Bullen, Tempest C., c/o Messrs. H. E. Moss & Co., K, Exchange Buildings, Newcastle-upon-Tyne ... ... (S O) Nov. 1891

C.

Caminos, T. L., Overseer, Argentine Navy, 47, Chester Street, Birkenhead... ... ... June 1896
Carr, Ralph, Thornleigh, Clayton Road, Newcastle-upon-Tyne (A & S O) Nov. 1886
Cassap, William, 15, East Field Road, Walthamstow, Essex ...(SUR) Feb. 1890
Caws, Frank, 22, Fawcett Street, Sunderland ... ... (C E) Oct. 1892
Cohan, Edward Asher, 2, Rumford Place, Liverpool ... ... (S O) Nov. 1889
Cooper, Charles, Average Adjuster, Wellington Road, West Hartlepool ... ... (A A) April 1893
Corbitt, Michael, Springfield, Gateshead-on-Tyne ... ... (R M) Jan. 1890
Cory, John, Cardiff ... ... (S O) June 1896
Coull, John, Baltic Chambers, Quayside, Newcastle-upon-Tyne ... (S O) Oct. 1886
Coverdale, R. H., Messrs. J. Coverdale & Sons, Steamship Owners, West Hartlepool ... ... (S O) Nov. 1888
Craik, A., Messrs. Blyth Dry Dock, Limited, Blyth ... ... (A) June 1896
Crawford, Thomas, 10, Haldane Terrace, West Jesmond, Newcastle-upon-Tyne ... ... (A) Oct. 1896
Crosier, Edward James, 3, The Hawthorns, East Boldon ... ... (A) Oct. 1889
Culliford, J. H. W., 45, West Sunniside, Sunderland ... ... (S O) Nov. 1884

D.

Dodds, E. F., 36, Side, Newcastle-upon-Tyne ... ... (A) Nov. 1893
Dodds, John B., 36, Side, Newcastle-upon-Tyne ... ... (CHEM) Oct. 1888
Donkin, Geo., Jun., 50, Grove Street, Newcastle-upon-Tyne ... (A) April 1897
Dove, Edward John, 5, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (M) Oct. 1890

E.

[redacted]

ELECTED.

Hedley, John H., 10, Esplanade West, Sunderland ... ... (S) Dec. 1886
Henzell, Robert, 43, Sanderson Road, Newcastle-upon-Tyne (*Life Associate*) ... ... (A) Nov. 1893
Heslop, Richard O., Akenside Hill, Newcastle-upon-Tyne... (I & S M) Oct. 1885
Hodge, W. P., c/o Messrs. John Cory & Sons, Mount Stuart Square, Cardiff ... ...(M S) Mar. 1896
Hogg, John Thomas, Tyneside Brass Works, Barry Docks, South Wales ... ... (I & S M) April 1896
Holliday, Henry, Beechgrove, Blackhill, Co. Durham ... ... (A) Nov. 1895
Hollis, H. E., 40, Union Street, Glasgow ... ... (I & S M) Feb. 1885
Hudson, Ralph M., Jun., 8, The Cedars, Sunderland ... ... (S O) Dec. 1886
Hudson, Robert, 24, Hotspur Street, Tynemouth ... ... (A) Nov. 1895
Hunting, Charles, 1, Exchange Buildings, Quayside, Newcastle-upon-Tyne ... ...(S O) April 1886
Hurndall, Sidney E., Printing Court Chambers, Newcastle-upon-Tyne... ... ... (A) Nov. 1893

I.

Innes, Charles H., Rutherford College, Newcastle-upon-Tyne ... (E) Oct. 1891

J.

Jenkins, Alfred, Tweed House, Victoria Terrace, Jarrow-on-Tyne (A) Nov. 1893
Jobson, W. J., c/o Messrs. Robert Stephenson & Co., South Street, Newcastle-upon-Tyne ... ... (A) May 1889
Jordan, John George, 24, Stansfield Street, Sunderland ... ... (A) Nov. 1892

K.

Kemp, James, Baltic Chambers, Newcastle-upon-Tyne ... ...(S O) Feb. 1896
Knott, James, Prudential Buildings, Newcastle-upon-Tyne ... (S O) Dec. 1896

L.

Lennard, William, c/o Messrs. J. M. Lennard & Sons, Middlesbrough ... ... (S) Dec. 1891
Lloyd, John, Deptford Shipyard, Sunderland ... ... (A) Oct. 1894
Lockie, John, Bank Chambers, Sandhill, Newcastle-upon-Tyne ... (S O) Oct. 1892
Lodwidge, Philip, Baltic Chambers, Sunderland ... ... (A) June 1896

M.

Macarthy, George E., 9, Dean Street, Newcastle-upon-Tyne ...(S O) Oct. 1887
Mail, Douglas B., 14, Humbleton View, Sunderland ... ...(M S) Feb. 1895
Maughan, William, 13, Mosley Street, Newcastle-upon-Tyne ... (A) Feb. 1887
McIntosh, R. Y., 34, Dean Street, Newcastle-upon-Tyne ... ... (E A) Nov. 1891
McIntyre, John, 3, Abbotsford Terrace, Newcastle-upon-Tyne ... (S O) Jan. 1885
Meek, John George, 13, Belle Vue Park, Sunderland ... ... (A) Dec. 1894
Milburn, J. D., Queen Street, Newcastle-upon-Tyne ... ... (S O) Nov. 1884
Miller, T. R., 9, Great St. Helen's, London, E.C. ... ... (A & S O) Nov. 1884
Mitcalfe, John Stanley, Chairman of Northern Maritime Insurance Co., Maritime Buildings, Newcastle-upon-Tyne ... (A & S O) Jan. 1892
Morton, Benjamin, 29, Azalea Terrace N., Sunderland ... ...(SUP) Dec. 1895

ELECTED.

Muir, James, 2, Dingle Lane, Liverpool ... ... (M S) Nov. 1893
Mulherion, G. F., 3, Rothbury Terrace, Heaton, Newcastle-upon-Tyne ... ... (A) Nov. 1884
Muller, J. C. F., 28, Vieille Route, Antwerp ... ...(SUR) Feb. 1890
Murray, Matthew, The Green, Wallsend-on-Tyne ... ... (A) Nov. 1893

N.

Nicholson, John, 7, Side, Newcastle-upon-Tyne ... ... (M S) Nov. 1890
Nixon, John, c/o Messrs. Blyth Shipbuilding Co., Blyth ... ... (A) Oct. 1894

O.

O'Hagan, James, 99, Quai de la Fosse, Nantes, France ... ... (A) Oct. 1888
Olsen, Hans Benedick, 70, Church Street, West Hartlepool ... (S O) Mar. 1893
Osbourne, Jas., 11, The Oaks, Sunderland ... ... (S) Jan. 1885

P.

Patterson, Thos., 2, The Elms, Sunderland ... ... (S) Jan. 1885
Petersen, Ferd. William, Messrs. Petersen & Tate, Bank Chambers, Sandhill, Newcastle-upon-Tyne ... ... (S O) Nov. 1893
Phalp, Oliver, Almora, 37, Richmond Road, Cardiff ... ...(SUR) Feb. 1889
Pinkney, Thomas, 3, Ashbrook Terrace, Sunderland ... ... (S O) Dec. 1886
Proctor, J. H., 22, Hawthorn Terrace, Newcastle-upon-Tyne ... (I M) Nov. 1893

R.

Radcliffe, Daniel, Cardiff ... ... (S O) June 1896
Radcliffe, Henry, Cardiff ... ... (S O) June 1896
Radloff, Captain O. ... ... (M S) Nov. 1891
Ramsay, J. W., 13, Northbrook Road, Lee, Kent ... ... (A) Feb. 1885
Reichwald, A., Lombard Street, Newcastle-upon-Tyne ... ... (A) Nov. 1884
Reid, Sidney, Printer, Akenside Hill, Newcastle-upon-Tyne ... Nov. 1884
Renwick, G., Messrs. Fisher, Renwick, & Co., Maritime Buildings, King Street, Newcastle-upon-Tyne ... ... (S O) Nov. 1884
Rickinson, John, 9, Church Street, West Hartlepool ... ... (S O) Nov. 1890
Riddle, John C., 60, Grey Street, Newcastle-upon-Tyne ... ... (A) May 1896
Robson, Frederick, 46, Dean Street, Newcastle-upon-Tyne (S I M) Oct. 1887
Robson, John William, 6, King Street, Newcastle-upon-Tyne ... (M) April 1896
Robson, Thos., Causeway House, Sunderland ... ... (S O) Nov. 1884
Runcieman, John Finley, Village Terrace, Westoe, South Shields (M S) Nov. 1892
Runciman, Walter, Fernwood House, Clayton Road, Newcastle-upon-Tyne ... ... (S O) May 1895

S.

Scholefield, A., 17, Sandhill, Newcastle-upon-Tyne ... ... (S O) Nov. 1884
Scott, W. H., Messrs. Scott Brothers, 46, Sandhill, Newcastle-upon-Tyne... ... ... (S O) Nov. 1884
Snowdon, W. F., 32, Side, Newcastle-upon-Tyne ... ... (E A) Dec. 1886
Squance, J. W., 13, The Avenue, Sunderland ... ... (M S) April 1888

ELECTED.

Storey, Christopher, 28, Holly Avenue, Jesmond, Newcastle-upon-Tyne... ... ... (A) April 1896
Swan, Isaac J., Grove House, Gosforth, Newcastle-upon-Tyne ... (S O) Feb. 1888

T.

Tate, Arthur, Messrs. Petersen & Tate, Bank Chambers, Sandhill, Newcastle-upon-Tyne ... ... (O) Nov. 1893
Thompson, V. T., Baltic Chambers, Sunderland ... ...(S O) Dec. 1886
Todd, John Stanley, Percy Park, Tynemouth ... ... (U) Nov. 1895
Towers, Edward, 4, Latimer Street, Tynemouth ... ... (A) Oct. 1888
Trechmann, Otto K., Church Street, West Hartlepool ... ... (S O) Oct. 1896
Turner, Edwin, 32, Powell Road, Clapton, London, N.E. ... ... (A) Oct. 1895

W.

Wade, Wentworth S., 2, Otteran Place, South Parade, Waterford (M S) April 1895
Wait, James, Maritime Buildings, King Street, Newcastle-upon-Tyne... ... ... (S O) Nov. 1884
Walker, James, 87, Jesmond Road, Newcastle-upon-Tyne... ... (S O) Mar. 1894
Watson, Thomas W., Gisburn House, Hartlepool ... ... (M S) Nov. 1890
Weatheral, Henry, 27, Alderson Street, West Hartlepool ... ... (A) Feb. 1893
Whitfield, John, Blyth ... ... (S) Nov. 1895
Wight, Robert M., 42, The Exchange, Cardiff ... ... (M) June 1896
Wilson, F. Alfred, 45, West Sunniside, Sunderland ... ... (I M) Nov. 1893

Y.

Yeoman, F., Messrs. Murrell & Yeoman, West Hartlepool ... (S O) Nov. 1888
Younger, Robert Laurie, Messrs. Greenock Steamship Co., Limited, Greenock ... ... (A) Feb. 1889

GRADUATES.

A.

Adams, Cecil Turner, 196, Holland Road, Kensington, London, W. (E) Oct. 1891
Adams, Dawson, 4, Richmond Terrace, Ripon Street, Preston, Lancashire ... ... (E E) Oct. 1894
Andrew, David, Jun., 33, Osborne Road, Newcastle-upon-Tyne ... (E) Oct. 1891

B.

Baker, Ernest F., Assistant Engineer, H.M.S. "Nile," Mediterranean Fleet, Malta ... ... (E) Nov. 1892
Barbour, John, 1, Logan Terrace, South Shields ... ... (E) Nov. 1890
Beale, Harry, Otterburn Terrace, Newcastle-upon-Tyne ... ... (S) Jan. 1891
Beilby, Norman Harry, 1, Kingsley Place, Heaton, Newcastle-upon-Tyne ... ... (E) Dec. 1893
Bentham, Frederick Lister, 9, Bellegrove Terrace, Newcastle-upon-Tyne ... ... (E) Dec. 1892
Binns, Aubrey B., 23, Thornhill Terrace, Sunderland ... ... (E) Oct. 1894

ELECTED.

Borthwick, Robert J., 8, Kensington Terrace, Newcastle-upon-Tyne ... ... (E) Dec. 1894

Boswell, Cecil Robert, Frances Villa, Highfield Road, Dartford ... (E) Nov. 1893

Bowden, John, Sheriff Mount, Gateshead-on-Tyne ... . (E) Jan. 1894

Brown, George M., 11, Alma Street, Sandyford Road, Newcastle-upon-Tyne ... ... (E) April 1895

Brown, Thomas Scott, Jun., 18, Nixon Street, Newcastle-upon-Tyne ... ... (E) Oct. 1895

Bryers, Charles, 10, The Avenue, Sunderland ... ... (E) Dec. 1892

Buchanan, Samuel, Jun., 51, Welbeck Road, Walker-on-Tyne ... (S) Feb. 1897

Bulmer, Albert Edward, 1, Graingerville North, Newcastle-upon-Tyne... ... ... (E) Nov. 1895

Bulmer, Septimus, 1, Graingerville North, Newcastle-upon-Tyne (E) May 1894

Burbidge, Alfred H., 15, North View, Heaton, Newcastle-upon-Tyne... ... ... (E) Oct. 1895

Burn, Donald B., 7, The Elms West, Sunderland ... ... (S) Nov. 1893

C.

Cadman, C. C., Clifton Holme, York ... ... (E) Nov. 1891

Cairns, Charles W., Cheriton House, Lothian Road, West Hartlepool ... ... (E) Nov. 1894

Carpmael, Richard Herbert, 20, East Parade, Newcastle-upon-Tyne (E) Jan. 1893

Carr, Ralph, Jun., Thornleigh, Clayton Road, Newcastle-upon-Tyne (E) Jan. 1894

Carter, Thomas, 6, Larkspur Terrace, Newcastle-upon-Tyne ... (E E) Oct. 1895

Chapman, John Frederick, 44, Falconar Street, Newcastle-upon-Tyne... ... ... (E E) Dec. 1895

Coatsworth, George S., Oaks West, Sunderland ... ... (E) Nov. 1891

Cole, Alfred, 5, Holmside Place, Heaton, Newcastle-upon-Tyne ... (E E) Jan. 1896

Cookson, John Annable, 2, St. Edmund's Road, Gateshead-on-Tyne (E) Dec. 1895

Coulson, Richard H. A., 12, East View, South Shields ... ... (E) April 1897

Crawford, J. F., "Palmyra," St. George's Road, Waterloo, near Liverpool ... ... (E) Nov. 1893

Crawhall, Henry F., 30, West Parade, Newcastle-upon-Tyne ... (E E) May 1894

[redacted]

ELECTED.

Duckitt, Talbot, Leazes Gate Villa, Spital Tongues, Newcastle-upon-Tyne ... ... (E E) Oct. 1891
Dunford, Thomas, 74, Osborne Road, Newcastle-upon-Tyne ... (E) Nov. 1896

E.

Edminson, Frank A., Fairfield House, Dumbarton Road, Partick, Glasgow ... ... (S) Nov. 1893

F.

Featherstonhaugh, Albany, 13, Park Place West, Sunderland ... (E) Oct. 1894
Fleet, Herbert A., Coney House, Birtley, Durhamshire ... ... (E) Mar. 1897
Ford, Hugh M., Assistant Engineer, R.N., H.M.S. "Trafalgar," Mediterranean Squadron, Malta... ... ... (E) Nov. 1893
Forster, Edgar S., 26, Hotspur Street, Tynemouth ... ... (E) Jan. 1894
Foster, L. P., 23, Lovaine Crescent, Newcastle-upon-Tyne ... (E) Nov. 1893
Fraser, John H., New Winning Tavern, Wallsend-on-Tyne ... (E) Oct. 1895

G.

Gibson, Thomas, 162, Roker Avenue, Monkwearmouth, Sunderland (E) Nov. 1893

H.

Harvey, Herbert B., Roker Villa, Heaton Park View, Heaton, Newcastle-upon-Tyne ... ... (E) Jan. 1896
Hepburn, James M., 17, Grosvenor Place, Jesmond, Newcastle-upon-Tyne ... ... (E) Nov. 1895
Hewitt, John, 29, Holly Street, Jarrow-on-Tyne ... ... (S) Nov. 1890
Hick, Charles, 2, Garibaldi Terrace, South Shields ... ... (E) Oct. 1894
Hinchliffe, Robert, 25, Hawthorn Street, Newcastle-upon-Tyne ... (S) Nov. 1893
Hudson, Charles J., 12, Cresswell Terrace, Sunderland ... ... (E) Nov. 1894
Hughes, Thomas C., 3, Summerhill Street, Newcastle-upon-Tyne... (E) Nov. 1893

J.

Jepson, Henry, 34, St. Mary's Place, Newcastle-upon-Tyne ... (E) Nov. 1893
Johnson, James, 11, Poplar Crescent, Gateshead-on-Tyne ... ... (E) Oct. 1896

K.

Kennedy, Robert Sinclair, 8, Granville Street, Gateshead-on-Tyne (E) April 1893
Kent, Samuel N., Lindenhurst, Heaton, Newcastle-upon-Tyne ... (E) Mar. 1896
Kitchin, Arnold ... ... (E) Dec. 1892

L.

Lace, Basil, 26, Heaton Grove, Heaton, Newcastle-upon-Tyne... (E) Nov. 1895
Laing, Bryan, Thornhill, Sunderland... ... ... (S) Dec. 1895
Leighton, James, 17, Eversley Place, Heaton, Newcastle-upon-Tyne ... ... (E) Jan. 1896

		ELECTED.
Lindsay, James D., Fernville, Gosforth, Newcastle-upon-Tyne ...	(E E)	Jan. 1897
Lishman, John James, Jun., 16, Lovaine Place, North Shields ...	(E)	Dec. 1892
Lumley, William, 38, Sidney Grove, Gateshead-on-Tyne	(E)	June 1896
Lynn, John Robert Dent, 11, Chatsworth Street, Sunderland ...	(E)	April 1893

M.

Macdonald, William C., 15, Union Street, Hartlepool	(E)	Mar. 1895
[illegible] Charles, c/o Messrs. J. Penn & Sons, Engineers, Greenwich	(E)	Nov. 1894
[illegible] George, [illegible], Albert Road, Jarrow-on-Tyne	(S)	Oct. 1896
[illegible], Frank E., 14, Belsize Park Gardens, Hampstead, London, N.W.	(E)	Nov. 1891
[illegible], Clifford R.	(S)	Oct. 1892
[illegible], Cecil, Ovington House, Ovingham, R.S.O., Northumberland	(E)	Oct. 1895
[illegible], Charles H. C., 37, Woodbine Terrace, Pallion, Sunderland	(E)	Nov. 1895
[illegible] Thomas, Alexandra Terrace, Govan, Glasgow	(S)	Oct. 1895
[illegible] Frank, 20, Victoria Street, Newcastle-upon-Tyne ...	(E)	Mar. 1889
[illegible], James Percy, 43, Grove Street, Newcastle-upon-Tyne ...	(E E)	Feb. 1897
[illegible], Edward F., 180, Gloucester Road, Newcastle-upon-Tyne	(E)	Feb. 1892

N.

[illegible] Bruce Gray, 37, Grove Street, Newcastle-upon-Tyne ...	(E)	Oct. 1891
[illegible], James Henry, 30, Azalea Terrace South, Sunderland ...	(E)	Mar. 1892

O.

[illegible] Hans B., Jun., Wellington Road, West Hartlepool... ...	(E)	Feb. 1895

P.

[illegible] Henry G.	(E E)	Dec. 1894
[illegible], Arthur, 10, Campbell Street, Newcastle-upon-Tyne ...	(E)	Nov. 1895
[illegible], Robt. G., Thorneyholme, Blaydon-on-Tyne	(E)	Jan. 1895
[illegible] Standen L., c/o British India Engineers' Club, Old Post Office Street, Calcutta	(E)	Dec. 1893
[illegible] James, 10, Beech Grove Road, Newcastle-upon-Tyne ...	(S)	Nov. 1893

[redacted]

	ELECTED.
Robinson, Charles O., Ingleside, North Shields	(E) Dec. 1893
Robson, Nathaniel E., 11, Point Pleasant Terrace, Wallsend-on-Tyne...	(E) Dec. 1894
Robson, Robert, 166, Rye Hill, Newcastle-upon-Tyne	(E E) Dec. 1894
Ross, William Daniel, 11, Alma Street, Sandyford Road, Newcastle-upon-Tyne	(E) Feb. 1896
Routledge, Herbert J., Stapleton House, Jarrow-on-Tyne ...	(E E) Mar. 1897
Rowles, Henry P., 8, Belle Vue Terrace, Gateshead-on-Tyne ...	(E) Oct. 1896

S.

Scott, Alex. C., Malvern House, Edward's Road, Whitley, Newcastle-upon-Tyne	(E) Jan. 1895
Scott, Joseph, 49, Leazes Terrace, Newcastle-upon-Tyne	(E) Dec. 1891
Scott, W. A., 100, George Road, Newcastle-upon-Tyne	(E E) Oct. 1894
Shand, William Lamont, 39, Holly Avenue, Newcastle-upon-Tyne	(E) Nov. 1895
Short, Thomas Smart, c/o Messrs. Short Brothers, Pallion, Sunderland...	(S) Oct. 1892
Sitwell, John Knightley, 24, Archbold Terrace, Newcastle-on-Tyne	(E) Nov. 1896
Smith, William S., West Villa, The Green, Wallsend-on-Tyne ...	(S) Dec. 1893
Squire, Charles E., Corporation Electricity Works, Blackpool ...	(E E) Nov. 1893
Stephens, Henry C. J., 94, Fortress Road, London, N.W.	(E) Oct. 1890
Stephenson, Robert, c/o Messrs. Robt. Stephenson & Co., Limited, South Street, Newcastle-upon-Tyne	(E) Mar. 1894
Stuart, John, 57, Heaton Park Road, Newcastle-upon-Tyne ...	(E) Dec. 1895
Summerson, Benjamin, Deneholme, Monkseaton, Northumberland	(E) Dec. 1892

T.

Thomas, Robert Gates, 6, Queen Anne Terrace, Gateshead-on-Tyne	(E) Nov. 1894
Thomas, William, 4, Victoria Crescent, Cullercoats...	(E) Oct. 1895
Townend, Sidney, 3, St. Eleanor Street, Cullercoats	(E) Nov. 1895
Turner, Charles N., 2, Newburn Lane, Newburn-on-Tyne... ...	(E) April 1896

V.

Vardy, George, Neptune Engine Works, Walker-on-Tyne... ...	(E) Oct. 1894
Varty, B. S., 16, Hawthorn Street, Newcastle-upon-Tyne	(S) Oct. 1895

W.

Walker, Gavin Knox, 87, Jesmond Road, Newcastle-upon-Tyne ...	(E) Mar. 1894
Ward, Joseph P., C Department, Messrs. Tangye's Limited, Birmingham	(E) Oct. 1895
Wawn, T. Noel, 6, Belle Vue, Sunderland	(E) Nov. 1893
Wildridge, Richard, 28, Grove Street, Newcastle-upon-Tyne ...	(E) Oct. 1895
Wilkin, Ernest Vivian, 11, Appold Street, Finsbury, London, E.C.	(E) Nov. 1892
Willcox, Reginald J. N., The Oaks West, Sunderland	(E) Mar. 1892
Wilson, John R. S., Lyndhurst, Gosforth, Newcastle-upon-Tyne ...	(E) Mar. 1894
Wilson, Percy P., Bank House, Fawcett Street, Sunderland ...	(S) Jan. 1896
Wright, George Hudson, 35, Washington Terrace, North Shields...	(E E) Feb. 1896
Wyand, Fred. W., 13, Eldon Street, Newcastle-upon-Tyne ...	(E E) Oct. 1894

THE NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

Constitution and Bye-Laws,

ADOPTED AT A GENERAL MEETING ON THE 4TH MARCH, 1885.

REVISED AT THE CLOSING BUSINESS MEETING HELD ON MAY 4TH, 1887.

RE-REVISED AT THE CLOSING BUSINESS MEETINGS HELD ON MAY 9TH, 1888, MAY 13TH, 1889, MAY 11TH, 1891, AND MAY 14TH, 1895.

CONSTITUTION.

I.—The NAME of the Association is "The North-East Coast Institution of Engineers and Shipbuilders." **Name.**

II.—The OBJECTS for which the Institution is established are:—The advancement of the science and practice of Engineering and Shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions. **Objects.**

III.—The Institution shall consist of Honorary Members, Members, Associates, and Graduates.

IV.—HONORARY MEMBERS shall be such distinguished persons as the Council may elect. **Honorary Members.**

V.—MEMBERS shall be Principals or Principal Managers engaged in Engineering or Shipbuilding; Civil, Military, or Mining Engineers, or Naval Architects; whose subscription shall be Two Guineas per annum: and other persons engaged in the above professions; whose subscription shall be One Guinea per annum. **Members.**

VI.—ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate membership. Their subscription shall be One Guinea per annum. **Associates.**

VII.—Graduates may be persons under twenty-four years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscription shall be Half-a-Guinea per annum.

VIII.—Any Member may become a Life Member by a single payment of Twenty Guineas, or any Associate may become a Life Associate by a single payment of Ten Guineas. All such compositions shall be deemed to be capital moneys of the Institution.

IX.—The Council of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, nine Vice-Presidents, fifteen Ordinary Members of Council, and an Honorary Treasurer.

X.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Ordinary Members of Council shall be elected annually. The retiring Vice-Presidents and Ordinary Members of Council shall be those who have served three years from their last election.

The President shall be eligible for re-election for a second year; should he be re-elected he shall retire at the conclusion of his second year of office, and shall not again be eligible until after an interval of one year.

The retiring Vice-Presidents shall be eligible for re-election. The retiring Ordinary Members of Council shall not be eligible for re-election to the same office until after an interval of one year, but shall be eligible for election to any other office.

The Honorary Treasurer shall be eligible for re-election annually, or for election to any other office.

XIV.—Graduates may attend all the General Meetings, they may read papers, take part in discussions, and support resolutions; they shall also receive copies of the Transactions, but shall not sign proposals for new members, vote, nor be eligible for office. **Graduates' Privileges.**

XV.—The General Meetings of the Institution shall be held during the months of October to May, inclusive, of each year. **General Meetings.**

NOTE.—When the word Member is initialled with a capital letter it signifies a member under paragraphs IV. and V., but when initialled with a small letter, it signifies a member of any class of the Institution membership.

BYE-LAWS.

MEMBERSHIP.

1.—Every candidate for admission as a Member, Associate, or Graduate shall be proposed and recommended according to the Form A in the Appendix, in which form the name, usual residence or the place of business, the qualification for, and proposed class of membership of the candidate shall be distinctly specified. Proposals for Graduates must give the date of, and age, last birthday. **Candidates for Admission.**

The form shall be signed by a Member or Associate of the Institution, as proposer, and by at least other three Members or Associates as supporters, certifying a personal knowledge of the candidate.

The proposal so made shall be submitted to the Council, when, if it be approved, the Chairman shall sign the approbation, which shall be inserted in the notice calling the next General Meeting, when the candidate shall be balloted for, and shall be accepted if three-fourths of the votes are favourable.

2.—Graduates desirous of becoming Members shall be proposed and recommended according to the Form B in the Appendix. **Graduates becoming Members.**

The proposal so made shall be submitted to the Council, who shall agree to or reject it.

3.—The balloting for membership shall be conducted in the following manner:—Each member shall be supplied by post with a list of the names of the candidates, according to the Form C in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected. These lists may be **Balloting for Members.**

returned to the Secretary by post, or may be deposited in the ballot-box by the voter in person on entering a meeting at which an election is to take place. The ballot-box will be closed at ten minutes after the advertised time of meeting. The lists shall then be handed over to the Chairman, who shall appoint two Scrutineers to examine them, after which examination the Chairman shall inform the meeting of the result.

Candidates to receive Notice of Election.

4.—Notice of Election as a member shall be sent to the candidate within one week after his election, according to the Form D in the Appendix; but his name shall not be added to the list of Members, Associates, or Graduates of the Institution, until he shall have paid his first annual subscription.

Rejection of Candidates.

5.—In case of rejection of the candidate, no mention thereof shall be made in the minutes, nor shall any notice be given to the unsuccessful candidate.

Subscriptions payable in Advance.

6.—All subscriptions shall be payable in advance, and shall become due on the 1st of August each year. Any Member, Associate, or Graduate, wishing to retire from the Institution shall continue to be liable for his annual subscription until he shall have given formal notice of his retirement to the Secretary, which notice must be given on or before the 31st of August in each year. Application for membership may be made at any time during a Session, and the subscription shall cover the membership up to the 1st of August following.

Receipt of Subscription.

7.—On payment of each subscription the Secretary shall forward to the member an official receipt.

Questions of Privilege.

8.—On question of privilege.—Any person who may be un- [redacted] in the opinion of the Council, have been guilty of such conduct as shall have rendered him unfit to continue his membership; and the Council may remove his name from the list of members: and such person shall thereupon cease to be a member of the Institution. Notice of such action of the Council shall be forwarded to the person in question, in accordance with the Form G in the Appendix. The reason for such action of the Council shall not be stated to the person expelled, without the sanction of the Council.

OFFICERS.

11.—The Annual Election of Officers shall be conducted in the following manner:—The Council shall meet in March or April, and shall arrange a list of nominations, in accordance with the Form H in the Appendix. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be one in excess of the number required in each section of the Council. Such list shall be presented at the General Meeting immediately preceding the last General Meeting of the Session, and any Member present shall be at liberty to nominate additional Members. The list shall show who remain in office throughout the Council, and who are retiring. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members of Council, to be filled in, in accordance with the instructions printed in the ballot form, and to be returned to the Secretary to be opened in the presence of the Council, at a Council Meeting which shall be held in April or May, when the scrutiny and counting shall be carried out by the Council. Any Member in voting shall be at liberty to erase any name or names from the list and substitute the names of any other person or persons eligible for each respective office other than those already placed on the ballot list by the Council and Members of the Institution. Election of Officers.

Any voting paper returning either more or less than one President, nine Vice-Presidents, one Honorary Treasurer, and fifteen Ordinary Members of Council, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer, to persons not so elected, shall count to them as Ordinary Members of Council, unless they have just completed a term of office in such capacity.

The voting list shall not be sent to any Member and Associate whose subscriptions are more than one year in arrear; nor shall any such Member be nominated on the list. For this purpose, the Secretary shall prepare, previously to the meeting of Council, a list of those Members whose subscriptions are more than one year in arrears.

Ballot to be declared at May Meeting.

12.—The result of the ballot for Officers shall be declared at the Closing Business Meeting, to be held in May, at which meeting general business shall be transacted. At this meeting the newly-elected Officers, after being declared, shall enter into office; and this shall be the last meeting of the Session.

Power of Council to fill up Casual Vacancy.

13.—The Council shall have power to supply any casual vacancy within itself (including any casual vacancy in the office of President), which shall occur between one May Meeting and another; and the Officers so appointed shall retire when the persons whose places they fill would have retired. Vacancies not filled during the year shall be filled at the General Election.

GENERAL MEETINGS.

General Meetings.

14.—The Annual General Meeting shall take place in October, and the Closing Business Meeting in May; each of these meetings shall be held in Newcastle-upon-Tyne. The Ordinary Meetings shall take place in the second week in each following month during the Session, unless otherwise arranged by the Council, and at such hours and places as the Council may determine.

17.—Twenty Members shall constitute a quorum for the purpose of a meeting other than a Special Meeting. Thirty Members shall constitute a quorum for the purpose of a Special Meeting. Quorum.

18.—The President shall be chairman at every meeting, and in his absence, one of the Past-Presidents or one of the Vice-Presidents; or in the absence of these, an Ordinary Member of Council shall take the chair; or if no Member of Council be present and willing to take the chair, the meeting shall elect a Chairman. Chairman at Meetings.

19.—The decision of a General Meeting shall be ascertained by a show of hands; or, when five Members or Associates shall demand, or the Chairman may think it desirable, the decision shall be taken by ballot. The manner of counting the votes shall be at the discretion of the Chairman, and an entry in the minutes, signed by the Chairman, shall be deemed sufficient evidence of the decision of a General Meeting. In cases of equality of votes, the Chairman shall have a casting vote; otherwise he shall not vote. Decisions of General Meetings.

20.—Questions of a personal nature arising in a General Meeting, shall, if possible, be referred to the Council, otherwise the decision of the meeting shall be taken by ballot on a motion or amendment put to the meeting. The ballot shall be taken by the voters (being Members or Associates) writing "for" and "against" on a slip of paper. The slips shall be folded and collected, and then counted in the presence of the meeting, and the result announced by the Chairman. Should fewer than twenty votes be given, it shall be understood that the question is shelved, and the votes shall be destroyed without being opened. Questions of a Personal Nature in General Meetings.

21.—At every General Meeting of the Institution, the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall be signed by the Chairman; business arising out of these minutes shall then be transacted. The Secretary shall read any notices which may have to be brought before the meeting. Notices of motion may then be given, and other business of the Institution may be attended to; but when a paper is to be read, the foregoing business shall not be extended beyond half-an-hour after the advertised time for commencing the meeting. The paper or papers for the evening shall then be read and discussed. Transactions of Business General Meetings.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be Dissolving a General Meeting.

dissolved, and all matters which might, if a quorum had been present, have been done at the meeting so dissolved, may forthwith be done on behalf of the meeting, by the Council; except the reading or discussion of a paper, which shall not proceed in the absence of a quorum.

Adjourning a General Meeting

23.—Any General Meeting of the Institution may be adjourned by a vote of the Members and Associates present if there be a quorum; if there be not a quorum, the case shall be met by the preceding paragraph.

Introduction of Friends.

24.—Each member shall have the privilege of introducing one friend to the General Meetings, whose name must be written in the Visitors' Book, together with that of the member introducing him; but if the introducing member be unable to attend the meeting, he may send the name of the visitor to the Secretary. During such portions of any of these meetings as may be devoted to any business connected with the management of the Institution, visitors may be requested by the Chairman to withdraw. This shall be done if five Members or Associates, or both, present request it.

COUNCIL MEETINGS.

Council Meetings.

25.—The Council shall meet before each General Meeting, or on other occasions when the President shall deem it necessary; being summoned in either case by circular, stating the time of meeting, and the business, so far as is known.

Convening Meeting for Expenditure of Funds.

No business involving expenditure of the funds of the Institution (except by way of payment of current accounts) shall be [redacted] and shall appoint a Chairman. These regulations shall not affect the Finance Committee.

27.—The Council may appoint Committees either from itself, or with the assistance of persons outside, for the purpose of transacting any special business, or of investigating specific objects connected with the work and interests of the Institution. **Sub-Committees.**

28.—All Committees or Sub-Committees shall be appointed by the Council, and shall be subject to that body, and shall report to it. The Council shall act upon these reports or recommendations as it may think best. The President shall, *ex-officio*, be a member of all Committees. **Sub-Committees.**

29.—Any member may by communication addressed to the Secretary petition the Council to lay before a General Meeting of the Institution the contents of any letter which shall in a short, concise, and clear manner draw the attention of the Institution to public matters of importance in connection with legislation proposed by any governing body in reference to the construction of ships, machinery, or the working of the same, so that members may by their scientific and practical knowledge demonstrate the soundness or otherwise of the proposed measure. **Communication to Council.**

30.—The Council may invite to General Meetings or to Council Meetings any person or persons whose presence and assistance it may desire, and strangers so invited shall be permitted to take part in the proceedings, but not to vote. **Invitation to Strangers.**

31.—The Secretary, who shall also act as Treasurer, shall be appointed by and act under the direction and control of the Council, and shall be paid such salary as the Council shall determine. He shall attend all meetings, Council and General, and shall take minutes of the proceedings, and enter them in proper books provided for the purpose. He shall write the correspondence of the Institution and Council, read minutes and notices at meetings, report discussions, and, if required by the Council, prepare papers for reading and publication, and read papers and communications at the meetings. He shall receive all payments due to the Institution, and shall bank the cash in hand whenever it amounts to ten pounds. The bank shall be determined by the Council and the banking account shall be in the names indicated in connection with the Finance Committee. He shall keep a cash account book, general and detail, which shall on all occasions be open to inspection by the Finance **Secretary and Treasurer's Duties.**

Committee or by the Council. He shall keep a register of the names of members, so arranged as to distinguish all members whose subscriptions are in arrear. He shall also perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department; and shall remain in office during the pleasure of the Council. He shall not vote on any resolution.

32.—The following Sub-Committees shall be appointed annually at the first meeting of the Council in each Session:—

Finance Committee.

(1) A Finance Committee, to consist of seven persons, viz.: one Past-President or Vice-President, who shall be Chairman; five Members of Council, and the Honorary Treasurer of the Institution; three of whom shall form a quorum. The Treasurer shall be empowered to pay all amounts due from the Institution which are under two pounds. All amounts of two pounds and upwards shall be paid by cheque, signed by the Chairman of the Finance Committee (or in his absence, by the President or a Past-President), the Secretary and the Honorary Treasurer.

Payment of Accounts.

(2) A Reading Committee, to consist of six members of Council. No member who has served on this Committee for three years in succession shall be eligible for re-election until after an interval of one year. (3) A Library Committee, in accordance with Library Rules, Nos. 1 and 3. (4) A Graduates' Award Committee to consist of five members.

Reading and Library Committees.

TRANSACTIONS.

Papers to be

33.—All papers shall be forwarded to the Secretary at least power to omit parts of discussion which may be foreign to the subject, or which it may be deemed undesirable to retain. Each paper shall bear the date on which it was read in General Meeting.

Copy of Papers supplied to members before reading, etc.

35.—Copies of papers to be read during any Session will be sent seven days before the date of reading to members who shall have applied to the Secretary for them, in writing, at the commencement of the Session. The discussion on a paper shall not be considered closed on the evening on which it is read, but shall be open for renewal at a subsequent meeting, prior to the reading of the paper set down for that date.

Proofs sent to members for Correction.

36.—The Secretary shall send to each speaker as soon as possible after a General Meeting a copy in manuscript of the speaker's own remarks for correction. This copy must be returned to the Secretary within four days. A printed proof will also be sent to each speaker for further revision; this must be returned to the Secretary within three days, otherwise it will be deemed correct, and printed off after receiving verbal corrections.

Liberty to Print Explanatory Notes.

37.—The Council shall be at liberty to print as Transactions, either with the papers and discussions or separately, explanatory notes, etc., communicated after the reading or discussing of a paper. Such communications must be approved by the Reading Committee, and shall bear the date on which they shall have been received by the Secretary.

Institution not responsible for statements.

38.—The Institution shall not be held responsible for the statements and opinions advanced in any of the papers which may be read, or in the discussions which may take place at the Meetings of the Institution.

Copies of Transactions to be sent to members.

39.—Twenty copies of each paper and discussion shall be presented to the author of the paper, for private use, and one copy shall be sent to each member. When a paper is prepared by two authors, fifteen copies shall be presented to each. Duplicate copies of parts of the Transactions mislaid or lost by members cannot be supplied to them, except as provided for in Bye-Law 42.

Transactions not supplied to members in Arrears.

40.—The Transactions shall not be supplied free to members whose subscriptions are unpaid.

Members not to receive Transactions till after First Payment.

41.—Any member elected at any time between the Annual General Meetings shall be entitled to copies of all the Transactions issued during the Session to which his first subscription applies; but not until the subscription has been paid.

Transactions the Property of the Institution.

42.—The Transactions of the Institution shall be the exclusive property of the Institution, and shall be published only by the authority of the Council. Additional copies of papers required by authors for their private use can only be procured from the Secretary, at prices fixed by the Council from time to time, and these copies must contain the whole of the discussion following the papers, and be bound in the usual cover, with the addition of the following words:—"By permission of the Council," and "Excerpt Minutes of Proceedings." Duplicate volumes and copies of parts of the Transactions, if in print, can also be obtained from the Secretary, and shall be sold only by him, in such manner and at such prices as the Council shall have fixed.

Rule of Discussion.

43.—During a discussion upon any paper, no person shall be at liberty to speak more than once (except by way of explanation), nor for a longer period than ten minutes.

ACCOUNTS, &c.

Accounts.

44.—The Council shall present the yearly accounts (up to the 31st of July preceding) at the Annual General Meeting in October of each year, after they have been audited by a professional Accountant, appointed by the members at the Closing Business Meeting in May.

Trustees.

45.—The capital, stock, and funds of the Institution shall be vested in the names of three Trustees, to be elected from time to time as vacancies occur by the members of the Institution at a General Meeting called for that purpose. All mortgages and

Closing Business Meeting in May, after notice of the proposed alteration or addition has been announced at the previous General Meeting.

The resolution may be modified by the Council meanwhile, should they so desire; but in this case it shall be read at the Closing Business Meeting in May in its original form before it is proposed in the amended form.

Such resolutions shall be stated in the notice calling the intervening Council Meeting, and also in the notice calling the Closing Business Meeting in May.

Any member unable to be present at the meeting at which such alterations are to be considered, but who is nevertheless desirous of recording his opinion thereon, shall be allowed to vote by proxy, such proxies shall be in Form J in the Appendix, which may be had on application to the Secretary, and may be used by any member present at the meeting on behalf of the absent member, and counted by the Chairman as of equal value with votes given in the manner provided in Bye-Law 19. Vote by Proxy.

THE GOLD MEDALS.

RULES.

1.—That papers read by members of the Council shall be eligible for the Gold Medals' Award.

2.—That the medals shall be awarded by the vote of the Council given at a meeting of the Council at which the business has been specially noted on the circular convening the meeting, and not by ballot papers previously sent out, as has hitherto been the custom.

3.—That when the Council proceeds to award the medals, authors of papers who are members of the Council shall not be present nor vote at such Council meetings.

4.—If at the meeting convened a quorum of the Council should not be present, or if the Council considers it desirable or cannot agree, the decision of the Council may be deferred and adjourned to a future meeting.

5.—That the medals shall be awarded annually, provided the papers are, in the opinion of the Council, worthy of the award, but not otherwise; and that they be awarded to the authors of the best papers, irrespective of their having previously obtained a gold medal.

THE LIBRARY AND READING ROOM RULES.

Committee.

1.—The Library and Reading Room shall be managed by a Committee, called the Library Committee, who shall have charge of all books, papers, specimens, etc., which may belong to the Institution. It shall consist of five members of the Institution, of whom at least two shall be members of Council.

Property.

2.—The books and other property of the Library shall be vested in the Trustees appointed by the Institution.

Appointment of Committee.

3.—The Library Committee shall be appointed annually, at the first meeting of the Council in each Session. No member who has served on the Committee for three years in succession shall be eligible for re-election until after an interval of one year. The Chairman shall be elected by the Council.

Librarian.

4.—The Secretary of the Institution shall be Librarian, and shall also act as Secretary to the Library Committee. Three members of the Committee shall form a quorum.

Duties of Committee

5.—The Library Committee shall be responsible for the binding and purchasing of books, periodicals, papers, etc., and for the expending of all money voted by the Council for its use. It shall appoint an attendant who shall act as Assistant Librarian. It shall make Rules for the management of the Library, subject to the approval of the Council, and present an annual report to the first meeting of the Council held after the annual scrutiny of the books referred to in Rule No. 13.

Hours of Opening and Closing, etc.

6.—Except when closed by special order of the Library Committee, or when the Council is sitting, the Library and Reading Room shall be open for consulting, borrowing, or returning [redacted]

8.—Each member shall be entitled to introduce a friend to the Reading Room, whose name shall be written in the Visitors' Book, together with that of the member introducing him. **Visitors.**

9.—The books marked with an asterisk in the Catalogue shall be kept only for consultation in the Library, and shall not be lent. Pending the preparation of a Catalogue, the Librarian shall be instructed by the Committee as to which books shall be withheld from circulation. **Reference Books.**

No periodicals, magazines, or pamphlets shall be issued for circulation until after they have been bound and added to the Lending Library. **Unbound Books.**

10.—The Librarian shall keep a register in which he himself or the attendant shall enter the titles of the books lent, the date of lending, the name of the borrower, and the date of the return of the book to the Library. The borrower of the book or the bearer of his order shall initial the entry of such borrowing, and the Librarian or the attendant shall initial the date of the return of the book. **Register of Books Lent, etc.**

11.—No person shall borrow or have in his possession at one time more than two volumes belonging to the Library. **Number Lent to each member.**

12.—No member shall retain a book longer than fourteen days, excluding the day of issue. He shall be responsible for the safe return of the book, and if it be damaged or lost he shall make good the cost of such damage or loss. **Return of Books.**

13.—All books belonging to the Library shall be called in for inspection, and the lending out of books shall be suspended from the second to the fourth Saturday of July, inclusive, of each year, and members shall be required by notice to return all books in their hands before the period mentioned. **Yearly Inspection of Books.**

Members failing to comply with this injunction shall pay a fine of two shillings and sixpence. **Fine.**

14.—Members are requested, when in the Reading Room or Library, to contribute to the general comfort by carefully abstaining from loud talking and noise of any kind. Smoking is not permitted in the Library.

15.—Any member being twelve months in arrears with his subscriptions to the Institution shall not be at liberty to use the Library or Reading Room after the commencement of the first Session following. **Members in Arrears.**

N.B.—The foregoing Rules may be amended at any time by the Library Committee with the sanction of the Council.

APPENDIX TO BYE-LAWS.

FORM A. (BYE-LAW 1.)

Name (in full)
Profession or Occupation and where Employed
Address
being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned, propose and recommend that he shall become*
thereof. We know him to be†
and eligible for the proposed membership.

* A Member, Associate, or Graduate.

† A Principal, Manager, or Draughtsman, etc. See Articles V., VI., and VII. of Constitution.

	FROM PERSONAL KNOWLEDGE.	SECTION OF MEMBERSHIP
Proposed by		
Supported by Three Members or Associates.		

Dated this day of

(*When a Graduate is proposed the age last birthday should be stated.*)

FORM B. (BYE-LAW 2.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being at present a of the North-East Coast Institution of Engineers and Shipbuilders, and upwards of

[redacted]

FORM C. (BYE-LAW 3.)

BALLOTING PAPER FOR MEMBERSHIP.

The Council having considered the recommendations for Membership of the following gentlemen, present them to be balloted for, viz.:—

Member, Associate, or Graduate.	Occupation.	Address.	Nominated by.	Supported by Three Members or Associates.

Strike out the names of such persons as you desire shall *not* be elected, and forward the list by post to the Secretary, or personally place it in the ballot-box at the Meeting.

FORM D. (BYE-LAW 4.)

Sir,—I am directed to inform you that on the day of you were elected a of the North-East Coast Institution of Engineers and Shipbuilders, but, in conformity with Bye-Law 4, your election cannot be confirmed, nor your name be added to the roll of membership, until you have paid your first annual subscription, the amount of which is £ : : , or, at your option, the Life Composition of £ : : .

Payment may be made to the Treasurer, Mr.____________

Address____________

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

N.B.—In case of a Graduate, strike out "*or, at your option, the Life Composition of £ : :* "

FORM E. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to draw your attention to Bye-Law 6, and to remind you that the sum of £ of your annual subscriptions remains unpaid, and that you are in consequence in arrear of subscription.

I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,

Yours faithfully,

Secretary.

FORM F. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-Law 9, the Council have determined that unless payment of the amount (£) is made previous to the day of next, they will proceed to declare that you have ceased to be a member of the Institution.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,

Yours faithfully,

FORM H. (BYE-LAW 11.)

BALLOTING LIST.

President.—One Name only to be returned, or the vote will be lost.

——— President for the current year (eligible for re-election.)*

———
——— } New Nominations, from whom to select ONE.
———

Vice-Presidents.—Nine Names only to be returned (including the six who remain in office), or the vote will be lost.

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——— } Six Vice-Presidents remaining in office, whose seats are NOT vacant.
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———
——— } Three Vice-Presidents retiring, eligible for re-election.
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———
——— } New Nominations, from whom to select THREE names.
———
———

Treasurer.—One Name only to be returned, or the vote will be lost.

——— Treasurer for the current year, eligible for re-election.

———
——— } New Nominations, from whom to select ONE.
———

Ordinary Members of Council.—Fifteen Names only to be returned, including the ten who remain in office.

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———
——— } Ten Ordinary Members of Council remaining in office. These do not require to be voted for at this election, as their term of service has NOT yet expired.
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——— } Five Ordinary Members of Council retiring, and NOT eligible for re-election.
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——— } New Nominations, from whom to select FIVE.
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* To be crossed out before issue, when the President is not eligible for re-election.

N.B.—(*a*) The names of those who remain in office will be counted in the total number required without being re-written by the voter.

(*b*) Any list having either MORE or LESS than the required number of names voted for in any section will be disqualified for that section.

(*c*) Votes as President for a person who is not elected will count for him as a Vice-President.

(*d*) Votes as Vice-President, or Treasurer, for persons not so elected, will count for them as Ordinary Members of Council, unless they have just completed a term of office in that capacity.

(*e*) This list, duly filled in, may be returned to the Secretary by post, or handed to him, so as to be on the Council table before the commencement of the scrutiny, which is appointed to take place in the Council Room, at 8 p.m., on 18

(*f*) A copy of this list shall be posted at least Seven Days previous to the Annual Meeting to every Member and Associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

Secretary.

FORM J. (BYE-LAW 45.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FORM OF PROXY.

FOR VOTES ON ALTERATIONS TO CONSTITUTION OR BYE-LAWS.

I,..., being [an Honorary Member, Member, or Associate] of the above Institution, do hereby appoint Mr... who is [an Honorary Member, Member, or Associate] of the same Institution, to act as my Proxy, and record my Vote at the General Meeting of the Institution, to be held on the... ....day of ...., 18......, and at any adjournment thereof.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Supplementary Bye-Laws Relating to the Graduate Section.

I.—The Graduate Section shall be controlled by the General Bye-Laws of the Institution, and the following Bye-Laws are supplementary to these.

This Section shall be open to all Members of the Institution who are under twenty-six years of age, who shall be at liberty to express their views upon any subject brought before the General Meetings of the Section.

Officers by Ballot.

II.—The Officers of the Section shall be elected from and by the Graduates, in accordance with the Form given in the Appendix, and shall consist of one Chairman, one Honorary Secretary, and five Committee-men. The Committee shall have power to select one of its members to act as Assistant Honorary Secretary if required.

Election of Officers.

III.—(*a*) The Officers shall be elected annually, and shall all be eligible for re-election until the age limit is reached.

Rider to General Bye-Law No. 11.

(*b*) Any voting paper returning either more or less than one Chairman, one Honorary Secretary, and five Committee-men shall be disqualified.

General Meetings.

IV.—The Annual General Meeting shall take place as early as possible after that of the Institution in the month of October, and the Closing Meeting shall be held prior to the Closing Business Meeting of the Institution in May.

Special General Meetings.

V.—A Special General Meeting may be convened at any time by the Committee. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting.

Quorum.

VI.—Nine Members shall constitute a quorum for the purpose of a General Meeting.

Excursions.

VII —Excursions shall be arranged during the Session as the Committee may find expedient. Any Graduate wishing to introduce a friend at such excursions must submit the name of his friend to the Committee at least three clear days before the date of the excursion.

Seven clear days' notice of every excursion shall be given to every Member of the Graduate Section.

COMMITTEE MEETINGS.

Committee Meetings.

VIII.—The Committee shall meet at as early a date as possible after the holding of a General Meeting, and on other occasions when the Chairman shall deem it necessary, being summoned in either case by circular, stating the time of meeting and the business so far as is known. All discussions of a personal character in the Committee shall be considered and treated as being strictly confidential.

Four members of Committee, including the Chairman, shall form a quorum.

Duties of Hon. Secretary.

IX.—The Honorary Secretary shall act under the direction and control of the Committee. He shall attend all Meetings, Committee and General, and shall take minutes of the proceedings and enter them in proper books provided for the purpose. He shall write the correspondence of the Graduate Section and Committee (excepting that arranging for excursions, which shall be arranged by the Secretary of the Institution). He shall keep a stamp account book, which on all occasions shall be open to the inspection of the Secretary of the Institution.

PAPERS.

[redacted]

APPENDIX.

GRADUATES' BALLOTING LIST.

CHAIRMAN.

*———— (E) } Nominations from whom to select ONE.
———— ( )

HON. SECRETARY.

*———— (E) } Nominations from whom to select ONE.
———— ( )

COMMITTEE.

*———— (S)
*———— (EE)
*———— ( ) } Nominations from whom to select FIVE.
———— ( )
———— ( )
———— ( )

NOTES.

1.—Any list having either more or less than the required number of names will be disqualified.

2.—All voting papers must be returned to the Secretary of the Institution on or before the day of , 18 .

3.—No signature must be put on this paper.

4.—* Signifies a member of the old committee.

5.—(E) Denotes Engineer; (EE) Electrical Engineer; (S) Shipbuilder.

6.—A copy of this list shall be posted, at least fourteen days previous to the Closing Meeting of the Session, to every Graduate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

7.—Votes as Chairman or Hon. Secretary, for persons not so elected, will count for them as members of committee.

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896–97.

PROCEEDINGS.

THIRTEENTH ANNUAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-ON-TYNE, ON WEDNESDAY EVENING, OCTOBER 14TH, 1896.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the Closing Business Meeting of last session, held in Newcastle-on-Tyne, on May 19th, 1896, which were approved by the members present, and signed by the President. The minutes of the Summer Meeting, held in Cardiff, etc., from June 23rd to 26th, 1896, were also submitted, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. A. Coote and J. R. Fothergill to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Blomberg, Carl A., Engineer, c/o Messrs. Newport News Shipbuilding and Dry Dock Company, Newport News, Va., United States of America.

Buckwell, George William, Engineer and Ship Surveyor, Board of Trade Surveyor's Offices, Custom House Arcade, Liverpool.

Davy, William, Engineer, Greenfield Terrace, Ryton-on-Tyne.

Garelli, Fabio, Shipbuilder, Via 20 Settembre, Sestro Ponente, Italy.

Harbottle, John, Engineer, 116, Hartington Street, Newcastle-on-Tyne.

Heaviside, Arthur West, Electrical Engineer, 7, Grafton Road, Whitley, near Newcastle-on-Tyne.

Nisbet, John Mowat, Ship Surveyor and Engineer, c/o M. W. Aisbitt, Esq., 47, Mount Stuart Square, Cardiff.

Sevenoaks, Edward, Engineer, West Hartlepool.

Trail, Robert, Engineer, 8, Newcastle Street, North Shields.

GRADUATES TO MEMBERS.

Mellanby, Alexander Lawson, Engineer Student, 47, Grove Street, Newcastle-on-Tyne.

Wood, John Scott, Ship Draughtsman, 6, Eslington Terrace, Newcastle-on-Tyne.

ASSOCIATES.

Brown, Percy Ledger, Engineering Agent, 1, St. Nicholas' Buildings, Newcastle-on-Tyne.

Crawford, Thomas, Accountant, 10, Haldane Terrace, West Jesmond, Newcastle-on-Tyne.

Roseby, J. J., Accountant, 18, Duke Street, Whitley, near Newcastle-on-Tyne.

Trechmann, Otto K., Shipowner, Church Street, West Hartlepool.

GRADUATES.

Johnson, James, Engineer Apprentice, 11, Poplar Crescent, Gateshead-on-Tyne.

Mace, George, Apprentice Shipbuilder, 253, Albert Road, Jarrow-on-Tyne.

Rowles, Henry P., Engineer, 8, Belle Vue Terrace, Gateshead-on-Tyne.

The Secretary read the Council's Twelfth Annual Report, and the President (Col. Henry F. Swan) delivered his Inaugural Address.

THE TWELFTH ANNUAL REPORT AND FINANCIAL [redacted]

COUNCIL REPORT.

(Twelfth Session, 1895-96.)

In presenting its twelfth annual report, the Council has pleasure in stating that the financial position of the Institution is still satisfactory, but regrets to state it has been found necessary to write off a considerable number of members who have failed to pay up their arrears. This, together with the large amount of subscriptions still unpaid, and the increased rental of the rooms occupied by the Institution, has left a smaller annual balance to the credit of the Institution than is usual.

The new measured mile posts are now completed, and they have been officially certified correct as regards the positions and distances between the posts. The whole cost has been defrayed by a call made upon the various shipbuilding and engineering firms in the district, particulars of which are appended to this report. After refunding to the Institution the sum of £77 17s. 9d. for money spent in repairs to the old posts and expenses incurred, there remains a balance of £133 17s. 2d., and the Council has thought fit to appoint Messrs. Robert Thompson and H. Macoll as a permanent committee and trustees to utilise this balance, as long as it shall last, in cleaning, painting, and maintaining the posts in a proper state of repair. The rental (amounting to £6 6s. per annum) is paid, as hitherto, out of the funds of the Institution.

During the session the Council was invited by the General Association of Clyde Shipbuilders and Engineers to consider the important question of representation of shipbuilders and marine engineers on the Executive of the Board of Trade on the same lines as those agreed upon with Lloyd's Register of British and Foreign Shipping. The Council expressed its willingness to act conjointly with the other institutions. Mr. C. T. Ritchie, M.P., President of the Board of Trade, was approached, and agreed to receive a deputation of representatives from the various institutions and societies interested. He acknowledged he was quite in sympathy with the movement, but was unable to accept the proposals put before him. He, however, intimated that, whilst he could not accept the Committee on the lines proposed, he would be only too happy to consult from time to time any committee they might appoint. The Council of this Institution was then called upon to elect four representatives, two shipbuilders and two engineers, to serve on this

Consultative Committee, and the following gentlemen were appointed :—Col. Henry F. Swan, Col. John Price, Mr. D. B. Morison, and Mr. J. H. Irwin.

The four representatives appointed by this Institution to sit on Lloyd's Technical Sub-Committee, having considered it due to the members of the Institution to give a brief account of the work done in committee since they were called upon to represent the Institution, submitted a report to the Council, which was accepted; and it was resolved that the same should be printed and included in Volume XII. of the *Transactions* (see page 179).

The President and Council of the Newcastle and District Association of Foremen Engineers and Draughtsmen having approached the Council on the question of permitting their members to use the rooms rented by the Institution, the Council agreed to accede to their request, on condition that the Association pay to the Institution a subscription of £20 per annum. This was accepted by the Association.

The Institution gold medals for the eleventh session were awarded as follows :—

The Engineering Medal to Mr. Henry Foster for his paper on "The Application of the Electric Arc to Machinery and Boiler Repairs."

The Shipbuilding Medal to Mr. Stonard O. Kendall for his paper on "Turret-deck Cargo Steamers."

The Council has thought fit to appoint a committee to consider whether any alterations of advantage to the Institution can be made in the present system adopted in awarding the gold medals.

The twelfth session of the Institution was opened on the evening of the 18th day of October, 1895, by a conversazione and ball, given by the [redacted]

At the Second General Meeting of the session, Mr. G. H. Baines called the attention of the members to the resolution passed by the Institution at the Closing Business Meeting of the previous session in favour of the adoption of the Metric System of Weights and Measures which had been sent to the Select Committee of the House of Commons; and stated that the Committee agreed to report to the House of Commons, "that it was desirable the metric system should immediately be legalised in this country for all purposes, and that its use should become compulsory after two years."

The Graduate Section of the Institution has now completed its seventh year. The Council has pleasure in reporting that the meetings held by this section during the past year have been better attended, and the following papers were read and discussed :—

1.—"Alternating Current Motors for use on Single Phase Mains." By Mr. J. B. Bent.
2.—"Some Notes on the Methods of Generating and Distributing Electric Power." By Mr. R. G. Thomas.
3.—"The Construction and Completion of the Propelling Machinery of High Speed Engines." By Messrs. L. P. Forster and A. H. Burbidge.
4.—"Notes on the Graduates' Visit to Messrs. C. S. Swan & Hunter's Shipyard." By Mr. C. Turnbull.
5.—Discussion on "Lubrication." Opened by Mr. C. W. Cairns.

The following places of interest were also visited, and the thanks of the Institution are due to the principals and managers of the various works for the kind and hospitable manner in which the Graduate members were received and the interest taken to render their visits instructive :—

1.—The Central Marine Engine Works, West Hartlepool.
2.—The Electric Lighting Station, Sunderland.
3.—The Shipyard of Messrs. C. S. Swan & Hunter.

The prizes for the best papers read in this section during the previous (sixth) session were awarded as follows :—

To Mr. E. F. Moroney for paper on "Screw Propeller Shafting"
„ E. F. Baker for paper on "Steam Pipes and Fittings, as found on Shipboard."
„ A. L. Forster for his Opening Address.

It having been found necessary to frame Supplementary Bye-laws for the more efficient working of this section the duty was undertaken by the Graduates' Committee, and new rules were drawn up, which, on being submitted to the Council of the Institution, were duly approved and added to the existing Bye-laws.

At the Closing Meeting of the Session, in May, Mr. Charles W. Cairns was elected Chairman of the Section, and Mr. Talbot Duckitt Hon. Secretary.

During the year the following additions have been made to the list of members:—Life Member, 1; Members, 55; Graduates raised to the rank of Members, 8; Associates, 22; Graduates, 35.

The Council regrets to have to record the loss of the following six Members by death:—Messrs. M. Gray, J. Hartness, W. Hindson, J. T. Jameson, M. W. Ruthven, and F. W. Willcox.

The Institution has also lost from resignations and other causes 42 Members, 10 Associates, and 12 Graduates.

The total number of members now enrolled are as follows:—

Honorary Members	3
Life Members	6
Members	721
Life Associates	2
Associates	123
Graduates	130
Total	985

In response to an invitation received from a large and influential body of gentlemen representing Cardiff and the Bristol Channel Ports, a visit was paid to that district during the week beginning June 22nd, 1896. The members received a very cordial welcome, and were most hospitably entertained. Tuesday was spent in Newport, Mon.; Wednesday in Cardiff, and in the evening the members were entertained at a reception and smoking concert, given by the Bristol Channel Centre of the Institute of Marine Engineers, when they were received by the President of the section, Prof. A. C. Elliott, D.Sc., Lord Windsor, Mayor of Cardiff, and other leading gentlemen of the district. On Thursday a general meeting of the Institution was held in the handsome hall of the [redacted]

NEW MEASURED MILE POSTS.

Donations received towards defraying the cost of the four new Measured Mile Posts on Hartley Links.

	£	s.	d.	£	s.	d.
Messrs. Sir W. G. Armstrong & Co., Limited, Elswick ...	42	10	0			
" " " Walker ...	42	10	0			
" " additional donation	25	0	0			
" R. & W. Hawthorn, Leslie, & Co., Limited	50	0	0			
" Palmer's Shipbuilding & Iron Co., Limited	50	0	0			
" N.E. Marine Engineering Co., Limited	40	0	0			
" Wigham Richardson & Co.	40	0	0			
" C. S. Swan & Hunter, Limited	40	0	0			
" W. Doxford & Sons, Limited	35	0	0			
" James Laing	35	0	0			
" J. L. Thompson & Sons, Limited	35	0	0			
" George Clark, Limited	25	0	0			
" John Dickinson & Sons, Limited	25	0	0			
" John Readhead & Sons	25	0	0			
" Robert Stephenson & Co., Limited	20	0	0			
" Wallsend Slipway & Engineering Co., Limited ...	20	0	0			
" William Dobson & Co.	15	0	0			
" Tyne Iron Shipbuilding Co., Limited	15	0	0			
" Short Brothers	12	0	0			
" S. P. Austin & Son	10	0	0			
" Black, Hawthorn, & Co., Limited	10	0	0			
" Blair & Co., Limited	10	0	0			
" Blyth Shipbuilding Co., Limited	10	0	0			
" Sir Raylton Dixon & Co.	10	0	0			
" Sir W. Gray & Co., Limited	10	0	0			
" T. Richardson & Sons, Limited	10	0	0			
" Sunderland Shipbuilding Co., Limited	10	0	0			
" Robert Thompson & Sons	10	0	0			
" Wood, Skinner, & Co.	10	0	0			
" Furness, Withy, & Co., Limited	8	0	0			
" Bartram & Sons	6	0	0			
" J. Blumer & Co.	6	0	0			
" J. Priestman & Co.	6	0	0			
" W. Allan & Co., Limited	5	0	0			
" R. Craggs & Sons	5	0	0			
" Osbourne, Graham, & Co.	5	0	0			
" Wm. Pickersgill & Sons	5	0	0			
" J. P. Rennoldson & Sons	5	0	0			
" Westgarth, English, & Co.	5	0	0			
" Baird & Barnsley	3	0	0			
" Edwards Brothers	3	0	0			
" Jos. T. Eltringham & Co.	3	0	0			
				757	0	0
Cr.						
By Total Cost of new Mile Posts	545	5	1			
" Amount refunded to N.E. Coast Institution of Engineers and Shipbuilders	77	17	9			
				623	2	10
Balance				£133	17	2

NORTH-EAST COAST INSTITUTION OF

STATEMENT OF RECEIPTS AND PAYMENTS

Receipts.

		£	s.	d.	£	s.	d.
To Balance from last Account—							
At Bankers					270	8	10
Subscriptions received for Session 1895-96—							
229 Members at £2 2s.	£480 18 0						
446 Members „ £1 1s.	468 6 0						
111 Associates „ £1 1s.	116 11 0						
124 Graduates „ 10s. 6d.	65 2 0						
910		1,130	17	0			
„ Association of Foremen Engineers and Draughtsmen—							
Half-year's Subscription to 1st August, 1896		10	0	0			
„ Life Member—John Gunn		21	0	0			
„ Arrears for Sessions 1892-95—							
10 Members at £2 2s.	£21 0 0						
17 Members „ £1 1s.	17 17 0						
3 Associates „ £1 1s.	3 3 0						
1 Graduate „ 10s. 6d....	0 10 6						
		42	10	6			
					1,204	7	6
„ Transactions sold this Session		24	17	3			
„ Copies of Members' Papers supplied		10	1	8			
					34	18	11
„ Tyne Improvement Commissioners—							
One Year's Interest to 21st June, 1896, on £605, at 3⅝ per cent.		21	18	6			

[redacted]

ENGINEERS AND SHIPBUILDERS.

FOR SESSION ENDING 30TH JULY, 1896.

Payments.

	£ s. d.	£ s. d.	£ s. d.
By Transactions and Papers—			
Lithographing		196 9 6	
Printing and Binding		179 10 0	
			375 19 6
„ Stationery and Circulars		86 12 6	
„ Reporting		23 6 8	
„ Rents—			
Offices		111 4 0	
Lecture Rooms		7 14 0	
Telephone		8 0 0	
„ Rates, Gas, Electric Light, and Insurance...		25 6 3	
„ Salaries—			
Secretary, Salary		275 0 0	
„ Commission		59 14 5	
Assistant Librarian		35 0 0	
Office Boy		10 0 0	
„ Postages, Stamps, Post Cards, Parcels, etc.		84 6 11	
„ Secretary's Expenses and Allowances to Hall Keepers, etc.		20 3 6	
„ Office Expenses, Coals, Cleaning, etc.		26 7 6	
„ Measured Mile Posts—Rent...	£6 6 0		
„ „ „ Expenses	3 3 6		
		9 9 6	
„ Cardiff Excursion Expenses...		24 19 6	
„ Auditor's Fee		5 5 0	
„ Lantern Expenses		0 15 6	
			813 5 3
„ Library Account—			
New Books		4 19 1	
Bookbinding		9 0 3	
			13 19 4
„ New Furniture			26 4 4
„ Gold Medals' Fund—			
Two Gold Medals awarded			11 0 0
„ Graduates' Award Fund—			
Amounts awarded for Papers			7 11 9
„ Balance at Bankers			378 19 5
			£1,626 19 7

[redacted]NCE SHEET FOR SESSION ENDING 31ST JULY, 1896.

[redacted]

£ s. d.	£ s. d.
300 17 9	
11 0 0	
	289 17 9
230 17 5	
7 11 9	
	223 5 8
126 0 0	
21 0 0	
	147 0 0
	1,461 2 9
	£2,121 6 2

[redacted]ON, F.C.A.

Assets.

		£ s. d.	£ s. d.
Subscriptions in Arrear—			
Session 1893-94		1 1 0	
„ 1894-95		5 15 6	
„ 1895-96		76 13 0	
			83 9 6
Stock of Transactions, valued at			174 3 8
Office and Library Furniture, Safe, etc., as at			
31st July, 1895	£137 16 7		
Less—Depreciation ...	13 15 7		
		124 1 0	
Additions this Session		26 4 4	
			150 5 4
Books in Library—			
As at 31st July, 1895 ...	£206 0 11		
Less—Depreciation ...	20 12 0		
		185 8 11	
Additions this Session—			
Purchases	£13 19 4		
Books received in exchange ...	30 0 0		
		43 19 4	
			229 8 3
Tyne Improvement Commissioners—Investment in respect of the following Accounts, viz.:—			
Gold Medals' Fund		274 0 0	
Graduates' Award Fund		215 15 0	
Payments by Life Members and Associates		115 5 0	
General Capital		500 0 0	
			1,105 0 0
Cash—At Bankers			378 19 5
			£2,121 6 2

The PRESIDENT said that having heard the report of the Council read, he thought they would agree that it was eminently satisfactory. The number of members in the report was 985, but the elections that had just taken place raised it to 1,001. He must say that it must be looked upon as a very satisfactory feature, that, whereas this Institution had only existed about a dozen years it had been enabled to increase its membership so much in that time and attain the position it now held. He was sorry they had such a small attendance that night; they seemed to have hit upon an unfortunate opening night, for he had a great number of letters, some from leading members of the Institution, who seemed from one cause or another unable to be present. He thought it a matter of great satisfaction that the mile posts referred to had been dealt with and put on a permanent basis. He remembered the time when the need of such was very much felt. They were then dependent upon the buoys at the mouth of the rivers Tyne and Wear for the measured distance, and the actual distance depended largely whether the buoys were taken or the leading lights at Shields to the Sunderland lighthouse or ballast buoys, so that they had a movable quantity at each end of the run, and the results were totally unreliable. Thanks to the interest which had been taken by some of the members and he would specially refer to Mr. Robert Thompson, of Sunderland; these important posts had now been put up and properly verified, so that they had a reliable distance from which they could derive their data. He could only wish that the position in which they were placed had been better. There was not the slightest doubt that for very high speeds the Clyde had a distinct advantage in that respect. Here they were in the open sea and exposed to very great difficulties, whereas on the Clyde they had an enclosed water space, with the assurance almost of being able to make a trial trip at any moment, so much so that some builders found it to their advantage to take their vessels to the Clyde to make their trial. They on the North-East Coast were too far off to go round to the Clyde to make their trials and therefore must make the best of their present circumstances. The Institution seemed to have had a very good time down in Wales. The account they had heard from the Secretary and the Council's report, he was afraid, rather conveyed the impression that they had had more pleasure than work. However, it was very valuable to see Cardiff and all belonging to it. The Institution must be very thankful to the associations of South Wales, that had incurred not only trouble, but so large an expense in entertaining. He did not know there was anything else he need specially refer to, and would therefore move the adoption of the Council's report.

Mr. J. R. Fothergill (Vice-President) seconded the adoption of the report. There were only two features he wished to touch upon. At the commencement of the report, it would be observed, attention was drawn to members in arrears. It was a matter that seemed difficult to explain; it was one, however, of great seriousness, and to the majority of members, no doubt, a cause of great astonishment. At the commencement of each session, it was found necessary to write off a considerable number of members who failed to pay their arrears, while during this last session they had absolutely had to write off no less than 23 members. Some were two, some three years, in arrears. Having been elected, they had received certain parts of the *Transactions*, and yet failed to pay anything, although retaining the *Transactions* received, but the unfortunate feature in connection with this was that during the period covering the last eight years the arrears amounted to no less a sum than £210 18s. 6d. Many "gentlemen," if he was right in using that term, had absolutely joined the Institution, had in most cases attended their meetings, received *Transactions*, and yet, although their attention had been drawn to the fact, refused to pay a half-penny of the fees that were due. He thought it right members should be fully informed on this subject, and although he did not know how they felt, yet he thought it was, to use the mildest expression, discreditable. The other matter he wished to refer to, and which the President had already touched upon, was that of the mile posts. The President had referred to what Mr. Thompson had done. He (Mr. Fothergill) could not but emphasize what the Past-President (Mr. Thompson) and Vice-President (Mr. Macoll) had accomplished. It was due to the energy, enterprise, and force of character of these gentlemen that the mile posts had been substantially renewed and [redacted]

PRESIDENT'S INAUGURAL ADDRESS.

BY COL. HENRY F. SWAN, J.P.

(DELIVERED IN NEWCASTLE-UPON-TYNE, OCTOBER 14TH, 1896.)

To occupy the position of President of an important body such as the North-East Coast Institution of Engineers and Shipbuilders is, no doubt, a great honour, but I could have wished that it did not carry with it the obligation to deliver an address, and the difficulty I feel is how best to select subject-matter for the same which would be of interest to the members.

The very title of the Institution indicates the great field which lies open to me, seeing that the construction of ships, with their machinery and appurtenances, coupled with the production and conversion of the various materials included in their construction, involves the whole range of the arts and sciences, and as it would be difficult to select any one subject which could be properly treated in an address of this description, I prefer not to attempt it, but rather to touch lightly in a retrospective manner on various matters which have come within my own experience and observation.

By a coincidence, which is very interesting at any rate to myself, the first iron steamer built on the Tyne, was launched at Walker, it being at the same place and in the same month that your humble servant first came upon the scene.

I have thus grown up, side by side, with what is now our predominant industry, and have watched with the deepest interest and satisfaction, the great strides it has made, until it has reached the high position which it now holds.

The first iron steamer built on the Tyne was named the "Prince Albert;" she was 155 feet long by 19½ feet beam, and 9 feet 6 inches deep, and was intended for passenger service on the Thames. She was launched on the 24th of September, 1842, from the yard of Mr. J. H. Coutts, which is now occupied by Messrs. Wigham Richardson & Co. From the same yard there emanated, in 1844, another historical vessel, viz., the "Q.E.D.," which was the first screw collier ever built, and she was, moreover, the first vessel to be fitted with a complete double bottom for water ballast, and it is a somewhat strange circumstance that for several years afterwards this important feature was not followed up, and various expedients, such as portable tanks, and even india-rubber bags, were tried for providing water ballast, and it was not until the early fifties that the double bottom came to be recognised as an inseparable part of a screw collier; whilst to-day it is quite the exception if a steamer of any kind is built with a single bottom, not only for ballast purposes, but as an element of safety, while for war vessels its importance cannot be over-rated. Ballasting by water is, moreover, now being extended to large sailing vessels, but in this case, principally in the form of deep tanks, which can also be used for cargo purposes.

At this early stage the facilities for iron shipbuilding on the Tyne were of the most limited description; and as regards the scientific part of the business, the young shipbuilder had to pick it up as best he could, as there were not then any of the opportunities which are now available to the apprentice, who, with the advantages at his disposal such as are afforded by The Durham College of Science, local classes of naval architecture and engineering, and association with our own Institution, has every opportunity of embarking on an intelligent and useful career, to the benefit of himself and the district generally.

As showing the great local development that has taken place in iron shipbuilding, it is interesting to note that for the five years, 1850-54, there were built on the Tyne 128 vessels of 34,121 tons, averaging 266 tons; whereas, during the last year alone, there were built 112 vessels of 174,047 tons, with an average of 1,554 tons.

The Wear, Tees, and Humber were not long in following the Tyne in commencing the construction of iron vessels, to be followed later by Blyth and Whitby; and the importance of this industry at the various ship building centres on the North-East Coast can be seen from their output [redacted] the Tees District, which diagram also shows a comparison between the amount of tonnage built on our three local rivers, as compared with the Clyde. The comparison, it will be seen, is very startling; and whereas the output of the Clyde and the three rivers in 1886 was precisely the same, the comparison three years later indicates that the output of the three rivers was just double that of the Clyde; and having regard to the endless variety and quality of the vessels involved in the total, it is evident that the suggestion that we have often heard that the Clyde must be looked upon as the leading shipbuilding centre, and the place to which a buyer must necessarily resort if he wants an exceptional or first-class vessel, is finally disposed of.

In the above total of the output of the Tyne, Wear, and Tees are included vessels of almost every imaginable description, although the Tyne has contributed the greatest variety; and whereas the average tonnage of the Tyne-built vessels is relatively smaller than those of the Wear and Tees, this is accounted for by the fact that the Tyne was the birthplace of the steam tug, the first of which was brought into use about the year 1818, and tug building became a specialty of the river to such an extent that there was scarcely a port of importance, either at home or abroad, where a Tyne tug was not to be found. But while the construction of these useful little vessels still continues, with the effect of reducing the average size of the vessels turned out on the Tyne, this river has, nevertheless, had much to do in introducing or producing many vessels of notable dimensions and types, amongst which may be mentioned large cable steamers, the now familiar tank steamer; and there is no doubt that the war cruiser of to-day is a development, on a very large scale, of the gunboat "Staunch," built in 1866, which exemplified the germ of the idea of putting a relatively heavy armament on a floating platform which could keep itself in the position of minimum exposure whilst its own heavy armament could be used with the greatest effect.

Another feature of Tyne shipbuilding has been the large number of vessels which have been shipped abroad to places where no shipbuilding facilities exist, to be there re-erected and set to work; and the latest and at the same time most notable instance of this is the huge combined ice-breaker and railway ferry, of 4,200 tons, and 4,000 horse-power, which has just been shipped to Russia, and which has to be carried overland a distance of some 3,500 miles to the shores of Lake Baikal, where it will be reconstructed and form an important link in the Siberian railroad, by carrying the railway trains across the lake (which at the point in question is 45 miles wide), and where it is intended that it will not only maintain the service in the summer months, but continue it long after the lake has become covered with ice of great thickness. In view of the size of the vessel, the difficulties of transport, and distance to be traversed, the magnitude of the operation exceeds anything hitherto attempted in this particular line, either in this or any other country.

In the foregoing remarks I have alluded principally to notable vessels built on the Tyne, and I must crave your indulgence if I have even apparently given prominence to the river with which I am naturally most familiar; but the Wear and Tees (in which district is included the Hartlepools) have also produced vessels possessing very special attributes. With a boldness which does them infinite credit, the builders at Hartlepool produced what is known as the "well-deck" vessel, which at first found little favour with the authorities, and it was only after several years' experience, and when this class of vessel had shown absolute immunity from loss, that the type came to be recognised as eminently safe. Since its first introduction various amendments have been made, all with a view of carrying the largest quantity at the least expenditure of capital and working expenses, and every day sees some new development in this direction.

On the Wear the same line has been pursued, but to Messrs. Doxford must be awarded special credit for the position they have attained with the turret steamer, which, after an up-hill fight, they have succeeded in establishing as a satisfactory and very economical vessel. In working out the details for these vessels, the builders have introduced many novelties, all tending to simplify the vessel's construction and facilitate operations in their daily working. This same firm has recently made [redacted] the "box" form to leave much scope for the naval architect. One very striking thing, however, is the enormous advance that has been made, more particularly during the last few years, in the size of vessels; and whereas, up to quite a recent date, vessels of 5,000 to 6,000 tons would have been looked upon as comparatively large, to-day many vessels are being built of double this tonnage, and a cargo vessel has just been launched at Belfast, named the "Pennsylvania," which is intended to carry about 14,000 tons.

It is a matter of serious import, and showing that foreign competition is not a myth, to know that a similar vessel is being built in Germany; moreover, there are also being built in that country some Atlantic liners, which will surpass anything at present engaged in this important service. These vessels are 625 feet long, 65 feet beam, 40 feet deep, with 20,000 tons displacement, with engines of 28,000 indicated horse-power, estimated to give them a speed in service of 22 to 23 knots. Although no vessels quite as large as the above have as yet been built on the Tyne, Wear, or Tees, each of these rivers has already built, or is building, cargo vessels, with a deadweight up to 12,000 tons, and if only the opportunity should present itself, and such orders were forthcoming, I have no doubt that the capabilities of the builders on either of the three rivers would be equal to the occasion, and that they would be prepared to produce vessels of even larger size and power than those above indicated. For this possibility the builders, and in fact the whole community, are indebted to the Conservancy Commissioners of the respective rivers, and in this respect, what has been done on the Tyne can be taken as an example. In my own recollection, the state of the river was such that a man could wade across it at almost any part, and even on the bar there was only 6 feet of water at low tide, and vessels drawing more than 17 to 18 feet were detained for weeks, or, in some instances, even months, waiting for sufficient water, whereas to-day there is scarcely a part of the river, from the mouth to Elswick, that has less than 20 feet at low tide, so that at high tide there is a depth of 35 feet, which will probably be sufficient to meet all requirements in the immediate future. This improvement, as far as the Tyne is concerned, has permitted an enormous development in the construction of war vessels, with the result that some of the largest and fastest vessels of that class afloat have been turned out on this river. The great development that has taken place, both as to the size of vessels and their rapid production, would scarcely have been possible but for the introduction of a new shipbuilding material, and, as surely as iron has superseded wood, so has steel now superseded iron.

The first steel vessel with which I had to do was built in 1859, and her plates cost £25 per ton—iron plates at that time being £9 per ton. Steel at such a price was obviously out of the question for general use, and it was not until new methods of manufacture had been discovered, and the cost of production greatly reduced, that its general introduction and adoption became possible. This new departure took place about twenty years ago, steel plates at that time being £13 per ton, and iron plates £7 10s. per ton. These sound very tempting prices to the manufacturer to-day, considering that we have seen prices both of steel and iron plates to be down to £4 15s. per ton, which meant that owing to its requiring less material, a steel ship was the cheaper of the two.

It is not only in the cost, but in the size, and particularly in the area of plates, that a remarkable change is to be seen. In the early days of iron shipbuilding, plates of about 10 feet long and 5 cwts. were used, whereas to-day 20 to 30 cwts., with correspondingly increased dimensions, are considered ordinary sizes.

The great craving for excessive speeds, involving the lightest possible structures, especially in torpedo boats, has led to the use of aluminium in some cases, but although this metal possesses many important qualities, and has been used with a certain amount of success, it cannot, so far, be reckoned as an important factor for general shipbuilding purposes.

Concurrently with the great increase in the tonnage of individual vessels, and the size and weight of plates, beams, and angles, used in their construction, so has it become imperative to devise and adopt enlarged and improved appliances for handling them; it has therefore been neces- [redacted] speak of a large expenditure of capital, to abolish existing steam engines, boilers, etc., and replace them entirely by electric power; some establishments are therefore dealing with the matter tentatively, whilst at Hartlepool one of the chief yards has been laid out for electric driving entirely, thus abolishing several isolated boilers and steam engines, and dispensing with the necessary attendants; and, in addition, obtaining the facility of being able to use only such individual machines as are actually required from time to time, instead of having, as at present, all machines going, whether wanted or not, which, with the loss of power, by transmission through long lines of main shafting, counter shafting, pulleys, belts, etc., involves a total loss of the power transmitted varying from 30 per cent. to as much as 70 per cent. When in Belgium with the Iron and Steel Institute two years ago, I was enabled through the courtesy of Mr. D. Selby Bigge (who has given special attention to this subject) to visit the Small Arms Factory at Herstal, near Liége. At this factory 2,000 hands are employed, and it is driven by two plants respectively of 500 and 300 horse-power. The former of which has been running for several years without having a single case of stoppage.

I have also had an opportunity of visiting at Middlesbrough the important installations at Messrs. Dorman, Long, & Co.'s steel works, and those of the Bedson Wire Company, and am deeply impressed with the fact that there is a great future for this mode of applying power, and in which I am fully convinced that great developments will yet be shown; and I hope that members of the Institution will turn their attention in this direction. Although electricity has been efficiently used as a motive power in small launches, it may, in the future, be not impossible to utilise this mode of propulsion for larger vessels. The application of electricity, whether to vessels, locomotives, tram-cars, or even to motor-cars—with an invasion of which we are threatened—furnishes great possibilities for the student who takes an interest in this important subject, and who is prepared to work hard with the view of producing some new development which may bring advantage to himself and also be a benefit to others.

In the foregoing remarks I have dealt chiefly with the great strides that have been made in shipbuilding; but concurrently there has been similar continued progress made in engineering, and although, owing to the great majority of our members being connected with naval architecture directly or indirectly, our thoughts are naturally inclined to dwell on the construction of steamers, their machinery, and appurtenances, we must not forget that to this district the world is indebted for the locomotive engine, and also for the introduction of hydraulic power, which has [illegible] made possible the creation of our local arsenal, but has furnished [illegible] indispensable element in the production and working of the [illegible] in which we are all so much interested.

The earlier steam vessels had a working pressure of about 5 lbs. This gradually increased till about the year 1850, when about 20 lbs. was customary. About the year 1866 saw the adoption of the compound engine, with a pressure of [illegible] lbs. This continued for about half-a-dozen years, when the triple expansion engine came into general use, with a pressure of 150 lbs. This has also gradually increased, until to-day there are steamers running with a pressure of over 250 lbs. The adoption of [illegible] pressures has almost necessitated a revolution in the steam boiler, seeing that the construction of cylindrical boilers with such high pressures [illegible] a thickness of plate which has about reached the limit. Engineers have, therefore, been forced to turn their attention to some other form of boiler, with the result that some half-a-dozen different descrip[illegible] boilers are in existence, some of which have done good work. [illegible] that perfection has not yet been [illegible], and that there is a good opening for any one [illegible] will possess satisfactory qualities [illegible] safety, and general reliability, combined with [illegible] cost of construction, working, and maintenance.

[illegible] increase of pressure, and also the great increase in [illegible] has suggested a larger number of cylinders [illegible] until recently, the triple expansion three-[illegible] adopted for steamers, we now find [illegible] engines, both for triple and quadruple expan[illegible] witnessed a still further departure in the

[redacted]

boilers of the "Rowan" type, and although a notable economy of fuel was obtained, viz., as low as 1·3 lbs. per indicated horse-power, nevertheless difficulties appeared which were, I believe, largely attributable to carelessness or indifference of those in charge of the vessels, and incidentally to the fact that they were trading in India and Australia, and therefore too far away from the builders and those who would have otherwise taken a careful interest in them. However, the result was that this type of machinery was not followed up at the time, but for which circumstance we might a quarter of a century ago have at any rate approached the position at which we have arrived to-day.

Two of the vessels went to Australia—a screw and a paddle. The paddle was a perfect success, because she fell into the hands of a company whose superintendent took a great interest in her, and did everything that could be wished. The screw, on the contrary, fell into indifferent hands, and after a time the boiler was taken out, but the owners of the paddle steamer were so satisfied with it that they bought it and had it put into a new vessel. This showed how necessary it was for the success of a new departure that it should get fair treatment.

A point which is now receiving very special attention is the balancing of engines, both by arranging the cylinders in certain relative positions as regards sequence, balancing the pistons, and also setting the cranks at such angles as to reduce, as far as possible, the shocks produced in giving the reciprocating motion, so that a certain amount of vibration which formerly existed, even in some large vessels, has been entirely done away with, and the system has been found of the utmost benefit in the fast type of war vessels, where immense engine power has to be combined with relatively slight scantlings of hull.

For many years past various arrangements have been tried to improve and intensify the combustion in boiler furnaces, both by means of closed stokeholds, forced and induced draught, and various modifications of all these systems is still taking place; it cannot, however, be said that we have as yet arrived at any system which does not leave much to be desired.

The use of liquid fuel has been continually receiving more attention in this country, and there is no doubt this system possesses a great many advantages, as has been proved in the Caspian Sea, where a full supply of suitable fuel is always obtainable at a very low price.

On the Caspian Sea there is not such a thing as a vessel running that is not worked by liquid fuel. A good many of the locomotives on the railways adjacent to the Caspian Sea are fired by liquid fuel. Indeed, it was a mere question of pounds, shillings, and pence. If the oil fuel could be got at anything like a reasonable figure the advantages it possessed were beyond all question. They at once got rid of all trouble of trimming, and also the disposal of the ashes. They had simply to set the machine agoing, turn the taps, and everything took care of itself, so he believed they would see a great advance in the future.

As there is a continual development going on in the oil fields of various countries, the time may not be far distant when we will see liquid fuel largely adopted, as there is no doubt it possesses many advantages, especially for war vessels, and we might even before long see tank steamers in attendance upon a fleet to supply torpedo boats with fuel, and it has even been suggested that such vessels should be anchored in certain places known only to the fleet, so that a supply of fuel could be obtained without encountering the difficulties which are met with in having coaling stations on land.

In conclusion, I would only say that the above remarks may be considered somewhat discursive, but my intention has been to draw attention to various subjects from a general rather than a deeply scientific point of view, with the object of interesting the members of this Institution, and at the same time with the hope that at any rate some of them may be induced to favour us by reading papers which will deal in a detailed and scientific manner with some of the subjects which I have touched upon, and in other ways contributing to the common fund of knowledge by the practical application of which, in our daily avocations, we may be assisted in producing the very best work at a cost which will enable us to compete with all comers. This may be considered rather low ground to suggest to the members of an Institution [redacted]

VOTE OF THANKS.

Mr. ARTHUR COOTE said their worthy President had expressed a wish that the office of presidency did not entail the necessity of reading an address. Speaking for himself, as one who had come simply to listen to that address, he wished his presence as a listener did not entail his being chosen as proposer of a vote of thanks. The Secretary, however, had apparently thought otherwise. When contemplating coming there that evening he had hoped to see a goodly number of Past-Presidents and Vice-Presidents, on one of whom he would have been very pleased to have seen devolve the duty of proposing the vote of thanks in his stead. While he had no doubt whatever that the excuses which had been forthcoming from them sufficiently explained their non-attendance, he could only regret the fact that they were not there. For his own part, speaking for one Past-President (Mr. Marshall), he could assure them that it was only through absence from the district that he had been prevented from being with them that evening. But if he had been deputed by his friend, Mr. Marshall, to stand up in his stead on that occasion, or had been called upon by the Secretary to represent Mr. Marshall, he should feel no greater pride than when, standing for himself, he asked them to give a cordial vote of thanks for the address which had just been given. When their President spoke of his own early shipbuilding days, he (Mr. Coote) could not help going back to the same time, for they started together, and he could distinctly recollect, on his being made a full-blown partner of A. Leslie & Co., how his firm shortly after received a circular stating that Mr. H. F. Swan had been taken into partnership with their late respected friend, Mr. C. Mitchell. Owing to the advance of science, and the increased facilities afforded to engineers and shipbuilders alike, shipbuilding had changed since those days—changed as only the older generation of shipbuilders knew how. On that subject, however, he simply wished to touch, and it gave him pleasure to find that their President, unlike some of his predecessors, had abstained from drifting into the discussion of elaborate details or intricate scientific and technical matters, comprehensible only to a portion of their number. He felt that the object of the Presidential address had been rather to make the opening meeting of the session interesting than unduly technical, and he thought the idea of making it so a very happy one. During the session there would be ample facilities afforded for the discussion of subjects commending themselves specially to individual sections, but they were all agreed, he thought, that the scope of their Institution should not be limited to those scientifically interested only. Theirs was an Institution which sought to open its ranks to all who were allied with the special industry, which, by their meetings, they endeavoured to improve. There was one point which had occurred to him on which he would like to say something, especially as he noticed the President had not alluded to it in the course of the history of shipbuilding he had given them. That was the status of the shipbuilder in the early days as compared with the present. They might smile, but it was a fact, that, at the time when their worthy President first came upon the scene, the shipbuilder's profession was a very dignified one. In those days the head of a shipbuilding establishment invariably carried a top-hat—he never went into the yard without it. In fact, the first time he saw his friend, the President, in the shipbuilding yard at Walker, he recollected very distinctly they both wore the orthodox top-hat. This he mentioned more particularly for the information of their younger members, who might find a difficulty in associating the top-hat with present day shipbuilding. The shipbuilding we still had with us, but the hat had gone, and it would be instructive to know the reason for the change. Of course, in alluding to top-hats he simply wished them to understand that in former days there was a gentlemanly dignity attaching to their industry beyond the general run—that, in fact, to be a shipbuilder was to be "somebody," and "somebody," too, whom people did not meet every day. Well, his own impression was that the degeneracy of their industry's dignity had arisen in a very great measure from the serious decline in its profits. And to what cause was this decline in profits mainly attributable? He should say to excessive competition for one thing. He did not mean general competition; this they must always have more or less. The competition he had before his mind was that existing amongst such friends as he saw before him, though he looked forward hopefully to the time when, between brother engineers and shipbuilders on the same river, that sort of thing should be a thing of the past. He believed that it was a matter of paramount importance that their Institution should turn its attention to the subject; that it should endeavour to find a means of making their industry as profitable as possible; that this policy of ruinous and fratricidal competition should be discouraged to the utmost; and means devised to prevent it by more fraternal communication with each other. Then at length they might hope to see restored that dignity which had been so conspicuous in the earlier days of shipbuilding. It gave him great pleasure to move that a hearty vote of thanks be accorded their worthy President for the excellent paper with which he had favoured them.

Mr. R. SAXTON WHITE said it gave him very great pleasure to second the proposal so ably made by their friend, Mr. Coote, awarding a very hearty vote of thanks to their President for his most interesting address. The result of the ballot for new members just taken presented one of the most interesting facts as showing the prosperity of the Institution. He was departing, perhaps, from the address; but as this was a record-breaking age—Her Most Gracious Majesty the Queen setting them such a glorious example, and long may her reign continue—he thought they should congratulate their President that he, also, was taking part in this record breaking, inasmuch as he was inaugurating his accession to the presidency of the Institution, by a considerable addition to their membership, as indicated by the ballot just taken, so that for the future, and long may it so continue, the membership of the Institution may now be numbered by the thousand, instead of by hundreds as in the past, on this ground therefore, as well as for his interesting address, their President deserved their congratulations and best wishes for a most successful term of office. Their President had made reference to the foreign competition they had now to meet, and so far as their German cousins were concerned, there was no question whatever, every day and every year was making that competition more keen. As the American shipbuilder put it, when he started a few years ago building Atlantic greyhounds, "he had come to stay," and he was afraid the German builder, although in a different language, is saying the same thing, perhaps with far greater reason; certainly they were factors they had to reckon with in the future. Personally, he had had most pleasant intercourse with both their American and German friends in building ships for them of various types and classes. He was very much afraid, however, as their President expressed it, their experience in that way was rapidly drawing to a close, and that possibly they might yet have to fight them on their own ground. Still, when that time came, he thought there would always be enough grit in the old country to meet them, and compete successfully on anything like fair terms, whether for the greyhounds of the Atlantic, or the big cargo steamers. He could not refrain from referring to one figure out of the many given by the President in his interesting address, and that was, where he referred to the average tonnage of the steamers built on the East Coast being more than 50 per cent. larger than the average tonnage of ships built upon the Clyde. He thought that was rather a startling fact, and one that certainly he had very little idea of ; all he would say, was to express the hope that it might still further increase from 50 per cent. to possibly double. He thought they would raise no objection to that, and then possibly they might hope to arrive once more at that state of prosperity indicated by the top-hat, so humorously referred to by Mr. Coote. He had very great pleasure in seconding the vote of thanks to their President for his most interesting address.

Mr. Coote put the motion to the meeting, and it was carried by acclamation.

The President begged to thank the meeting very much indeed for the very cordial way in which they had received that proposal. It had been his pleasure to know Mr. Coote from the first time he set foot in this part of the world, and although they had been competitors in business he must say they never had had a word of disagreement of any kind whatever. He looked upon Mr. Coote as one of his oldest and best friends, and the words that had fallen from him he could assure him were received with very great pleasure. As to the top-hat : now that he mentioned it, he thought he remembered it also, and he would account for it, as Mr. Coote very properly remarked, that in those days the shipbuilding business was one of the pleasantest anybody could be connected with ; it was much pleasanter than the ordinary merchant's business, selling so much coal and that sort of thing, for they were producing something, creating some new object in fact ; and while they not "cutting each other's throats," metaphorically, he was afraid if they did not cut closely themselves, it would simply mean that the work would go to other rivers in their own country, or, what was worse, go out of it altogether. There was no doubt that the foreigner was undercutting them, and largely, from the position that he was in as regarded labour. Men were under better control, they earned very much less wages, and they were steadier and more reliable. They could not do the work their men could do if the latter chose, but taking things as they stood their work was much too costly. He was afraid that was a thing they would have to fight more and more, and could only hope that they would keep their heads above water, and compete with all comers. He begged to thank them very kindly for the way they had received his address.

This concluded the business of the meeting.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896-97.

PROCEEDINGS.

SECOND GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUNDERLAND LITERARY SOCIETY, SUNDERLAND, ON WEDNESDAY EVENING, NOVEMBER 11TH, 1896.

ROBERT THOMPSON, ESQ., J.P., PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on October 14th, which were approved by the members present and signed by the Past-President. Communications were received from the President (Col. Swan), Messrs. J. R. Fothergill, T. Mudd, G. H. Baines, and others regretting their inability to attend.

The ballot for new members having been taken, the Past-President appointed Messrs. F. Graham and F. Gross to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Adamson, James Young, Ship Draughtsman, 94, Ramsden Street, Barrow-in-Furness.

Billetop, Torben Christian, Engineer, 3, Guildford Place, Heaton, Newcastle-on-Tyne.

Bush, Montague, Electrical Engineer, c/o Messrs. Ernest Scott, Mountain, & Co., Close Works, Newcastle-on-Tyne.

Dove, Herbert J., Engineer, 25, Ashfield Terrace West, Newcastle-on-Tyne.

Ford, John McLaren, Ship Draughtsman, c/o Messrs. Naval Construction and Armaments Co., Limited, Barrow-in-Furness.

Hawkins, Charles Gittens, Engineer, 65, Westmoreland Road, Newcastle-on-Tyne.

MacColl, Hugo, Engineer, 12, Victoria Terrace, Newcastle Road, Sunderland.

Tuxen, Holger, Ship Surveyor, Bureau Veritas Register of Shipping, Custom House Court, Quayside, Newcastle-on-Tyne.

GRADUATES TO MEMBERS.

Golledge, William, Electrical Engineer, Royal Agricultural Hall, Islington, London.

Warburton, John Arthur, E. Draughtsman, 9, Foyle Street, Sunderland.

GRADUATES.

Dunford, Thomas, E. Draughtsman, 74, Osborne Road, Jesmond, Newcastle-on-Tyne.

Sitwell, John Knightley, E. Apprentice, 24, Archbold Terrace, Newcastle-on-Tyne.

THE MILE POSTS.

The Past-President intimated that he and Mr. Macoll had, on the previous Monday, inspected the measured mile posts. They had been newly painted and were in very good order and condition. He hoped they would show their colours plainly to those using them for some time to come.

THE GOLD MEDALS.

3. That when the Council proceeds to award the medals, authors of papers who are members of the Council shall not be present nor vote at such Council meetings.

4. If at the meeting convened a quorum of the Council should not be present, or if the Council considers it desirable or cannot agree, the decision of the Council may be deferred and adjourned to a future meeting.

5. That the medals shall be awarded annually, provided the papers are, in the opinion of the Council, worthy of the award, but not otherwise; and that they be awarded to the authors of the best papers, irrespective of their having previously obtained a gold medal.

TRANSACTIONS.

The PAST-PRESIDENT drew the attention of members to the following resolution, which had been agreed to by the Council, and was now put in force:—

"The *Transactions* will be issued *in parts* to those members who may intimate their wish to receive them in that form, provided their annual subscriptions are paid before November 30th in each year. With this exception the *Transactions* will be issued complete (unbound) at the close of the session to those members whose subscriptions are paid for that session."

The discussion on Mr. J. F. Walliker's paper on "Notes on the Maintenance and Repairs of Marine Boilers" (see page 223, Vol. XII., of *Transactions*) was resumed.

The discussion on Mr. J. R. Fothergill's paper on "Marine Boilers, particularly in reference to Efficiency of Combustion and Higher Steam Pressures" (see page 235, Vol. XII., of *Transactions*) was resumed.

Mr. R. M. Ferrier read a paper on "Water Gauges for High Pressure Steam Boilers," by Mr. T. C. Billetop.

ADJOURNED DISCUSSION ON MR. J. F. WALLIKER'S PAPER ON "NOTES ON THE MAINTENANCE AND REPAIRS OF MARINE BOILERS."*

The SECRETARY (Mr. Duckitt) read the following communications on Mr. J. F. Walliker's paper, "Notes on the Maintenance and Repairs of Marine Boilers," read at the Summer meeting held in Cardiff :—

LEEDS FORGE, LEEDS, *November* 10*th*, 1896.

DEAR MR. DUCKITT,

I regret being unable to be present at your meeting on the 11th, but should like to offer a few remarks upon Mr. Walliker's most interesting paper. I feel that every engineer will thoroughly endorse his remarks as to the design of marine boilers. It used to be said that the roomy boiler was a good boiler in every respect, inasmuch as not only did its accessibility tend to long life, but the same features also made it a good steaming boiler. I am afraid that sufficient importance has not been given to what I may call the "shadow of the warship," which has been very much over all merchant ship design for some years. Our friends at the Admiralty appeared to think for some years that it was only necessary to get a certain amount of grate and heating surface into a boiler, neglecting altogether the size (and I am sure that a great many of the members of the Institution will remember this), as a large number of boilers fitted to warships simply consist of a mass of tubes and other heating surface, jammed into the smallest possible space. The result has been in many cases disastrous, and to this I attribute a great deal of the troubles that have been experienced in our own and other navies, as it is impossible to get good circulation in such a boiler, and no boiler without good circulation can be efficient.

As to manufacture, no one who visits a modern marine boiler shop can fail to be struck with the wonderful advance that has been made in this direction, as the accuracy in boiler making is now almost as great as it is in the machine shop.

In management, in spite of the wonderful improvements that have been made in evaporators, and in other directions, it appears the human factor is still the governing factor as to the success or failure of any departure from the beaten track. This appears to be Mr. Walliker's opinion, when he says that some people even to-day allow scale to accumulate on the tubes till it is ¼ inch thick. We used to have it in our copy-book

* See page 223, Vol. XII., of *Transactions*.

headings that "cleanliness was next to godliness." I am not sure that it is not before it as regards the management of a marine boiler. One thing is certain, that as long as the surfaces are kept perfectly clean in a well designed boiler, no one hears anything of the repair bills.

I have read with interest Mr. Sisson's remarks as to the staying of the combustion chambers, and while quite agreeing that there is a great deal in the view that he has put forward, I think it might interest members of the Institution if I related what came under my notice a short time since:—The boilers of a ship that we all have an interest in were put under hydraulic test at the end of the usual period. When the pressure was some 90 lbs. above the ordinary working pressure one or two sharp reports were heard, and upon a careful examination being made several stays were found to be fractured close to the shell, and it struck one of the officials who were present that it might be advisable to test the steel of which these stays were made. Stays which were not fractured were therefore carefully withdrawn, and upon being tested it was found that close against the shell the steel was of a remarkably brittle nature. A little farther away from the shell it was still somewhat brittle, but not to anything like the extent as the part immediately adjoining the shell. Still farther away the steel was very ductile, and although screwed would bear bending to considerably more than a right angle without fracture. Upon enquiry it was discovered that before the stays were screwed they had been sent to the smiths' shop to have a square worked on the end of them so as to enable them to be conveniently held in the screwing machine, and also conveniently screwed into position. Other stays were then taken out and annealed before testing, when it was found that the results were quite as good as the original tests of the steel recorded before

As to the value of Mr. Walliker's paper, there can be no two opinions; and I think the Institution has great reason to be thankful to him that out of the abundance of his experience he has consented to put on record what he has done.

Yours faithfully,

Ernest Gearing.

Earle's Shipbuilding and Engineering Co., Limited,
Hull, *November 9th*, 1896.

Dear Mr. Duckitt,

I have read both Mr. Walliker's and Mr. Fothergill's papers with some interest, especially the former, as I think the writer of it has helped unconsciously to forward the argument in favour of the water-tube boiler, inasmuch as he shows that the construction of the tank boiler is inevitably such as to lead to the disasters he names, and that although care and attention may put off the evil day, still the sword is always hanging by a very fine thread over the head of him who has to do with it.

In Mr. Walliker's paper I do not think sufficient consideration was given to the part that temperature plays in deformation of the internal parts of the tank boiler. It is very difficult, and practically impossible, to build a boiler in the cold state so that the strains in the hot state may be resisted in the ways intended by the designer, and we are too apt in considering a boiler drawing to treat it as if it represented the boiler in the hot working state. I long since gave up making combustion chambers cylindrical at the top, and I think with advantage; for it really made a change of method of staying, and caused unfair strains to come on the stays in the immediate neighbourhood of the gusset plates.

There is no doubt that the suggestion made by Mr. Sisson as to the heavy cross strains that are put on screwed stays by fire-boxes and combustion chambers being stayed at top locally, without consideration for the effects on the general structure, is quite correct. We recognised this at least ten years ago from observations made during the testing of large boilers built to Admiralty scantlings. The increase in vertical diameter when the test pressure is put on a boiler is only what might be expected, because the effect of the weight of the shell is then reduced to a minimum. All boilers show this peculiarity, but especially large ones.

I again repeat, that all Mr. Walliker's statements, theories, and arguments work in the direction of proving the tank boiler to be past redemption for very high pressures and consequent high temperatures, although apparently he is not a believer in the water-tube boiler. For my own part I do not ask anyone to pin his faith without reserve on any of the existing forms of water-tube boiler; but I do say that a boiler whose every part is a cylinder or part of a sphere, and whose structure is not necessarily rigid, must be a safer instrument than one having of necessity the difficulties and dangers pointed out by Mr. Walliker.

This gentleman has also helped matters a step further by admitting that the commonest class of cargo boat is now fitted with an apparatus for the supply of fresh water to the boilers, and that engineers do not use oil for lubrication, because the want of fresh water and the presence of oil with the feed water prevent the successful use of the more delicate forms of water-tube boiler from which more economic results are obtained in the way of steam production than is experienced with the Belleville or the Babcock and Wilcox boiler. I should venture to say also that the better the members of our Institution become acquainted with the water-tube boiler, the less prejudice will they have against it; in point of fact, there are really fewer difficulties to be overcome in making the water-tube boiler a success for general purposes than there were in bringing the marine boiler from its original simple form to the one we now find used for 180 lbs. pressure.

As regards the possibility of pressure, we have no certain limit. Before I was born Loftus Perkins made boilers for 700 lbs. pressure, so that there is no reason why we cannot produce steam at the same pressure if we can make an engine capable of receiving it and digesting it. At the present time we are making boilers for 300 lbs. pressure for warships, the Admiralty having gone ahead by leaps and bounds until the mercantile marine is left entirely behind in that respect. But supposing that we cannot make engines to work satisfactorily at such high pressures, I think there is every reason to expect good results by employing the

BALTIC CHAMBERS,
NEWCASTLE-UPON-TYNE,
November 11*th*, 1896.

DEAR MR. DUCKITT,

I am sure we are all deeply indebted to Mr. Walliker for his most interesting paper on marine boilers, and I am only sorry that I have not been able to go more fully into it. I agree with him that the design of a boiler is the first and most important consideration, and that about nine out of ten are built with too many stays in about the proportion he points out, through the draughtsman not recognising that steel plates cost about £6 10s. per ton, where screwed stays cost about £20 per ton. I certainly advocate ⅞ inch C.C. backs and sides. I would also like to point out some other stays I am trying to avoid putting in a boiler I am designing, those tying back and front plates together above the bottom manhole doors, by doubling the end plates instead; and, as regards the thickening of plates, I would not hesitate, if allowed by the powers that be, to put furnace plates in 1 inch to 1⅛ inches thick. I, and all shipowners, I am sure, hope Mr. Walliker is right in giving present day boilers a 30 years' lease. Four months ago I set the valves of a pair of 75 lbs. pressure boiler, 18½ years old, to their original pressure, and with all their original furnaces in; hence, with the improvements that have been made in boiler making since these were built, there is no reason why boilers should not now last the time stated if properly looked after, but everything depends on the management or treatment they receive, as the best of boilers can be ruined in six months by careless treatment. I should like to mention here that the best boiler fluid I have yet found, and I have tried most of the best ones, is Cooper and Smith's tannate of soda, made by the Aston Chemical Co., as it removes scale, prevents it forming, and stops pitting. Several times lately I have been complimented by Mr. Walliker's colleagues on the condition boilers were in on putting them through surveys, practically as they came off the voyage; this fluid imparts a white flour instead of a red dust to a new steel boiler. I am at one with Mr. Walliker in keeping the tubes clean, and also his remarks about end guard plates. Boiler bottoms should certainly be covered, not only for their own good but also for the tanks if there be any under them. Old jobs can be largely protected by putting a wooden platform between the seatings, loosely laid on angles attached to the same, and about 6 inches from the boiler bottoms.

I am more in agreement with Mr. Walliker than Mr. Sisson regarding the fracturing of the small stays. The way that combustion chambers are stayed at the bottom, where the heat is first applied and is most intense, makes them, in my opinion, expand upwards bodily, the top stays being short have not so much chance of bending as breaking. I would also like to point out to Mr. Sisson that the gussets or palms, latter preferable, are to stay the boiler back more than the combustion chamber top, which is self-supported by its own thickness.

I agree with Mr. Sisson that combustion chamber stays should all be nutted, not only to stiffen the plates, to use his own words, but to get a greater pitch of stays, give more elasticity to the plates, and easier accessibility for cleaning and repairing, all of which are important factors in the designing of boilers.

Passing to Mr. Hurst's criticism, I agree with him, with the exception of the wooden rake, as it must be a very badly put in rivet to be loosened by an iron rake taking out the mud. I think leaky rivets are caused by the bottoms being cold when the tops are hot, or, in other words, by want of circulation. I strongly emphasize Mr. Fothergill's and Mr. Baines's remarks about hydraulic tests, and think 1½ times the pressure is enough. Mr. Hurst's remarks about the shells of double-ended boilers, and my own experience of them at work, go to prove Mr. J. C. Spence's theory that a boiler shell is a beam; but for my part I would never allow a double-ended boiler to be put into a vessel with which I had anything to do. I am very glad Mr. Walliker has brought this most interesting, and also most important, subject of boilers before us, as there is no doubt that the boilers of a vessel are to the ship what [redacted]

Mr. **Geo. D. Weir** said he was sure all agreed with Mr. Walliker's remark that "he would place accessibility in the fore front of boiler design," but when he went on to say that after the heating surface and grate surface was allowed for, the boiler should be so made (and it could be made) as to render all its parts accessible for cleaning and examination, then he was afraid Mr. Walliker left out of consideration a factor which those of them who were engaged in the designing of marine boilers were compelled to face, and who, after every attempt to make the boiler accessible, as far as possible, in all its parts, found their good intentions knocked on the head by either Lloyd's, Board of Trade, the Hamburg Board of Police, or some kindred society, whose object sometimes seemed to be to make such alterations in the design of the boiler as to admit of a thorough examination being practically impossible. In these remarks he did not wish it to be understood that he underrated the true value of these societies, but he thought most of the members present would agree that they all seemed to have certain peculiarities which they compelled engineers to comply with, and very often a certain point or detail in the design or strength of the boiler, which one, or even two, of these institutions might consider quite practical and perfectly in order, the third would condemn with the utmost rigour. Let him give them an example: Some time ago there was submitted for approval to two of these societies a plan of a boiler, as shown in Fig. 1 (Plate II.), having the back plate stayed to the shell by means of a gusset plate. This was approved by one of them, and the tracing returned unaltered, while the other society would not approve of the boiler unless the gusset plate was taken out and a through stay fitted, as shown in Fig. 2 (Plate II.), which completely blocked up the manhole on the front end of the boiler, and prevented the cleaning and inspection of the sides of the furnaces; and it was in order that this could be done that it was proposed originally to fit the gusset plate. He did not wish to compare the societies, but he did think that it was rather a pity that one society should allow a working stress of 7,500 lbs. per square inch of section on iron stay tubes, and another society only allow 5,000 lbs., and yet with the large amount of practical experience which engineers have at their command, they do not find that the former limit was unsatisfactory. He also instanced the case of screwed stays of steel, say, 1½ inches diameter, where one society only allowed a working stress of 8,000 lbs., while the other allowed 9,000 lbs. per square inch. He also instanced the case of a boiler whose shell plate was made in one strake of plating, fore and aft, without any central circumferential seam, and now that it was possible to get steel plates 11 feet wide, many makers had put down special plant in order to build boilers, say, 10 feet 6 inches long without the centre circumferential seam, thus, in his opinion, making a better, more satisfactory, and, perhaps, stronger boiler, yet he found that these makers were compelled by some societies to make the shell plates considerably thicker, and would not allow them to use a less factor of safety than 4·9, whereas if the shell had been made in two strakes of plate, they would have passed a factor of 4·5. In this way the boilermaker was penalised for the trouble and expense he took to make, in his opinion, a better boiler. Mr. Walliker, in his paper, advocated the use of wide pitch stays in the combustion chamber. Here again they found that one society would not allow these stays to be pitched at a greater distance than 8 inches, from centre to centre, and stays in the steam space 16 inches, from centre to centre, no matter how thick the plate was made, nor how heavy the stay, nor at what pressure the boiler was to work. The result was, that in boilers built to pass the survey of these authorities, close-pitched stays had to be adopted, and the very thing which, in his opinion, Mr. Walliker rightly condemned as being bad for the boiler, because it prohibited inspection and retarded cleaning, the boilermaker was compelled to adopt. The diagrams, Figs. 1 and 2 (Plate III.), showed two boilers of approximately equal dimensions, and both for the same working pressure, but one of them is shown as stayed to fulfil the requirements of one society, and the other to fulfil the requirements of another. The difference could be clearly seen, and the greater accessibility in the one boiler over the other would be apparent to all; yet shipowners and superintending engineers having boilers built for the average cargo tramp steamer insisted that their [redacted] consistently put their vessel in the hands of an engineering firm for short periods, when the boilers could be thoroughly cleaned, and the machinery overhauled, they would find it would certainly pay them in the long run, but, unfortunately, a great many of them seemed to think that engines and boilers were machines which would go on working for ever, without requiring any special care or attention other than that given them by the engine room staff.

With regard to the pressure to which new boilers should be tested, he did not agree with Mr. Baines that it was unnecessary to test a boiler to double the working pressure, and if the case was looked at from an unbiassed point, he thought that the authorities were quite right in the stand which they had taken. He knew of certain cases where stays had broken and rivets given way between the working pressure of 160 lbs. and the test pressure of 320 lbs., and which might have led to dangerous results if the boilers had not been subjected to the double test. Then why did some engineers wish to reduce the test pressure? Was it because of the extra cost involved? That surely was a mere trifle, and it could not be because they thought the material was unduly strained or ruptured. If that were so, then, in his opinion, the whole argument in favour of reducing the test pressure fell to the ground, as he was sure they must all admit that very much greater strains were put on the material due to the expansion of the materials alone, and the general alteration in the form of the boiler, which took place between the time when fires were lighted and steam generated at the working pressure; and he for one would advocate the testing of boilers, even for the high working pressure of 255 lbs., which of course meant greater heat and greater strains due to this cause, to at least double the working pressure, if the present system of cold water test was to be adhered to. In conclusion, he thanked Mr. Walliker for his very able and interesting paper.

Mr. J. H. BUCHANAN said he was sure all who had the good fortune to take part in the recent visit to Cardiff, and the neighbouring ports, must have felt that the occasion was a very suitable one for Mr. Walliker to bring before them the advisability of constructing boilers in such a way as to facilitate to the utmost the operations of cleaning and examination—for during these visits they were constantly having impressed upon them the great despatch in loading which could be given in those ports—and it followed that the time available for overhauling was thus extremely limited. They were all, he supposed, like himself, fully convinced of the soundness of the author's views on this question of accessibility to all parts of the boilers, but he would point out that an additional inducement to move in the opposite direction had of late years been presented to the boiler designer. He referred, of course, to the prominence given in Lloyd's register book to the heating surface and area of the fire-grate. This information had been recently added to the particulars given of steamers. If they would suppose two steamers exactly alike—except that one had roomy boilers, such as Mr. Walliker advocated, the other with boilers of the same size, or even less diameter, but into which the utmost possible heating surface had been got—they would see that the last would appear from the register book to have the better boiler power. For his own part he should much prefer to see the diameter and length of boiler stated, rather than these other figures which might or might not be a practical guide to what the boat could do, and he thought if this were done Mr. Walliker would derive very material assistance from the change—in bringing boiler designers to his view.

Mr. W. G. SPENCE thanked Mr. Walliker for his paper. He quite agreed with him on the importance of widely pitched staying. At one point in the paper Mr. Walliker said: "there appears to be no reason why a limit of $\frac{9}{16}$ inch or $\frac{5}{8}$ inch should be imposed on a flat plate at this part (combustion chamber backs) when a $\frac{3}{4}$ inch one is in successful use in an equally hot or hotter part, viz., the furnace." He might mention that for the last three years at least, he had seldom used less than $\frac{11}{16}$ inch plate, with 10 inch pitched staying for the parts indicated, and had found it advantageous; there were special cases where a smaller pitch had to be adopted, such as the Hamburg Police Law, but they were exceptional cases. With regard to the round top combustion chambers which had been spoken of, these were fitted a good deal in the earlier days of 150 lbs. pressure, but they gave trouble at the gusset rivets and were soon abandoned in favour of the flat tops with dog stays. For this reason he had no great love for the gusset plate arrangement shown by Mr. Weir: they could arrange to have room and still avoid gussets. He thought Mr. Weir misunderstood the object of owners occasionally specifying Hamburg Police regulations for their boilers. It was not that they thought they would thereby secure a better boiler, but because through that means they opened up an additional market for their vessel in the event of their wishing to sell her. If the boilers were not built to German law, they could only be sold to German firms at a disadvantage.

The PAST-PRESIDENT moved a vote thanks to Mr. Walliker for his paper, and remarked upon the wide amount of interest it had excited. He was sure it was of great value to the Institution, and when they got his reply to the discussion it would add very materially to the value of it. They would have at hand a great amount of information upon boilers and be, perhaps, better able to understand those not quite up to their expectations.

The motion was carried by acclamation.

ADJOURNED DISCUSSION ON MR. J. R. FOTHERGILL'S PAPER ON "MARINE BOILERS, PARTICULARLY IN REFERENCE TO EFFICIENCY OF COMBUSTION AND HIGHER STEAM PRESSURES."*

Further discussion ensued upon Mr. J. R. Fothergill's paper, read at Cardiff, on "Marine Boilers, Particularly in Reference to Efficiency of Combustion and Higher Steam Pressures."

The SECRETARY read the following communications :—

LEEDS FORGE, LEEDS, *November 10th*, 1896.

DEAR MR. DUCKITT,

Mr. Fothergill raises a very wide and interesting question in his paper read before the Institution in June, and while agreeing with him as to the advisability of higher pressures as long as they can be carried without the introduction of undue complication, I am constrained to say that up to the present the introduction of the water-tube boiler has been accompanied with such a mass of complication that, whatever good it may possess, has been quite overshadowed by the troubles and failures which have attended the carrying out of the design. It will be within the recollection of most of the members of our Institution that economisers or feed-water heaters have been repeatedly tried in conjunction with the present form of cylindrical boiler, but I do not think that any member can point to a ship which is now running with such appliances. In all cases it has been found that the gain from the application of the feed-heater has had to be discounted to such a large extent by the increased cost of upkeep, etc., that it has been eventually done away with, so that the old saying, "The nearer you keep to simplicity the nearer you are to success," still appears to hold good. There have been several cases lately where the pressure nominally carried in the boilers has been 300 lbs., but on the trial trips it has been necessary to reduce this pressure to something like 225 lbs. to obtain anything like a result, and the care and attention then necessary has been such that one cannot refrain from thinking that in the stress of an action a tithe of these precautions could not possibly be attended to.

A great deal has been said as to baffles that require to be fitted to water-tube boilers, or other checks put upon the escaping gases, so as to

* See page 235, Vol. XII., of *Transactions*.

keep them the longest possible time in contact with the heating surface of the boiler. Does not the whole of this apply to the boiler which is at present in use? in other words, slow combustion gives the most economical results. This simply means large boiler power, and I venture to think that had this been kept more in view in the design of a great number of our ships, we should have heard a good deal less of their failures. It is a common thing now in warships for 3 to 3½ square feet of heating surface to be allowed for 1 indicated horse-power, whereas in the much-abused cylindrical boiler 1½ to 1¾ square feet was a very common limit, and when added to this the boiler shells were made as small as was possible, consistent with squeezing the heating surface into it, I do not think it can be wondered that under such conditions boilers gave trouble. The engine appears to be considered as some negligible quantity in this direction. Are we quite certain that with some 300 lbs. pressure our engines will not require some radical alterations in the present design? If those who have had recent experience would tell all they knew, I am sure that this side of the question would receive a great deal of consideration.

It is only by such papers as Mr. Fothergill's that the steps which we are always making in advance can be recorded, and I hope you will allow me to express my sense of the value of his paper.

Yours faithfully,

ERNEST GEARING.

CARDIFF, *November* 9*th*, 1896.

DEAR MR. DUCKITT,

[redacted]

and gratifying result to the owner of a reduction in the coal consumption from 20 tons per day to 15½ tons per day, and with the same speed of vessel. I see no reason why this cannot be applied to the case of the quadruples, and I think some of our friends on the Tyne could give us some satisfactory figures with a working pressure not exceeding 200 lbs., and with the present type of boiler.

Secondly, Mr. Fothergill's experience with escaping gases in tubes is exactly opposite to mine. In cases of boilers worked with induced draught, or a funnel height of 60 feet from the grate and upward, I have always found the lower tubes contain the most soot and deposit, and only in the case of boilers fitted with retarders, where "the area of the top tubes is purposely reduced," have I found the upper tubes with much more than a trace of soot. I may add that the designers of these retarders must have had the same experience as I have, as, without doubt, they found that in the top tubes the most compression was required in the escaping gases.

I must express my thanks to Mr. Fothergill for his valuable and instructive paper, and hope that if a water-tube boiler be adopted in this country it may be British in design and manufacture.

Yours faithfully,

John F. Walliker.

Bureau Veritas (Engineering Department),

Newcastle-on-Tyne, *November 11th*, 1896.

Dear Mr. Duckitt,

I am very sorry to inform you that indisposition prevents me attending to-night's meeting at Sunderland. I take much interest in Mr. Fothergill's paper on water-tube boilers, and would have liked to say a few words on the subject in the way of discussion. If you consider it advisable, I would thank you to read, on my behalf, the following few lines at the meeting :—

I think most engineers will agree that, for steadiness in keeping steam, it is desirable, and almost necessary, to have a large quantity of water in the boiler, which acts, so to say, as a fly-wheel does in an engine, and no extraordinary care in firing is required. In water-tube boilers generally, the quantity of water in the boiler is considerably reduced in proportion to the water contained in the ordinary circular marine boilers of the present day, and therefore much greater care in the uniformity of supply of feed-water and in management of the fires is necessary to keep the steam at a steady pressure, which is so essential for the regular and satisfactory working of the engines. I think, therefore, that for ordinary mercantile steamers, where weight is not of such extreme importance, as in torpedo boats and other war vessels, and where the management of the fires is to a great extent left in the hands of ordinary unskilled firemen, it should be a matter of great consideration in the designing of water-tube boilers to provide a sufficient amount of water space. I also think that tubes of small diameter, especially when exposed to great heat and to the direct action of the fire, are not as good and reliable as larger tubes. I am of opinion that it is quite possible for the water in a small tube, particularly if horizontal or only slightly inclined, to be so quickly evaporated, that the steam cannot get quickly enough out of the tube, and if such an event takes place, it is quite possible for the tube to become very hot and fail quickly. I am to some extent confirmed in my opinion by the failure of some boilers which came lately under my notice, and which boilers compared very unfavourably with other boilers of similar design, which, as far as I know, worked quite satisfactorily. In the former case the tubes, principally exposed to the action of the fire, had a diameter of $1\frac{7}{8}$ inches, and failed by pitting and corrosion within about three months. In the latter case the tubes, similarly exposed to the fire, had a diameter of 4 inches, and worked quite satisfactorily for over eighteen months already, the management of the boilers being in both cases practically alike.

Yours faithfully,

ANT. G. SCHAEFFER.

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of combustion of 15 to 20 lbs., gave an efficiency of, say, 60 to 65 per cent. He did not think even that result would compare unfavourably with most, if not all, the water-tube boilers at the present time; but when the Serve tube came forward with ships having natural draught and a funnel height of 70 feet and over, with just the same boilers as before, the substitution of Serve tubes for plain tubes gave the shipowner the advantage of an economy of 10 per cent. There were now a large number of ships—appreciably over one hundred—with these Serve tubes and natural draught, and the facts were no longer disputed as to the economy which resulted. Taking still the natural draught, some owners had introduced retarders into the plain tubes when the funnel heights had allowed it, and had at once benefited on an average to the extent of 5 per cent., but in similar ships with similar funnel height, and similar size boilers, the introduction of the retarders into the Serve tubes had brought an exactly corresponding advantage, so that in natural draught boilers the Serve tube was still the best friend of the shipowner. Mr. Howden had shown them how they could increase with mechanical draught the rate of combustion very appreciably without losing, and even gaining appreciably in economy. For his purpose, having the advantage of mechanical draught, Mr. Howden found it desirable to use a long boiler, with long small diameter plain tubes and retarders, thus obtaining a large ratio of heating surface. He (Mr. Gross), on the other hand, believed the shipowners' best interests were lying in the direction of a much shorter boiler with much larger diameter Serve tubes, only 6 feet long, with a reduced heating surface not to exceed 28 to 1, thus reducing the weight and space very appreciably, and, besides the economy, giving much better working conditions. He had purposely not spoken in connection with Mr. Walliker's paper, but the various remarks made by other speakers had a bent in the direction of large tubes widely spaced being better than smaller tubes closely spaced. When they came to the introduction of the Ellis and Eaves suction draught they found, as was to be expected, that still using the same size of boiler as Mr. Howden did, with plain tubes and retarders, they had an advantage over his system from the fact that all their surfaces were clean, and that they had a larger amount of heating surface in the air-heating boxes. If they put in the Serve tube instead of the plain tube, the same advantage in economy followed, just as it did follow in the case of the Howden draught boilers, with Serve tubes in lieu of plain tubes. They had now reached the stage that, with Serve tubes and the Ellis and Eaves draught, they could guarantee an efficiency of 75 per cent. of whatever coal they gave the boilers, burning at 30 lbs. per square foot of grate. A later modification, known as the helical draught, gives still greater economy, namely, 80 per cent. on 30 lbs. per square foot of grate. He was speaking of absolute figures on which guarantees would be ready when required. He need hardly say that 80 per cent. of efficiency was one that broke the record in all directions, taking into account the small floor space which the plant would occupy. He thought it would be exceedingly difficult for any water-tube boilers to approach these results, and the same means which produced the economy also produced better working conditions for the boilers and men. The suction draught they need not discuss that night, but there was no question that it was easier upon the boilers than forced draught. He would come at once, in order to be as brief as possible, to the helical draught, for that was the greatest modification of the objectionable working conditions of the cylindrical return tube boiler. Instead of having air-heating tube boxes that heated the air by the waste gases, the same process was applied in a different manner, in two compartments entirely enveloping the shell of the boiler. The divisions between these compartments were only made of thin plates, ⅛ inch thick, and put together in a very convenient manner for easy removal. The gases, when they left the front end of the boiler, were drawn by suction draught in a helical or spiral direction to the back of the boiler, thus surrounding the boiler entirely at the bottom, at the sides, the top, and the ends. Through the outer compartment, the air entering from the back end of the boiler was also drawn in a helical or spiral manner to the front of the boiler. It followed that, on the one hand, the heat of the waste gases heated

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matter of fact there was no reason why, with a cold boiler and cold grate, they should not at once put their suction fan into operation, as soon as the fire was laid on the grate, and get up steam as rapidly as they liked, the bottom part being heated just as much as any other part of the shell. With these altered conditions one need hardly say that, having the advantage of the great economy of much smaller floor space occupied than with corresponding water-tube boilers, it would be very difficult for the latter to gradually displace the cylindrical return tube boiler, especially when bearing in mind that the class of firemen now was not of the most skilled kind, and it seemed the very simplest arrangement, being, after all, only like natural draught, with the additional advantage of being able to regulate their draught at will, which could not be done with natural draught. He did not think it would be considered unfair if, after pointing out the economy and the much smaller place occupied, he drew attention to the fact that, compared with the boilers of which they had heard so much of late in connection with their own navy, they could meet the "weight" question perfectly easily, taking boiler water and coal together, if with that boiler they also took boiler water and coal together. What they had in the cylindrical boiler in the way of weight of a larger quantity of water, which he did not think from what they had heard was an unmixed evil, they much more than counterbalanced with a much smaller weight of coal they had to carry on long-voyage steamers. He would only finally draw attention to the very large number of regulations which had been laid down to govern the working of the Belleville boiler, which had appeared lately in one of the American technical journals, and the non-observance of which had been given as the cause of the failure of the boilers in question on the big American lake steamers, and about which, some time ago, they heard a great deal. He thought they would agree, if they read the large number of conditions, that with the present firemen it was impracticable to expect them to comply with those conditions, even in fair weather, whereas in prolonged foul weather they would be impossible to observe.

Mr. J. H. BUCHANAN said he was disappointed that Mr. Fothergill's paper did not contain some reference to the most recent novelty in the working of ordinary boilers—the use of spiral retarders in the tubes, which were now being so largely used with natural draught, and from which such remarkable results were said to be obtained. He noticed them in plenty at Cardiff, and he came across them elsewhere; but his own experience, although so far favourable, was not large enough to warrant him in introducing any figures. He hoped Mr. Fothergill would, in his reply, give them an explanation of the precise action of this simple appliance, as affecting the first part of the subject of his paper.

The discussion was adjourned.

WATER-GAUGES FOR HIGH-PRESSURE STEAM BOILERS.

By T. C. BILLETOP.

[Read before the Institution, in Sunderland, on November 11th, 1896.]

The universal adoption of high steam pressures during the last couple of years has necessitated departures in various directions, and presented engineers with problems and difficulties which did not arise at the lower pressures. One of these has been to produce a safe and reliable water-gauge for high-pressure boilers, in particular boilers of the tubulous and sectional types, where the evaporation is so rapid and the quantity of water so small that in a comparatively short space of time the water may fall to a dangerously low level; and as even the most perfect feed regulators may fail, the engineer who has charge of such boilers dare not trust these fittings implicitly, but must keep the glass in view constantly. The time lost in replacing one or two glasses, should these happen to break simultaneously, can ill be afforded under such circumstances; and, besides, the uncertainty in running such a boiler for even a few minutes without any glasses, there is the danger to those in the near vicinity from glass splinters and rush of steam or water. Again, there is the probability of such a thing happening repeatedly, owing to the packing being misplaced in hurriedly replacing a broken glass, with the serious consequences well known to engineers.

The old transparent glass tube, in spite of all its disadvantages, has been retained for want of anything better, and various devices have been adopted to minimise risks of the, at the best, unreliable glass tube. Cocks have been made with automatic closing ball valves, which, however, have never become favourites with engineers, who wisely keep clear of complications in such important fittings. Hand gears have been commonly introduced for shutting off. Guards of plate glass or wire have been fitted round the gauge. Special makes of glasses have been tried, glasses have been annealed, or coated internally with different kinds of varnish, but with it all the same uncertainty exists. One glass might last a week or a month, another one minute! The cause of these failures cannot always be defined, for while bad workmanship, clumsy or careless handling, or unusually trying conditions can easily be traced, it is very often impossible to state the reason why, and various theories have been advanced, such as the special condition of new glass tubes, the cutting action of the steam at the top of the glass, or that the condensation in the steam space of the glass is damaging to it, or that the constituents of the glass are not always similar even in the same kind of make. However, one thing is certain, that glass exposed to such high pressures and temperatures cannot bear the strain of sudden changes or shocks which the gauge glass under ordinary working circumstances is subject to. Therefore, to avoid such sudden changes, different means have been tried, which are all nothing more or less than guard plates or shields, to afford protection against the effects of failures rather than preventing them. In some cases these guards have been made steam-tight, so that besides acting as a protection to the glass from the spray and cold air currents, they may as fitted in their frame take the place of the gauge glass itself, in case this should break. This latter method is not very efficient, as practical tests have proved that even a very thick glass plate is often broken by the force of the explosion if too close to the glass, and as in this case confining the area of the explosion. It should also be noted that the glass, although well protected is unbalanced, as the pressure is on the inside only, hence the glands must be set up hard to prevent leakage, and the glass is not protected against sudden or careless blowing through. Others have aimed at keeping the glass cool by fitting the gauge on a cooling column, but have not as yet obtained any great [redacted] supplied with two gauges, one fitted with glass tubes the other with talc plates. The talc gauge is generally shut off, to be only used when replacing a broken glass in the working gauge.

It has been observed, and experiments prove, that talc remains transparent if exposed to dry steam only. With this in view a gauge is proposed* where the ordinary glass tube, which is the water-gauge proper, is surrounded by a steam jacket consisting of a gun-metal case fitted with talc plates, through which the water in the glass tube can be observed. The glass is thus in perfect balance, being surrounded by steam of same pressure as it contains, and only being lightly packed top and bottom is practically free to expand. It is effectively protected from all sudden changes, it can be blown through with impunity, water can be dashed on the gauge, and the roughest usage does not affect it. On the other hand, the talc plates in the jacket case, which are only in contact with live steam, keep transparent, as many months of actual work on a boiler have proved. The jacket is fed by steam from the boiler, the connection for which it should be noted must be led from some higher part of the boiler, and not have any direct connection with the water-gauge proper, so as not to affect the water level, as this steam jacket is drained to a trap on the drain system, and the rush of steam through the jacket when draining it, if it was in direct connection with the interior of the glass, would slightly affect the level in the same manner as it is possible to get a false level where the steam connection to a water-gauge is close to a valve from which the steam is drawn.

It should also be noted that the connection to the jacket must be so arranged that a steam jet is not blown against the glass direct, but somewhat baffled, as shown in the diagram (page 56), which gives a general idea of the gauge as suggested.

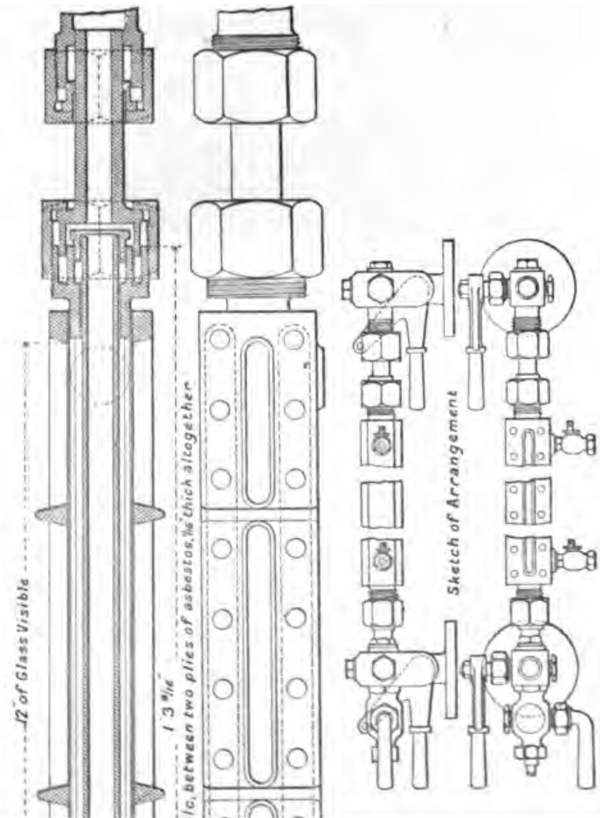
The glass, fitted and protected in this manner, should last a very long time, and should it happen to break nothing serious will occur; there is no explosion taking place to injure the talc, while water and steam is merely transferred from the inner glass tube to the jacket, which then acts as the water-gauge proper.

In cases where there is no drain system, an ordinary closed vessel with a connection to a hot well or tank will serve the purpose for the drain from the jacket, as the smallest connection is sufficient.

Another decided advantage is this, that the danger of getting the packing for the glass misplaced, and choking it is avoided, the glass being packed before the talc case is coupled up, and the glass passing through the gland similar to a valve spindle.

* Watson's Patent, page 56.

Where gauges are fitted at some height, there might be a slight difficulty in seeing the water from below, but as high-pressure boilers are



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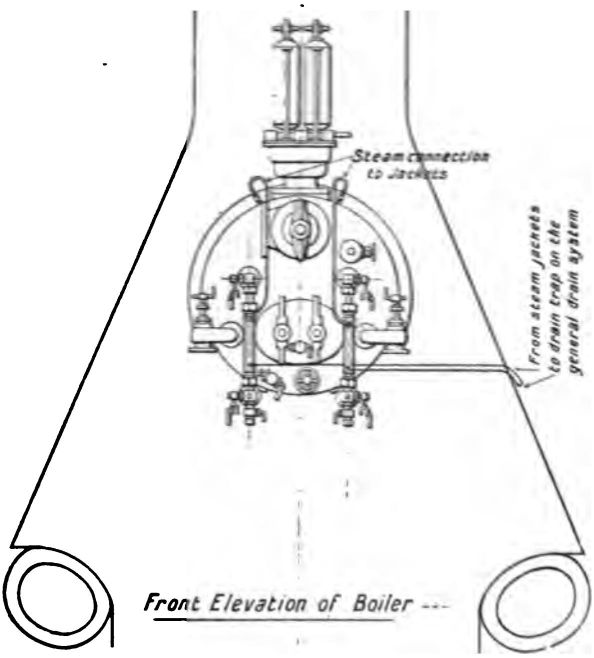
suggested, without complication, gives perfect safety, and is in every way reliable, which has practically been proved, it ought to remove one of the



difficulties which high pressures have placed before the modern engineer in supplying him with a suitable water-gauge.

The discussion was postponed till the following meeting, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896–97.

PROCEEDINGS.

THIRD GENERAL MEETING OF THE SESSION, HELD IN THE ATHENÆUM, WEST HARTLEPOOL, ON SATURDAY EVENING, DECEMBER 19TH, 1896.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on 11th November, 1896, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Professor R. L. Weighton and Mr. T. Mudd to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Boulton, Thomas, Consulting Engineer, 33, Broad Chare, Newcastle-on-Tyne.
Clarke, William Henry, Engineer, The Hermitage, Gateshead on-Tyne.
Cowan, Robert, Engineer, 14, Osborne Avenue, South Shields.
Crawford, William, Engineer, 60, Holly Avenue, Newcastle-on-Tyne.
Hodgson, Rich. Bowness, Ship Draughtsman, Gordon Street, Workington.
Hougland, Even, Engineer, Lloyd's Surveyor, Bergen, Norway.
Maxwell, William Ward, Engineer Draughtsman, Messrs. H. Charlton & Co., Engineers, Gateshead-on-Tyne.
Meagher, H. L., Engineer, Messrs. Sir W. G. Armstrong & Co., Ltd., Elswick Ordnance Works, Newcastle-on-Tyne.
Piercy, Frank, Engineer Draughtsman, 1, Bolton Terrace, Newcastle-on-Tyne.
Pollard, T., Engineer Draughtsman, 21, Kingsley Place, Heaton, Newcastle-on-Tyne.

Roper, Leopold, Naval Architect, Palace Chambers, Westminster, London, S.W.

Rosenthal, James H., Mechanical Engineer, 147, Queen Victoria Street, London, S.E.

Snook, Francis W. G., Engineer, 83, Park Road, Newcastle-on-Tyne.

Stephenson, Bernard, Engineer Draughtsman, 15, St. John's Terrace, Middlesbrough.

GRADUATE TO MEMBER.

McKenna, Francis, Engineer, c/o Messrs. E. F. Wailes & Co., 4, St. Nicholas' Buildings, Newcastle-on-Tyne.

ASSOCIATE.

Knott, James, Shipowner, Prudential Buildings, Newcastle-on-Tyne.

GRADUATE.

Pierce, Robert Cecil, Electrical Engineer, 4, Simonside Terrace, Heaton, Newcastle-on-Tyne.

The PRESIDENT remarked that this was the first time he had had the pleasure of presiding over a General Meeting since they did him the honour of electing him President of the Institution. He was sorry it had been such bad weather, as it must have deterred many from attending. Still, they had brought a few from Newcastle, and but for the weather they would have had a larger attendance. He thought it was very important having meetings in Hartlepool and Sunderland as well as Newcastle, as they thereby met in a way they should not otherwise do. There were many members they knew by name; but it was only on occasions of this kind that they saw them personally and had the opportunity of comparing notes, by doing which they often picked up ideas which might prove beneficial.

MR. J. F. WALLIKER'S REPLY TO THE DISCUSSION ON HIS PAPER ON "NOTES ON THE MAINTENANCE AND REPAIRS OF MARINE BOILERS."

BUTE DOCKS, CARDIFF,
December 10*th*, 1896.

DEAR MR. DUCKITT,

It is very satisfactory that the short paper I read on "Notes on the Maintenance and Repairs of Marine Boilers," at the Cardiff Summer Meeting, has led to such an extended and valuable discussion, and I beg leave to make a few remarks in reply to the various members who have written and spoken on the subject.

I think that Mr. Sisson's ingenious theory as to the fracture of combustion chamber short stays requires a little further consideration; at the same time, even when allowing for its truth, he has given, in my opinion, too much weight to stress due to the difference of areas in the crown and bottom, and too little to the differences in temperature. It may, certainly, have been a factor in the first case (*i.e.*, in the single-ended boilers), but it appears to me that his theory will not account for the fracture found in the top row of stays in combustion chamber sides of double-ended boilers, and that here, at all events, we must take either (*a*) the expansion theory, (*b*) that mentioned by Mr. Gearing with regard to harder material, or (*c*) the change of form noted by Mr. Hirst. For my own part, I believe that to the expansion due to unequal temperatures and to construction may be attributed the failure alluded to. I am glad that Mr. Gearing is so thoroughly in accord with the points brought forward, and that he has brought testimony of his own experience in favour of "room, and plenty of it."

Mr. Seaton appears to deem me an opponent of the water-tube boiler, but I think he has done me an unconscious injustice in so doing. I tried to be very guarded in this matter, as my experience of water-tube boilers is limited, and I endeavoured to confine myself to what I considered the drawbacks of the ordinary type (or tank boiler, as Mr. Seaton calls it), and to elicit an expression of opinion from the members as to where these were found. I also quite fail to see the advantage to be gained by building a boiler for a higher pressure than that at which the engine driven by it can be efficiently worked, and deem the adoption of this principle to be a distant one in our mercantile marine. I had, some years ago, the supervision of the machinery for a boat, where I adjusted the safety-valves to a load of 600 lbs. per square inch, but I believe that pressure was not so successful as to induce the owner to recommend it to his friends. I am afraid I have treated the boiler in this paper more commercially than theoretically, and was only anxious to point out its deficiencies from my point of view without in any way trenching upon the province of the designers and adapters of more advanced types. I am sorry to have to differ from Mr. Buckland as to the drawbacks of double-ended boilers; my knowledge of these, where properly managed, having been invariably in their favour, and many boats run these most successfully, and with an absolute immunity from repairs.

The trials that beset the manufacturer in endeavouring to please everyone are, may I say, almost humorously, set forth by Mr. Weir, and if I were not perfectly confident that he had no ground of complaint against at least one of the registration societies, I might, perhaps, enlarge on the troubles he has experienced to give a satisfactory commercial article to his customers. It is quite unnecessary for me to say that he meets with almost universal sympathy in endeavouring to make a roomy boiler, and that the high limits placed upon staying, etc., combustion chamber and other flat plates by foreign registries, will not favour their boilers where placed in competition with those built under the conditions of our wider experience. Mr. Weir has so ably put the case for the retention of the double test pressure that I feel it unnecessary to add one word to the arguments he has, in my opinion, so properly brought forward.

Mr. J. H. Buchanan's remarks with reference to particulars given to details of boilers in Lloyd's Register are undoubtedly correct so far as they go, but I do not believe that boats change hands altogether on the basis of these figures, but that a good roomy boiler would still command which I believe deserves some consideration. Mr. Robert Thompson, at the Cardiff meeting, said "he had often wondered why engineers covered two-thirds of the boiler and left the bottom unprotected;" but this matter is now receiving more attention, and doubtless with our modern experience abnormal waste in tanks at this part will soon be a thing of the past.

In conclusion, I would reiterate my opinion that whatever type may be adopted in the future for the marine boiler, the present one will still be made for a considerable time, and feel assured that the discussion we have had has tended to clear up several points of interest to those concerned in its construction and upkeep.

Yours faithfully,

JOHN F. WALLIKER.

The PRESIDENT asked the members to accord a hearty vote of thanks to Mr. Walliker for his very able paper.

This was accorded by acclamation.

ADJOURNED DISCUSSION ON MR. J. R. FOTHERGILL'S PAPER ON "MARINE BOILERS, PARTICULARLY IN REFERENCE TO EFFICIENCY OF COMBUSTION AND HIGHER STEAM PRESSURES."

Discussion was resumed on Mr. J. R. Fothergill's paper on "Marine Boilers, Particularly in Reference to Efficiency of Combustion and Higher Steam Pressures."

Mr. T. MUDD said he took it that Mr. Fothergill brought forward two points in his paper: the first, that they were bound shortly to have much higher pressures in marine engine work; and, secondly, that, in his opinion, water-tube boilers must be the method on which they were to arrive at that higher pressure. With one of these he agreed, and with the other he differed. The company he was connected with had a set of cylindrical boilers working at a higher pressure than was afloat in any other ship. They would, therefore, not be surprised to hear that he was an advocate of increasing boiler pressure. That was the way, to his mind, towards higher efficiency; but when Mr. Fothergill argued in favour of the water-tube boiler for the mercantile marine he felt inclined to join issue with him. He had not brought forward any argument to show that water-tube boilers were more efficient than the cylindrical boilers, and most of them were already aware that water-tube boilers up to the present had not proved themselves as efficient as cylindrical boilers. That was the crucial point—the question of efficiency, the reduction of coal consumption—for why were they going to higher pressures? It was not because they took a fancy to one pressure in preference to the other; but because they wanted a lower consumption of coal per horse-power per hour, and if the water-tube boiler required more fuel than the cylindrical, they were simply giving away with the left hand what was got by the right. So until it proved itself more efficient, he did not see they were justified in moving from the boiler they had already. Mr. Fothergill had confined himself mainly to the question of combustion; he had not touched upon some other points that water-tube boilers claimed, and, therefore, he did not know he should introduce them in the discussion; but he would just say in passing, that, in his opinion, none of the points claimed by water-tube boiler makers were of any serious value to the mercantile marine. They were points of importance in some particular cases. For instance, it might be of great value and importance to the torpedo boat or man-of-war to get up steam in twenty minutes; but that was not of the slightest value in cargo boats. The points they had to take notice of were, firstly, safety, and, secondly, full economy, and on neither of these points had the water-tube boilers proved themselves better than the ordinary cylindrical boiler. Mr. Fothergill might say—"Can we go to higher pressures in cylindrical boilers?" The demand was being met. They had a pair at sea at 250 lbs. working pressure, which, after a year's operation, were as tight as a bottle, with no leak or difficulty whatever. The boilers were not very large, 11 feet diameter by 10 feet 6 inches long, but he saw no reason why they should not go to 260 or 300 lbs. pressure in boilers ranging up to 14 feet diameter. He saw, therefore, no bar at present to progress in that direction with cylindrical boilers.

The PRESIDENT—What about weight?

Mr. MUDD—When they added the extra coal that had to be carried for the water-tube boilers, it came out in favour of the cylindrical boiler.

Mr. J. R. FOTHERGILL, in reply to the discussion, said he was somewhat disappointed that his paper had not elicited a more definite expression of opinion as to the possible value of the water-tube boiler if higher steam pressures were to be the accepted necessity of the near future. He was afraid, from the views expressed by some of the speakers, the important feature, or what he might describe as the "pith" or "essence" of his paper, had not been clearly understood.

160 lbs. pressure, having furnaces 3 feet 6 inches diameter, but, with the ordinary boiler having, say, 250 lbs. pressure, in which, from exigency of the case, it was difficult to use furnaces having diameters exceeding 2 feet 8 inches or 2 feet 9 inches. He fully agreed with Mr. Seaton* that a better acquaintance with the water-tube boiler and a more careful consideration of its advantages would remove a great deal of the present prejudice. From various considerations he did not anticipate the water-tube boiler would find favour with the majority of boiler manufacturers, but with others there was a general consensus of opinion that the present type of boiler would not continue its efficiency under higher pressures, and this he had endeavoured to explain in his paper. He was at some loss to understand Mr. Walliker's explanation of his experience *re* the escaping gases. If the percentage of the escaping gases did not pass through the lower tubes—whilst those tubes were clear—how did they become blocked up with deposit? The deposit must have been carried there by the escaping gases, and as these tubes choked up, of course the gases would in greater volume pass through the higher tubes.

The great value of the retarder was not what its name would imply, but that it broke up the gases in passing through the tubes, and by contact with them conducted their heat to the water, which would otherwise escape to the funnel.

There was no doubt there was room for considerable development in water-tube boilers, particularly if they were to be used in ordinary mercantile steamers, and it would require experience to show in which direction development was most required. Mr. Schaeffer's remarks were very valuable, and it certainly was desirable for ordinary mercantile steamers that the quantity of water should not be cut down to a minimum. In reference to the remarks of Mr. Gross, he might say that it had been his pleasure to visit Messrs. John Brown & Co.'s works very recently; he had carefully looked into what they were doing, and he had no hesitation in saying the results they were getting were most exceptional and satisfactory, and certainly considerably better than he had anticipated. In conclusion, he desired to express his thanks and appreciation to those who had criticised his paper, for he considered broad criticism was the greatest compliment that could be paid the writer of a paper.

The PRESIDENT said he would now ask the meeting to pass a vote of thanks to Mr. Fothergill for the very able paper he had given them. He

* See Mr. Seaton's remarks upon Mr. Walliker's paper, page 35.

quite thought with him that the water-tube boiler was one still in its infancy, and he believed this Institution would have many papers before it in the future dealing with the question in many phases which, at the present moment, they did not think of.

The vote was accorded by acclamation.

DISCUSSION ON MR. T. C. BILLETOP'S PAPER ON "WATER-GAUGES FOR HIGH-PRESSURE STEAM BOILERS."

Prof. R. L. WEIGHTON, in opening the discussion, said he knew something about the special appliance referred to in the paper. He thought, in the first place, there was need for a new water-gauge. Some of his friends said they never had had a water-gauge broken. This he could not understand. He had been in close proximity to boilers carrying 210 lbs. pressure over lengthened periods, and the water-gauges had repeatedly given way, sometimes both together, and stopped the trials. They were always breaking, and he never felt safe in their proximity. There was, first, the danger to life and limb, principally in regard to one's eyesight, and then the detriment to the working efficiency of the boiler. He thought, first of all, it ought to be granted that there was need for an improved water-gauge. To have a mere glass between them and what was practically a magazine of enormous bottled energy was not sufficient, the slightest change in temperature was apt to lead to a burst, and it occurred with such violence that there was no chance of saving one's self. This device, which, he knew, worked well, was such that they could put their eye close to it and look with safety. They could not do that safely with a glass. There was a little trouble in getting it tight at first, there being a good many joints about it. That was a defect, for it took some adjusting; but once it was adjusted it seemed to him (Prof. Weighton) to serve its purpose very well. Indeed, he wished to give his testimony in that respect.

Mr. R. HIRST said he quite endorsed what Professor Weighton had said. There were a good many men who could say they had lost an eye or been nearly blinded by the glass giving way. He thought the German method of fitting two gauges was what they should come to in this country; they should not be dependent upon one, especially with double-ended boilers. When they lost the one they were left to grope in the dark.

Mr. J. R. FOTHERGILL (Vice-President) said there was a feature of interest not generally understood in relation to gauge glasses, and that was the effect the boiler water under high-pressure steam had upon the glass. Gauge glasses were usually condemned on the assumption that they would not stand the pressure. No doubt, to a large extent, this was true. Certainly the pressure blew them to pieces, but there were several causes other than the pressure which accounted for glasses breaking. Glass was decomposed by some boiler waters under high-pressure steam, due to various salts contained in the water. When a gauge glass bursts, if the remaining portion in the lower stuffing box be carefully removed, it will frequently be found eroded, particularly inside the glass. As this action proceeds the glass becomes less able to stand the pressure, and ultimately bursts.

Mr. D. B. Morison said that if Mr. Billetop's arrangement prevented the breakage of gauge glasses, and there was no trouble with the various joints, and the talc did not cloud, then the device was a valuable one. He would expect, however, that the extra cost beyond many of the simple protectors in the market would interfere with its general adoption. He (Mr. Morison) referred to a defect in many gauge fittings which enabled packing to get below the end of the glass, and so partially close the orifice, as was the case in the recent explosion on H.M.S. "Blake." He also described an arrangement for preventing such an accident, which consisted in a flanged tubular ferrule, the flange of which is placed in the bottom of the packing box and the tube inserted in the glass, the length of the tube being such that its top is visible above the gland nut, so that if any packing is squeezed out of the box it would be forced between the ferrule and the glass, and could not possibly block the waterway.

Mr. T. Mudd said, as to the rubber rings working under the glass, the woodite packing got over the difficulty. It was held by a flange under

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heated up there was apt to be a slight shift between the one and the other, and that clearance allowed for any movement apart from any direct expansion on the tube. At all events, with that clearance and care taken with rings they had not had a great deal of trouble. For his part, he hoped some simpler gauge glass than the one before them would be devised—one with fewer joints.

Mr. MORISON—Did they fill up the entire box with woodite rings?

Mr. MUDD—They fitted one woodite ring on the top and one on the bottom of the glass.

Mr. FOTHERGILL could corroborate what Mr. Mudd had said about the woodite rings; they had used them on several occasions.

Mr. MILLS—What does the shipowner say about the price of this new gauge?

Mr. C. T. BILLETOP, in reply, said Mr. Morison asked if there was any tendency in the talc to cloud? Talc had been tried for a good many years in different ways, and it was found that it only became dull when in contact with boiler water, principally in the way of the water-line, where there was the possibility of oil floating about. In the case under consideration the talc was only in contact with steam, and it had remained transparent under working conditions for a long time.

The PRESIDENT—Did they mean for years?

Mr. BILLETOP—No; six or seven months. The jacket being filled with dry steam and drained, dirt could not get into it; and there was no more chance of an obstruction getting into the glass than with the ordinary gauge. As to the number of joints, several of these might be considered permanent. For instance, the talc sheets if once made would last for a very long period, and the glass which passed through its stuffing-box, like a valve spindle, required very light setting up, and when once that was done it did not require further attention. That only left two or three couplings, one being for the removal of the talc case. The cocks at the jacket were only 1-16th of an inch in diameter, so there was not much leakage possible there. The cost of this gauge was not prohibitive, it would not be much more than the ordinary talc gauge used for high-pressure boilers, and the objection to the old talc gauge becoming discoloured had been overcome.

The PRESIDENT—Have you had any failures?

Mr. BILLETOP—No. He desired to add that the gauge showed no false water-level, because the outside jacket had no connection at all with the inner part of the tube.

The PRESIDENT said they were all obliged to Mr. Billetop for the paper with which he had favoured them. He should have liked a little more exhaustive discussion upon it; but still they had had one or two new points brought out. He begged to thank Mr. Billetop for his paper, and to move that they accord their thanks to him by acclamation.

This was duly done by the meeting.

THE EXPERIMENTAL ENGINES AT THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-ON-TYNE, WITH SOME RESULTS FROM SAME.

By Prof. R. L. WEIGHTON, M.A., Vice-President.

[Read before the Institution, in West Hartlepool, on Saturday, December 19th, 1896.]

The subject of the present paper will be best dealt with in two parts. Part I. comprising a description of the engines and their accessories, and Part II. detailing and discussing some results which have been obtained from them.

Before, however, proceeding to the subject-matter proper of the paper it may be of some interest to notice the method by which the engines were procured; moreover, the writer is specially desirous that the names of those firms and individuals who so generously and readily supplied such an important and expensive machine—the largest experimental engine plant as yet in existence anywhere—should be put on record in the *Transactions* of this Institution.

The entire engines and boiler, with all their numerous fittings, were a free gift to the Engineering Department of the College, and they were contributed on a system which seems to be unique in the history of such matters.

The designs were prepared in full detail by the writer, and the several parts were contributed by the engineers on the North-East Coast of England and elsewhere, the working drawings being distributed so as to spread the work over as wide an area as possible. One firm very kindly volunteered to receive all the parts as they were finished by the makers, and to erect the engines complete, not only in their own works, but also in position in the College laboratory. This scheme—the credit of initiating which is due to certain engineering friends of the writer's—proved a great success, the whole of the parts being obtained without any trouble, and in the most spontaneous manner. The detail designs were so arranged as to permit, as far as practicable, of each part being finished independently by its makers, and the writer believes he is correct in saying that the whole assemblage fitted together with wonderful accuracy in the process of erection. The following is the list of contributors, with the parts they severally supplied :—

1. Erection of the engines complete, and supply of various details, by Messrs. Wigham Richardson & Co., Walker.
2. Two cylinders, with liners, covers, and pistons complete, by Messrs. W. Gray & Co., Hartlepool.
3. Condenser, with guides, by Messrs. Joseph L. Thompson & Sons, Sunderland.
4. Bed-plate, with bushes, complete, by Messrs. The Wallsend Slipway and Engineering Company, Wallsend.
5. Two cylinders, with liners, also two water traps, by Messrs. T. Richardson & Sons, Hartlepool.
6. Built steel crank shaft complete, by H. Fownes, Esq., Ouseburn Forge, Newcastle; couplings bored, by Messrs. R. & W. Hawthorn, Leslie, & Co., Limited, St. Peters.
7. Front pillars, by Messrs. Westgarth & English, Middlesbrough; and Messrs. The Darlington Forge Company, Darlington.
8. Back pillars, with guides, complete, by Messrs. Readhead & Sons, South Shields.
9. Piston rods, complete with guide blocks, by Messrs. Blair & Co., Stockton.
10. Connecting rods, complete with bushes, by Messrs. R. & W. Hawthorn, Leslie, & Co., Newcastle.
11. Links, drag links, and valve spindles, by John Dickinson, Esq., Sunderland.
12. Main and expansion slide valves, by Messrs. Doxford & Sons, Sunderland.
13. Expansion valve regulating gear, eccentric rods, and spindles, by Messrs. Geo. Clark, Limited, Sunderland.
14. Reversing gear complete, by Messrs. Black, Hawthorn, & Co., Gateshead.
15. Wyper shaft, levers, and bushes, by Messrs. R. Stephenson & Co., Newcastle.
16. Air pump levers, pump rod, and crosshead, by Messrs. Reunoldson & Sons, South Shields.
17. Air pump liners, bucket, and valves complete, by Messrs. The North Eastern Marine Engineering Company, Sunderland.
18. Eccentrics and straps, by Messrs. Scott & Mountain, Newcastle.

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29. Covering for boiler and steam pipes, by W. P. Snowdon, Esq., Newcastle.
30. Governor and stop valve, by Messrs. Tangyes, Limited, Birmingham.
31. Metallic piston rod packing, by Messrs. The Combination Metallic Packing Company, Newcastle.
32. Castings of two cylinder covers, pistons, and casing covers, by Messrs. Chapman, Carverhill, & Co., Newcastle.
33. Girders for travelling hoist, by Messrs. Dorman, Long, & Co., Middlesbrough.
34. Indicator cocks and jacket valves, by Messrs. M. W. Swinburne & Son, Wallsend.
35. Wrought iron main steam pipes, by Messrs. D. Richmond & Co., Glasgow.
36. Reducing valves for jackets, by Messrs. D. Auld & Sons, Glasgow.
37. Pressure and vacuum gauges, by Messrs. Hannan & Buchanan, Glasgow.
38. Various cocks, valves, and couplings, by Messrs. Proud & Hogg, North Shields.
39. Water trap fittings, by Messrs. Billington & Newton, Staffordshire.
40. Boiler uptake plates, by Messrs. The Consett Iron Company, Limited, Consett.
41. Drain cocks for cylinders, etc., by Messrs. J. Carter & Sons, Stalybridge.
42. Water trap castings, by Messrs. Swinney Brothers, Morpeth.
43. Furnace fronts and doors, by Messrs. Douglas Brothers, Limited, Blaydon.
44. Asbestos covering for small pipes, by Messrs. J. H. Bentham & Co., Newcastle.
45. Dynamometer, by Messrs. J. L. Thompson & Sons; Hawthorn, Leslie, & Co.; Short Brothers; Scott & Mountain; and S. P. Austin.
46. Lubricators, by Messrs. Felt & Co., London.

Where all were so generous it were invidious to single out individuals, but the writer feels personally that he cannot possibly pass on without mentioning three names to whose zealous and disinterested exertions and assistance the ultimate success of the project was largely due—Messrs. Wigham Richardson & Co., Walker-on-Tyne; Mr. Robert Thompson, North Sands Shipyard, Sunderland; and Mr. John Gravell, Newcastle-on-Tyne.

Part I.

Description of the Machinery.

The general features of the design of any engines, as well as their detail proportions, must be, to a large extent, determined by the purposes to which they are to be applied, and the conditions they are intended to fulfil. In the case of *commercial* engines the conditions in practice may be manifold. They may, for instance, be utmost, or any desired attainable economy of fuel, maximum power on given weight or space occupied, or any combination of these two conditions; or, again, they may be simplicity of design, with a view to economy of first cost, and of upkeep afterwards, and general efficiency, and so on. In the case of the engines under review the objects aimed at in the design were twofold; first, that they should be suitable for *research* purposes independent of any direct educational value to college students; and, second, that they should be adapted for educational or demonstration purposes in the interests of the students directly.

These objects largely determined the character of the design. An engine which is to be used for research purposes should obviously be of such a size as will produce results comparable with those obtained in the case of ordinary commercial engines—a mere *model* engine is of no use whatever for this purpose. It should also be so arranged in its details as to permit of all possible measurements being made with accuracy, of its methods of working being varied to a reasonable extent, and of its using steam of as high a pressure as possible consistent with safety in the circumstances. Moreover, if the information which it yields is to be used in connection with the design or working of the ordinary engine of commerce, it would seem to be essential that the design of the experimental engines should embody no very abnormal or unusual features, but should approximate—in its essentials at least—to the design of the great majority of engines.

On the other hand, if the engines were intended for demonstration purposes only, in the interests of the elementary student, they need not be of any great size—a working model being practically sufficient,—and they would possibly be better if designed on abnormal lines, embodying as far as possible the various devices current in practice for fulfilling given ends. In this case, however, the engines could scarcely be regarded as typical, and their value for research would be impaired.

Considerations such as these, as well as many others which need not be referred to here, determined the general and detail design of the [redacted]

From the drawings (see Plates IV., V., VI., and VII.) it will be seen that there is nothing at all novel in the design of the engines. For the reasons already given they were purposely made of a plain ordinary type, with link motion reversing gear, and slide valves throughout.

Possible Variations in Working.—The following are the changes or variations of which they are susceptible:—

(*a*) *Ratios of Cylinders.*—By means of the four additional liners and pistons already mentioned the engines may be worked on the following different systems, viz.:—

	Inches.	Inches.	Inches.	Inches.
Quadruples	8½	12	16½	23 (smallest ratio of cylinders).
	7	10½	15½	23 (largest ,, ,,).
Triples ...	—	12	16½	23 (smallest ,, ,,).
	—	10½	15½	23 (larger ,, ,,).
	8½	—	16½	23 (,, ,, ,,).
	8½	—	14	23 (,, ,, ,,).
	7	12	—	23 (largest ,, ,,).
	7	—	15½	23 (,, ,, ,,).
Doubles ...	—	—	14	23 (smallest ,, ,,).
	—	12	—	23 (larger ,, ,,).
	—	10½	—	23 (,, ,, ,,).
	8½	—	—	23 (,, ,, ,,).
	7	—	—	23 (largest ,, ,,).

Singles.—Any one of the above can be worked single expansion. In all cases the full pressure of 210 lbs. may be used, except in the case of the singles with 23 inches cylinder.

(*b*) *Cut-off in each Cylinder.*—By means of expansion valves the steam may be cut off at any point between 3 inches and 14 inches, the main valves being adjusted to cut off at the latter figure.

(*c*) *Sizes of Intermediate Receivers.*—These may be increased or diminished by opening or closing a valve (see drawing of cylinders, Plate VIII.).

(*d*) *Jackets.*—These are provided not only on the barrels, but also in the covers and bottoms of the cylinders, and steam of any pressure up to boiler limit may be admitted or not at will to any one or all.

(*e*) *Angle of Cranks.*—By means of suitable and accurately bored couplings the cranks can be set at any desired angle to each other within the limits of one-eighth of a revolution.

(*f*) *Condensing.*—The condenser may be worked either surface or open jet condensing by closing one valve and opening another, and any desired amount of condensing water may be supplied.

(*g*) *Revolutions.*—The speed of the engines may be regulated to any desired number of revolutions at any given power down to the minimum at full power, by means of the dynamometer adjustment to be noticed later.

(*h*) *Throttling, etc.*—The engines being provided with reversing gear can be worked full gear or linked up to any desired extent, and of course the steam may be throttled by the stop valve on the engines to any desired extent.

(*k*) *Drains.*—By means of separate drain cocks and measuring traps, any one or all of the receivers and jackets can be drained or not at will, and the quantity condensed in each may be measured independently.

Description of the Engines.

Cylinders.—One of the working drawings of these is given in Plate VIII. All the liners are portable, and absolute steam tightness is secured by a metallic joint at the bottom and a stuffing box at the top, the latter being asbestos packed, with a brass gland set up from the outside of the cover by brass screws. The steam tightness of the liners is in every case proved before the cylinder is closed up by admitting steam to the jackets, the gland being secured for this purpose by temporary set screws. It is found possible to make an absolutely tight liner in this way.

Distribution Valves and Gear.—The valves are flat slide valves throughout, with variable expansion valves on Meyer's principle for each cylinder, so that the cut off can be varied in any cylinder while the engines are running. The links are of the ordinary double bar variety. The valves were made of the *flat* type in order to avoid the disturbing effects of the leakage which is always associated to some extent with valves of the piston type.

Pistons.—The pistons are of cast iron, hollow, and fitted with Rams- [redacted]

Pillars.—At the front there are four pillars of wrought iron, those at the back are of cast iron, and carry the motion bars. The guide blocks are of the slipper type, and adjustable for wear.

Bed-plate.—The bed-plate is cast in two pieces, and bolted together. There are two bearings for each crank close up to the crank webs, or eight bearings in all. Each cylinder is thus self-contained, and can work by itself even when its shaft is disconnected from its neighbour's, the eccentrics for each cylinder being fitted on the shaft belonging to that cylinder. The bearings are of brass $4\frac{1}{2}$ inches long.

Crank Shaft.—The crank shaft is of ingot steel, with built cranks, and is made in five pieces, each cylinder having an independent crank shaft. The fifth piece carries the dynamometer. As already mentioned the couplings permit of variation of the crank angles.

Steam Piping.—Owing to the relative positions of laboratory and boiler house the steam pipe is of great length, being over 100 feet long. It is of wrought iron, lap welded, 3 inches inside diameter by $\frac{3}{8}$ inch thick, and is coupled up in suitable lengths by special iron flanges screwed on to the pipe. The pipe runs along an underground corridor, and is adequately covered with asbestos non-conducting composition. A separator and automatic drain trap are inserted at the lowest part of the piping to draw off any water which may collect. There are no expansion joints fitted, the expansion being provided for by bends in the piping, and so far this pipe has given no trouble whatever.

Dynamometer.—Plate IX. shows, on a greatly reduced scale, the working drawing of the dynamometer, or instrument for measuring the effective horse-power transmitted by the engines. It is hydraulic in its nature, on the ingenious and beautiful method invented by the late Dr. William Froude. A description of the principle of its action will be found in a paper by Dr. Froude in the *Transactions* of the Institution of Mechanical Engineers for 1877, to which paper I would beg leave to refer those who desire fully to understand it.

The particular design and arrangement as regards the measurement of the reaction or tendency to turn about the shaft (see outline on Plate VI.) were adopted to meet what appeared to be the requirements of the case. Known standard weights are suspended at a radius of 6 feet on the rising arm, and at the same radius on the falling arm a strong spring in compression is interposed. The scale of this spring with all its fittings in position has been carefully ascertained by actual trial with standard weights. The balance of the whole instrument, full of water and in working trim, has also had careful attention, and been allowed for. The action is thus :—When the engines are moving the tendency is for the whole instrument to turn with the shaft; it is prevented from turning by the joint action of the weights and the spring just mentioned, and these together measure the total turning moment; the weights are constant in any one experiment, and are therefore known; the compression of the spring may and does vary from time to time due to several unavoidable causes, *e.g.*, variation in boiler pressure or in vacuum, and the state of the engine rods or bearings as regards lubrication; the compression of the spring must therefore be constantly recorded and measured, and this is effected by automatic recording gear. In this gear a strip of tracing paper is wound continuously from one drum on to another, the drums being actuated from the engine main shaft through a suitable and simple mechanism. One pencil connected to the *bottom* of the spring—and therefore stationary—traces a straight line at right angles to the drum axis as the paper moves under it. This is the zero line for measurements, and its vertical position on the diagram depends upon the initial compression of the spring, which is adjustable at will. Another pencil is attached to and moves with the top of the spring. When the spring is uncompressed both pencils coincide on the paper and trace *one* line. When the engines move and compress the spring, the latter pencil will indicate on the paper the amount of spring compression and its variation at every instant, by a more or less wavy line, the vertical distance between the two lines indicating—to the proper scale—the pounds load on the spring at each instant, and the average distance indicating the average load during any given experiment. The same mechanism is utilized as a counter, giving with absolute accuracy, the total number of revolutions made by the engines during any experiment. The effective horse-power is thus virtually recorded. The dynamometer is supplied with water from the mains of the city at a reduced pressure of 25 lbs. per square inch. As the whole of the power is transformed into heat, the water requires constant changing to prevent its attaining an inconveniently high temperature. The cold water supply enters at the centre at each side, and the exit of the heated water is regulated by a cock at the periphery of the vortex. The instrument is usually worked at a temperature between 120 degs. and 150 degs. Fahr. The revolutions at any power are regulated by means of sluices which break up the water vortices inside, and which sluices can be adjusted from the outside at any time.

This dynamometer has answered its intended purpose most admirably, and giving, as it does, a continuous record of the turning moment transmitted from instant to instant, the effective horse-power recorded in the results may be looked upon as being absolutely in accordance with fact. It is also very sensitive in its action, showing graphically the effect of any cause, however slight or temporary, which affects the speed of the engines, and therefore the power. For instance, a slight seizing of the high pressure piston rod in its stuffing box suffices to produce a considerable disturbance in the outline of the diagram (see Diagram A, Plate X.). Or again, the general effect of altering the cut-off in the low-pressure cylinder in compounds is shown graphically, as in Diagram B (Plate X.). The same thing is shown in Diagram C (Plate XI.), which is a diagram from quadruples. These diagrams also show by the width of the lower line the variation in angular speed during a revolution.

Description of the Boiler.—The boiler is of the ordinary single-ended multitubular marine type. It is 8 feet diameter by 8 feet 6 inches long, and has two plain furnaces 2 feet 2 inches diameter. It is fitted with Serve tubes 3¼ inches external diameter, the heating surface being 459 square feet, and the grate surface 16 square feet. It is constructed of steel throughout for a working pressure of 210 pounds per square inch above the atmosphere, in accordance with Board of Trade special survey requirements.

All the appliances necessary for the determination of boiler efficiency are provided, but as yet this part of the work has not been undertaken systematically. The engine trials are being conducted quite separate and distinct from any boiler trials, and therefore the boiler question will not further concern us at present.

Measuring Appliances (see Plate VI.).—These comprise the following:—

1. *Air-pump Discharge.*—The water discharged from the hot well includes all the water from the receiver and jacket drain traps as well as the water which has passed through all the cylinders as working steam. The whole of the steam—and water also, if any—which enters the high pressure cylinder is therefore measured here, whatever is drained from receivers or jackets being subjected to separate measurement before it reaches the hot well, as will be seen later on. The measuring apparatus consists of two tanks provided with accurately graduated floats, into either of which tanks the hot well discharge may be directed by means of a two-way cock. After being measured the water is allowed to run off into the feed tank in boiler house.

2. *Condensing Water.*—The quantity of condensing water used in any trial is measured by means of a trough fitted with an outlet of known size, and a graduated float to show the "head" over the outlet orifice.

3. *Jacket and Receiver Drains.*—All the drains—of which there are eight—are led to separate calibrated traps fitted with gauge glasses, and are there measured separately, being thence drained off into the hot well, and finally into the measuring tanks for same, where they are again measured along with the condensed working steam, as already explained. The high pressure steam chest trap is not drained to the hot well, the object being to obviate as far as possible the debiting of the engines with steam which they never receive. The engines may, of course, be worked with the receivers undrained when such is desired, shut-off cocks being provided for this purpose on the cylinders.

4. *Temperatures.*—The temperatures recorded are as follows :—

(*a*) Hot well; which is assumed throughout as the temperature of discharge in heat balance sheets.

(*b*) Hot well measuring tanks; for the purpose of converting gallons into pounds.

(*c*) Condensing water at inlet to, and outlet from condenser; for the purpose of ascertaining the units of heat rejected.

5. *Pressures and Vacuum.*—A Bourdon pressure gauge is fitted for each receiver and jacket, and a vacuum gauge as well as a mercury column are provided for the condenser. A mercurial barometer is also arranged alongside, in order that the barometric pressure may be readily recorded along with the vacuum.

6. *Indicator Diagrams.*—Diagrams are taken simultaneously every fifteen minutes by four Richard's indicators, driven in the usual way. The mean pressures in every case are carefully calculated by means of the planimeter, and the areas of the piston rods are allowed for in the [redacted]

Observations during a Trial.—The trials are conducted as follows:—On the day of a trial the engines are started early, and are very gradually worked up, and adjusted to the intended trial conditions. They are then allowed to run under these conditions, and without any change whatever being made in their adjustments, for one hour before any observations or measurements are recorded, the object of this, of course, being to make sure they are fully settled down to work uniformly under the required conditions. All registers are brought to zero, and every observer being at his post, at a given signal the observations and measurements begin by the counter and brake-recording apparatus being thrown into gear, the hot well discharge diverted, the exact time noted, etc. The *duration* of a trial depends on circumstances. The writer has found a trial of half an hour to give quite as accurate and consistent results as a trial of one, two, three, or more hours' duration. Probably one hour may be taken as a standard amply sufficient for the actual measuring and recording. So long as the machinery is thoroughly settled down into steady running, and there are no sensible variations in boiler pressure or other conditions, a fairly short trial is preferable to a long one. In the latter case, the observers get fatigued, and are apt to get careless as well, and besides it is difficult to preserve uniformity of conditions over a protracted period. At the end of the trial another signal is given, the counter, etc., is thrown out of gear, the time noted, and all the records and measurements cease at that instant.

The observations made during a trial comprise the following, viz.:—

Hot well discharge in gallons.

Temperatures of hot well and measuring tanks, every five minutes.

"Head" of condensing water over outlet orifice.

Temperatures of condensing water at inlet and outlet, every five minutes.

Receiver and jacket drains in pounds, when required.

Boiler pressure, receiver and jacket pressures, and vacuum, every five minutes.

Barometer.

Indicator diagrams, every fifteen minutes; the intervals being utilised, as far as possible, for reckoning up the mean pressures.

The dynamometer being self-recording requires no attention, but one observer is usually stationed to see that the pencils are in order and to note the amount of the weights, and the position of the sluices.

In addition to the above, the following data must be recorded once for all in the case of each trial:—

The cut-off in each cylinder.
The relative positions of the cranks.
The positions of the reserve receiver valves.
The jacket steam on or off.
The drains open or shut.
The position of the links, or the throttle valve.

Any unusual occurrence, such as a hot piston rod or bearing, which may affect the results, must also be noted and recorded. To make the above observations efficiently twelve to fourteen observers are required, and as many as twenty are sometimes employed.

PART II.

SOME RESULTS FROM THE ENGINES.

It is intended ultimately to make a complete series of trials with a view to ascertain, with what accuracy may be possible, the relative efficiencies of working double, triple, and quadruple expansion under various conditions as to ratios of cylinders, ratios of cut-offs, crank angles, pressure, total expansion, revolutions, etc., and a considerable amount of data towards this end has been obtained.

Up to the present time, however, only one series of trials has been fairly completed, viz., that dealing with quadruple expansion at a constant ratio of cylinders, and a boiler pressure of 210 lbs. per square inch, the cylinders being 7 inches, 10½ inches, 15½ inches, and 23 inches.

In conducting these experiments the writer very soon found the [redacted] condition, or allied set of conditions. Only thus is it possible to eliminate accidental errors and irregularities, and to detect anything of the nature of a law in the results.

The trial results here presented have been obtained by following this method. They consist of two groups.

In the first group, the object aimed at was to ascertain how the economy of the engines was affected by variation in power, when the latter variation was brought about by means of expansion valves. This group will be referred to as "expansion trials" or "expansion results."

In the second group, the object was to ascertain how the economy of the engines was affected by variation in power, when the latter variation was brought about by throttling the steam as it entered the high-pressure steam chest, the high-pressure cut-off being retained constant. This group will be referred to as the "throttled trials."

The general results obtained are tabulated in Tables I. and II., pages 86 and 87, and are further elucidated in the diagrams on Plates XII. and XIII.

Throughout the trials the only condition which was varied was, in the first group, the number of times the steam was expanded; and in the second group, the initial pressure in the high-pressure cylinder. The revolutions were preserved throughout, as nearly as was possible at 140 per minute, by adjustment of the dynamometer sluices. The vacuum, also, was kept as near constant as possible at 24 inches by regulation of the condensing water. The reason why it was kept so low was chiefly in order to economise water, which, in Newcastle, is expensive. As one vacuum was for our purpose practically as good as another, and as it was found more difficult to keep a steady vacuum when the latter was high—due to fluctuations of pressure in the water mains of the city—it was deemed preferable to adopt a fairly low figure as a working vacuum, and to express the feed-water results in terms of some standard vacuum. The standard adopted was 26 inches; the water used per horse-power is, therefore, reduced to this basis, the method of reduction being given in the Appendix, page 93. The manipulation of the water used in this fashion also serves to eliminate the disturbing effects of accidental or temporary variations in the vacuum in different trials. With a high vacuum, of course, less water is used per horse-power than is the case with a low vacuum; but if the hot well temperatures be taken into account, and the efficiency expressed in heat units per horse-power, the effects of the variation in vacuum will be eliminated from the resulting efficiencies. This is really what is done in this case.

LE I.—POWER REGULATED BY EXPANSION VALVES.

l Expansion; the Boiler pressure, Revolutions, and Vacuum being preserved through- following values, viz.:—Boiler pressure, 210 lbs. per square inch; Revolutions, ers, 7 ins., 10½ ins., 15½ ins., and 23 ins.; stroke, 18 ins. Sequence of Cranks so— H, L, 1_1, 1_2 ned into Hot well. All pressures given above the atmosphere.

…er …ure.	H.P. Steam-chest Pressure.	Barometer.	Vacuum.	Revolutions per Minute.	Mean Pressure reduced to L.P.	I.H.P.	E.H.P.	E.H.P. / I.H.P.	Heat Units used per Minute per I.H.P.	Heat Units used per Minute per E.H.P.	Pounds of Water used per Hour (reduced to a Standard Vacuum of 26 Inches) per I.H.P.	Pounds of Water used per Hour (reduced to a Standard Vacuum of 26 Inches) per E.H.P.
…per …In.	Lbs. per Sq. In.	Inches.	Inches.		Lbs. per Sq. In.							
·8	204·7	29·5	24·76	141·97	11·22	59·74	44·56	·746	270·5	362·6	14·6	19·56
·8	203·2	29·5	24·20	149·2	11·86	66·49	50·77	·763	261·5	342·6	14·1	18·48
·6	203·1	29·5	24·24	152·0	11·97	68·29	53·37	·781	261·4	334 5	14·1	18·05
	204·4	29·25	24·43	140·3	16·04	84·44	67	·793	250	316	13·49	17·05
	206	29·25	23·83	147·5	16·99	94·06	77·34	·822	237	289	12·79	15·59
	204·1	29·25	24·12	150·0	17·23	96·99	80·76	·832	238	286	12·84	15·44
·8	203·6	30	23·98	142·17	19·90	106·14	89·36	·84	239	285	12·90	15·38
	203·9	30	23·81	144	20·21	109·16	92·56	·848	242	285	13·06	15 38
·7	203·1	30	23·70	143·63	20·20	108·82	91·82	·843	245	291	13·22	15·77
·2	205	30·1	24·07	138·13	22·77	118	103·21	·874	243	278	13·11	15·00
·7	205·4	30·1	23·99	139·5	23·22	121·46	105·75	·870	241	277	13·00	14·94
	202·4	30·1	24·19	138·85	23·12	120·15	104·02	·866	243	280	13·11	15·20
·7	204·7	29·6	24·02	144·73	25·86	140·34	122·2	·871	236	271	12·73	14·62
·5	205	29·6	24·19	146·66	26·26	144·46	126·56	·876	241	275	13·00	14·84
	205·5	29·6	23·88	146·2	25·98	142·55	125·44	·879	245	278	13·31	15·00
·7	202	29·5	23·92	140·1	28·98	152·55	137·32	·900	243	270	13·12	14·57
·6	202·7	30·1	24·12	139·93	28·99	152·10	138·95	·913	244	268	13·17	14·46
·1	203·9	30·1	24·24	140·6	29·18	153·94	138·50	·899	245	272	13·22	14·68
·2	199·8	30·1	24·03	139·8	31·08	163	145·12	·890	234	263	12·63	14·20
·6	201·72	29·5	24·24	141·7	32·02	170·2	152·74	·897	242	269	13·06	14·55
·1	201·5	29·5	24·2	139·23	31·5	164·47	149·56	·909	249	273	13·44	14·74
	200·7	30·1	24·09	148·97	33·72	188·45	168·93	·896	237	264	12·79	14·25

TABLE II.—Power Regulated by Throttling.

Results arranged in the order of *Degree of Total Expansion*—Conditions same as for Table I.

Date. 1896.	Equivalent Number of Expansions as per Table I.	Cut-offs in Cylinders.				Boiler Pressure.	H.P. Steam-chest Pressure.	Barometer.	Vacuum.	Revolutions per Minute.	Mean Pressure reduced to L.P.	I.H.P.	E.H.P.	E.H.P. / I.H.P.	Heat Units used per Minute per		Pounds of Water used per Hour (reduced to a standard vacuum of 26 ins.) per	
		H.	I_1	I_2	L.										I.H.P.	E.H.P.	I.H.P.	E.H.P.
		In.	In.	In.	In.	Lbs. per sq. in.	Lbs. per sq. in.	Inches.	Inches.		Lbs. per sq. in.							
Nov. 16th...	69·7	12	8	8	8	201·1	83·64	29·7	24·05	150·2	11·5	64·82	51·95	·801	295	368	15·9	19·9
,,	46·4	12	10	10	10	201·4	102·14	29·7	24·35	144·5	15·28	82·81	71·02	·857	274	320	14·83	17·31
Nov. 20th ..	34·8	12	10	10	10	201·8	133·3	29·65	24·16	143·1	19·77	106·19	92·95	·875	256	292	13·83	15·78
,,	27·87	12	10	10	10	200·7	144·7	29·65	24·15	141·0	21·4	113·21	101·02	·892	255	286	13·78	15·46
,,	23·2	12	11	11	11	200·1	164·38	29·65	24·09	143·6	24·97	134·48	120·07	·892	247	277	13·35	14·97
,,	19·8	12	12	12	12	200·4	192·3	29·65	23·95	141·8	30·08	160·02	141·69	·885	238	269	12·86	14·53
Nov. 23rd...	17 4	13½	12	12	12	209·3	185·2	30·1	24·07	140·73	30·7	162·	146·23	·902	239	265	12·91	14·32

The trials were made with steam shut off from all the jackets, the intermediate receivers were all drained regularly into the hot well, the amount being measured in the process, and the cranks were set at right angles to each other in the sequence H, I_1, I_2, L. Whatever leakage the jackets made, and it was very small indeed, also went into the hot well, and was measured.

The expansion trials began with a cut-off in the high-pressure cylinder of 3 inches, corresponding to a total expansion—after allowing for the piston rod areas—of 69·7 times, and terminated with a high-pressure cut-off of 13½ inches, corresponding to a total expansion of 15·46 times. This latter cut-off was found to be the limit of the boiler power at 140 revolutions, and therefore a later cut off was not possible.

With the exception of the full boiler power trial, at least three trials were made at each degree of total expansion. These trials were made with different cut-offs in the last three cylinders, viz., the two intermediate and the low pressure. The object of this was to obtain a mean result, the cut-offs in these three cylinders affecting the economic results considerably in some cases. This will be seen from the tables where the cut-offs are given, and it is also seen from the brake diagrams already referred to.

The throttled trials were made in each case with the same dynamometer adjustment as the expansion trials which corresponded, and the steam was throttled in each case to such extent as gave practically 140 revolutions per minute.

With the exception of the last trial of the series, the high-pressure cut-off was allowed to remain constant at 12 inches throughout all the throttled trials, and one trial only was run in each case, where three had any useful form at present. The differences in the quantities dealt with are small, and the least change occurring in the conditions during a trial or between two trials would seem to be sufficient to utterly confuse the results. Further and more discriminative trials will therefore be necessary to elucidate this point.

Construction of Diagram on Plate XII.

The tables give the results of each trial individually in the form of heat-units expended, and in pounds of water used, for each horse-power realised, both indicated and effective. It will be noticed that there are considerable irregularities in some of the results, though there is a decided and fairly consistent general tendency in one direction.

It was found impossible to represent on a diagram the water consumption per horse-power direct from the tables, recourse was therefore had to a method which corrects minor irregularities, and at the same time represents graphically the gist of the results in a fashion more trustworthy than separate figures tabulated direct from separate trials can possibly do.

This method is carried out in Plate XII. by plotting to rectangular co-ordinates, not only the powers and mean pressures, but also the total quantity of water used per hour as reduced to the standard speed of 140 revolutions per minute, and a standard vacuum of 26 inches.

As effective horse-power is the real index of efficiency, the results are plotted to a base representing the loads on the dynamometer, the other base scales being subsequently inserted simply for reference, and not being necessary in the construction of the diagram.

1. On a base of brake loads, the mean pressures reduced to the low-pressure cylinder are plotted. The points will, of course, lie on a straight line—the loads, plus a constant, being proportional to the mean pressures at any given brake-adjustment. At constant revolutions, indicated horse-power will be proportional to mean pressure. In this case, at 140 revolutions, indicated horse-power equals 5·25 times the mean pressure. We therefore get the straight diagonal lines marked indicated horse-power and mean pressure, with their appropriate scales for power and pressure. The point on the vertical mean pressure scale, through which this line passes (when produced) at zero brake load, indicates the initial friction of the engines. For the expansion trials it amounts to 2·7 lbs. per square inch of low-pressure piston, and for the throttled trials to 2·1 lbs. per square inch.

2. The effective horse-power at constant revolutions varies as the brake load; and in this case, at 140 revolutions, it equals the brake load, divided by 6·25. This gives the lower diagonal line marked effective horse-power and brake load, to which the same scales apply as for indicated power and mean pressure. This line necessarily takes its rise from zero brake load; and one line represents both groups of trials, as the positions of the black and red spots respectively will show. The vertical distance at any load between the lines of indicated horse-power and effective horse-power shows the horse-power absorbed in driving the engines at that load, without doing any useful work. At 140 revolutions it amounts to an average of sixteen horses for the expansion trials, and thirteen horses for the throttled trials; it increases very slightly as the powers increase, as shown by the divergence of the lines.

3.—The total quantity of water used per hour is laid down to the same base as the others. It will be seen that for the expansion trials the observation spots lie in a curve, while for the throttled trials they are approximately in a straight line. This peculiarity was first pointed out by the late Mr. Willans, and the writer has, so far at least, found the straight line to represent the law with wonderful accuracy when the steam is throttled, though there does seem to be a tendency of the spots to rise above the straight line at the lower powers. However, it is not possible to draw aught but a straight line through the points; and, on the other hand, for the expansion trials it is not possible to draw aught but a *curve* through the points.

4.—The water used per indicated horse-power and per effective horse-power is next plotted to a scale which is made to read from the top downwards, so that the resulting curves may at the same time [redacted]

First.—The efficiency of the engines as represented by water used, or units of heat expended, per effective horse-power, rises as the power rises for both the expansion and the throttled conditions, and does not attain a maximum up to at least a power corresponding to a total expansion of about 16 times, and a cut-off in the high-pressure cylinder of 75 per cent. of the stroke.

The variation in efficiency which is associated with variation in percentage of full power exerted is illustrated on Plate XIII. This diagram is deduced from the curves of "water per effective horse-power" on Plate XII.; "full power" being assumed to correspond with a total expansion of about 12½ times, and a mean pressure of about 40 lbs. The efficiency of the "full power" is assumed to be unity. In this diagram the expansion and throttled curves are both shown to the same scale of efficiency. This is not quite in accordance with Plate XII. at maximum power end of the scale, but the error involved is so small as to be practically negligible for our present purpose. It will also be observed that the curves, like those of Plate XII., are extended beyond the range of the highest power trials made. This liberty seems to be justified by the fact that the curves of water used per effective horse-power on Plate XII. show no indication of changing their character and turning downwards.

Second.—The water used, or units of heat expended per indicated horse-power, are for the expansion trials very nearly constant over a wide range of power, viz., for all powers above that corresponding to 40 expansions, or about 19 lbs. mean pressure.

Third.—For all powers that lie between the total expansions of 85 and 20, *i.e.*, between mean pressures of 9 and 28½, reduction of power by means of throttling is less economical than by means of expansion valves on the high-pressure cylinder. Beyond these limits, however, there seems to be some advantage in favour of throttling. This is intelligible for the lower powers, but why there should be any advantage due to throttling at the higher powers is difficult to understand. This is a point which appears to the writer to be somewhat doubtful and to require further study and confirmation. It does not, fortunately, affect the validity of the principal deductions afforded by the trials.

Broadly speaking and in general terms, the practical lesson which, above all others, would seem to be taught is, that *engines should be made small for the power developed.* So far as these experiments go they cannot be made too small. Assuming, however, for the moment that a total expansion of 15 measures the limit of smallness, the following comparison is significant.

Let it be assumed that we have two sets of quadruple expansion engines, each transmitting, say, 1,000 effective horse-power, with the same stroke and at the same revolutions and boiler pressure. Let each set be exactly similar to the other in all respects, except in one particular, viz., in the number of times to which the steam is expanded. Let No. 1 engines expand it 15 times, corresponding to 35 lbs. mean pressure, and let No. 2 engines expand it 36 times, corresponding to a mean pressure of 20 lbs. per square inch. Then, assuming a common piston speed of, say, 490 feet per minute, the low-pressure cylinder of the first engines will be about 52 inches diameter, and that of the second engines 71 · inches diameter; and the smaller engines will require 6½ per cent. less water than the larger ones in a given time. The boilers of the smaller engines may therefore be made 6½ per cent. less than those of the larger engines, without sacrificing any boiler efficiency.

For details of the calculation, see Appendix, page 94. This illustration is of course an extreme case, but it is purposely chosen so, in order to emphasize the illustration.

The writer is quite aware that the lesson here taught is not altogether new, but he thinks that its significance and importance are, as a rule, not fully realised in marine engineering practice.

It will be noted that the smallness of size of cylinders above referred to is not secured at the expense of piston speed, or by the sacrifice of any desirable quality in the engines. Small size, other things equal, is desirable, and small size follows from a diminution of total expansion, with the consequent increase of mean pressure. This in itself would be a gain, but when it is associated with economy of fuel, the importance of the matter is obvious.

that in his opinion these results cannot be made to yield any reliable information as to the relative economy of triple *versus* quadruple expansion. Indeed, any comparison which may be instituted between the absolute water consumption of these engines, and that of other engines of different design and size, worked or tested under different conditions, cannot possibly be expected to yield any trustworthy information. Where the possible differences are comparatively minute, absolute identity of circumstances and conditions are essential before valid comparisons can be made between one system of working and another. Even with any one engine it is difficult to secure this identity of conditions; with different engines it is practically impossible.

For valuable and indeed indispensable help rendered in taking and calculating indicator diagrams, and for assistance in many ways, the writer has to thank Mr. R. M. Ferrier, B.Sc., and Mr. A. L. Mellanby, B.Sc.

APPENDIX.

1.—The feed-water used is reduced to a standard vacuum of 26 inches from the recorded observations as follows :—

Let W = the total pounds of water discharged per hour from the air-pump hot well as actually measured, *i.e.*, including receiver and jacket drains.

Let H = the units of heat expended per hour.

Let T_1 = the total heat per pound of saturated steam (above 0 deg. Fahr.) corresponding to the pressure in the high-pressure cylinder steam-chest as recorded.

Let t_H = temperature of the hot well as recorded.

Let 121° = temperature of condenser corresponding to a vacuum of 26 inches.

Let Q = the pounds of water used per hour reduced to a standard vacuum of 26 inches.

Let q = the lbs. of water used per horse-power per hour reduced to a standard vacuum of 26 inches.

Then, assuming that the engines are responsible for the heat expenditure which takes place between the temperatures of the high-pressure steam-chest and the hot well, but that they are not responsible for losses of heat which may occur in the steam pipe or in the feed pipe, we have—

$$H = W(T_1 - t_H),$$

and $$Q = \frac{H}{(T_1 - 121)};$$

$$\therefore q = \frac{Q}{\text{I.H.P.}} \text{ or } \frac{Q}{\text{E.H.P.}} = \frac{W(T_1 - t_H)}{(T_1 - 121)\ \text{I.H.P. or E.H.P.}}$$

2.—The following shows the details of the comparison made on page 92. As in Plate XIII. it is assumed that "full power" has an efficiency of unity and a mean pressure of 40 pounds, corresponding to about 12½ expansions:—

No.	Expansions.	Mean Pressures.	Per Cent. of Full Power.	Effective Horse-power.	E.H.P. / I.H.P.	Indicated Horse-power.	Stroke.	Revolutions.	Low-pressure Cylinder (Diameter).	Water per Effective Horse-power.	Efficiency.
	Total.						Inches.		Inches.	Lbs.	Per Cent.
I.	15	35	87·5	1,000	·9	1,111	42	70	52	14·4	99
II.	36	20	50	1,000	·85	1,176	42	70	71	15·4	92·5

The PRESIDENT said he was sure they were very much indebted to Prof. Weighton for such a very exhaustive paper. They had still time for a short criticism if anyone would be good enough to favour them with any remarks.

DISCUSSION.

[redacted]

entirely upset one should welcome the contradiction of one's past belief; because one might at once feel that he was making a step further towards truth. That was possibly the position of a good many of them that night. There was one great lesson that Prof. Weighton had put before them as the result of this very elaborate and valuable series of experiments, and that seemed to him that they could not have the number of expansions too small. That was, they could not carry the steam too far on the stroke if economy were aimed at, or have the engine too small for the given power at fixed revolutions. Well, that was to him a very startling conclusion. One, of course, knew very well there was an opposite limit. That is to say, one could very easily make an engine too large for a given power; but without having at one's hand the possibility of being able to assign an exact position as the place where the number of expansions were most economical, one had thought from practice that they knew the region where that really lay. Still, he found engineers' views on that point varied very considerably. He had been asked on several occasions, one he particularly remembered, what pressure, referring to the low-pressure cylinder, seemed to him to be most economical. He thought somewhere about 26 lbs. or 28 lbs. when the boiler pressure was 160 lbs. The gentleman he was speaking to had a very large and scientific experience in much smaller engines. He said, "Oh, we go further than that, we find we get increased economy up to 33 lbs." Now, Prof. Weighton came amongst them with his very excellent series of experiments, and said that with 210 lbs. initial pressure he had gone to as much as 40 lbs., and did not think he was at the end of his tether in economy even then. Of course, one must remember the difference between 160 lbs. and 210 lbs., which would account for a little; but it would not account for all there was between his 26 lbs. or 28 lbs., or his friend's 33 lbs., and the 40 lbs. mentioned by Prof. Weighton. They had the utmost reliance in Prof. Weighton; and in leaning upon his conclusions in an important matter like this, they had the comfort of feeling that neither he nor his engine was capable of propagating a scientific lie. It was of the utmost advantage to have an experimental engine in the district upon which the most accurate experiments could be made. The results over a large series of experiments might be taken once and for all as absolutely true, and upon which one might base their future practice. One question occurred to him, and that was with regard to the conditions that might have affected the results. He would like to be quite clear whether the port area of the various cylinders could have affected the result, as a basis of determining a general law, or whether Prof. Weighton wished them to take it that there were no conditions existent at the time of the trials that would affect the establishment of the general law, that down to as low a ratio of expansion as 12 for 210 lbs. boiler pressure there was increasing economy of steam. Such a conclusion was very striking and important, and was opposed to the general acceptation on the subject amongst engineers. He should have liked to see the indicator diagrams, especially those of late, cut off. In any case, he did not think there could be anything too extravagant said in praise of this paper, which, he thought, might lead to more practical results than had been the case from any paper previously laid before the Institution. He did hope it was only a foretaste of what they were to have of practical results from the experimental engine. He was sure they would like Prof. Weighton to keep them acquainted with the most valuable results he would from time to time be able to adduce from his experiments on the engine.

Prof. Weighton—With regard to what Mr. Mudd had said as to the effect of relative port area upon the water consumption, he did not see himself why even a large variation in port area, relative to cylinder capacity, should affect the law of consumption. It would affect absolute results, but, as far as he could see, not relative results. With normally designed commercial engines the absolute results would probably be a little better than here shown. He could not see why a variation in port area should affect the law of the consumption of water per hour, or should affect the angle of any of the lines on the diagram. He did not think it could. On the other hand, with regard to the indicator diagrams, he quite admitted that was a point which required

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896-7.

PROCEEDINGS.

FOURTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-ON-TYNE, ON WEDNESDAY EVENING, JANUARY 20TH, 1897.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held at West Hartlepool, on December 19th, 1896, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Prof. R. L. Weighton and Mr. James Thomson to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Clark, Charles, Superintendent Engineer, c/o Messrs. Irvine & Co., West Hartlepool.
Hogg, Archibald, Ship Draughtsman, Norham House, Whitley, Northumberland.
Ord, Godfrey C., Electrical Engineer, The Esplanade, Sunderland.

GRADUATE TO MEMBER.

Mould, Francis H., Engineer, 36, Salter's Road, Gosforth, Newcastle-on-Tyne.

GRADUATE.

Lindsay, James D., Electrical Engineer, Fernville, Gosforth, Newcastle-on-Tyne.

The discussion on Prof. R. L. Weighton's paper on "The Experimental Engines at The Durham College of Science, Newcastle-on-Tyne, with some Results from same," was resumed and closed.

Mr. A. E. SHARP read a paper on "The Resistance Areas of Transverse Sections." The discussion was opened and adjourned.

ADJOURNED DISCUSSION ON PROF. R. L. WEIGHTON'S PAPER ON "THE EXPERIMENTAL ENGINES AT THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-ON-TYNE, WITH SOME RESULTS FROM SAME."

Mr. Alex. Taylor resumed the discussion on Prof. Weighton's paper on "The Experimental Engines at The Durham College of Science, Newcastle-on-Tyne, with some Results from same." He said as he had not heard the paper read, and did not know what questions had been asked or answered, he hoped they would excuse him if he should say anything that had been already said. First of all, he wished to say he felt greatly indebted to Prof. Weighton for his very valuable paper. He was quite sure the experiments were most carefully conducted and thoroughly reliable. Prof. Weighton said: "Whatever leakage the jackets made—and it was very small indeed—also went into the hot well, and was measured." He would like to ask if these drain cocks were continuously open to the hot well?

Prof. Weighton—No; the jacket drain cocks were closed.

Mr. Taylor said his reason for asking the question was that they all knew what an important part a defective jacket might play. It might become a surface condenser in reality if continuously in communication with the hot well. Looking at the experiments as a whole, he (Mr. Taylor) was very sorry that the boiler did not allow Prof. Weighton to further reduce the number of expansions, and show the effect. They all knew that no engineer at the present moment would contemplate designing an engine to use steam at 210 lbs. pressure with about 70 expansions. Therefore they had got further in that direction than they need practically go; but he would have liked to see the effect of carrying the steam three-fourths of the stroke in each cylinder. He had to enquire for Mr. Robert Doxford, while on his feet, if Prof. Weighton intended to continue these experiments, reducing the revolutions gradually by reduction of the mean pressure, and also by increased resistance?

Prof. Weighton—Yes.

Mr. TAYLOR thought both of these would afford valuable information. He again thanked Prof. Weighton for the extremely practical and valuable paper which he had given them.

Mr. M. SANDISON, on being asked to speak, regretted that he had not had an opportunity of studying Prof. Weighton's valuable paper, and said he had come there rather to hear words of wisdom than to offer any remarks. It, however, occurred to him, that the engineers in the district might, with great advantage to themselves, take up the matter again, and present Prof. Weighton with a new boiler and set of cylinders to enable him to keep abreast of the times. He noticed that the present available boiler pressure was 210 lbs. A boiler of ample size, adapted for at least 300 lbs. pressure and suitable cylinders, was what was required.

Mr. W. G. SPENCE said he had only had a hasty glance at the paper, and, so far, he must say, he was somewhat surprised at the result. As far as his own previous ideas on the subject were concerned, they had been more a matter of faith than knowledge; and off-hand, if he had been asked to say which was the more economical, to work an engine at 15 expansions with a mean pressure of about 33 lbs. or to expand down to 19 lbs., he would certainly have said 19 lbs.; but in this paper the experiments seemed to point to the reverse. These opinions they had been led to form from marine engines. He did not know what the form of this particular engine was; but it struck him when he saw the statements that, perhaps, it had a very large ratio of exposed surface in chests and jackets to cylinder capacity compared with the [redacted] engines. Naturally, when putting in larger engines, they looked ahead, and put them in a good deal larger than required, in view of future increase of machinery. The result was to replace an over-powered engine by one under-powered, and when these large engines were started they very often found the consumption of coal was no better than before; and it took a good deal of explaining by engineers to show that this resulted from being too generous, and that working with such high rates of expansion and large cooling surfaces reduced the efficiency, and it was pointed out that when the engines would be working up to their normal power, better results would be got. The curve shown was certainly a most interesting one to him, and a surprise. He wished it could be carried far enough to see where it turned, and if this could be done, they would be even still further indebted to Prof. Weighton.

BELLEVUE, WORMIT, FIFE,
January 21st, 1897.

DEAR MR. DUCKITT,

I was unable to be present at the reading and discussion of Prof. Weighton's valuable paper, but would like to make a few remarks thereon. The results of this series of experiments, if thoroughly reliable, should be of great value to marine engineers, and the promised series on the influence of boiler pressure and stage expansion should be of still greater value. In the series now given Prof. Weighton does not make any mention of any test for the dryness, or otherwise, of the steam supplied to the engine, and the inference is that no such test was made. If such was the case, then the conclusions drawn by Prof. Weighton should be accepted with a certain amount of reserve.

It may be argued that the experiments show comparative results only, but there is no possible ground for supposing that the steam supplied would be of constant quality for the whole series of experiments. It is stated in the paper that the steam pipe is over 100 feet long, and although this pipe might be well clothed, yet there would probably be a considerable quantity of steam condensed, and it is quite possible that the whole or a part of this condensed steam might remain suspended, and thus pass to the engine. The indicated horse-power varied from about 60 to about 180, or roughly speaking, the weight of steam passing through the steam pipe in a given time would be three times as much for the high power than for the low power. Now, if the whole or a part of this water condensed were to remain suspended, then, although the total quantity of steam condensed might be the same for each case, yet the percentage of suspended water would be greater in the case of the low powers, and thus, apparently, lower their economy.

Prof. Weighton speaks in one part of his paper of apparently contradictory results sometimes obtained. May this not be due to the varying quality of steam? To remove any doubt as to the truth of experiments of this kind, some test of the quality of the steam is very necessary, and failing any satisfactory apparatus for this determination, would it not be possible to superheat the steam a *few degrees* before it enters the engine in order to be absolutely certain of the amount of heat received?

Yours faithfully,

W. R. Cummins.

PROF. R. L. WEIGHTON'S REPLY.

Prof. R. L. Weighton, in reply to the discussion upon his paper, said he quite agreed with Mr. Taylor that a jacket might have a prejudicial effect if it were continuously open to the atmosphere. In the present case, however, the jacket drain cocks were never opened during a trial. The only use made of the jackets during these trials was to heat up the engines before starting. After starting, jacket steam was shut off, the jackets emptied, and the drain cocks closed. During a trial there was generally a slight leak into each jacket, as shown by the jacket water trap. After each trial the amount of this leak was noted and added to the feed-water in the results. In the trials, therefore, the jackets merely acted as non-conductors in relation to the working steam.

He also agreed with Mr. Taylor that it would have been desirable to have carried the number of total expansions below the lowest recorded in the trials. They had, however, complied with Mr. Taylor's desire, at least in regard to the cut-off in the first cylinder at full power, in which it will be seen from Table I. that the steam was carried to three-quarters

[redacted]

Referring to Mr. Doxford's question as to varying the revolutions, that involved another set of experiments altogether, and it was his intention to make such experiments by and by; the revolutions would be varied by varying both the mean pressure on the cylinders and by varying the resistance at the dynamometer.

Mr. Sandison's remarks regarding 300 lbs. boiler pressure reminded one very forcibly of the rapidity with which, in practice, we were ascending the scale of working steam pressures. When he designed these engines about three years ago, 210 lbs. working pressure was looked upon as being very high indeed, and now Mr. Sandison talks of 300 lbs! He did not think, however, that he was far behind the times with 210 lbs.

With regard to Mr. Spence's remarks, he was quite prepared to hear of his surprise that the efficiency apparently rose as the expansions diminished, and he (Prof. Weighton) quite sympathised with him in this respect, as he himself, when he began these experiments, expected to find the efficiency curve attaining a maximum height at some point considerably before fifteen expansions were reached.

These engines—as would be seen from the drawings—were of the ordinary marine type, and had no more exposed surface in relation to cylinder capacity than was the case in an average specimen of commercial engine; at least they had no more than was necessarily entailed by smallness of size. He did not, therefore, think this would account for the sustained economy in the results at low degrees of expansion.

He wished, however, to say that as the paper was rather hurriedly got together, he had not had much time to thoroughly analyse some of the results, and he was, therefore, not prepared to dogmatise on any point. He had recorded the observed facts as faithfully as he could, and he left them for the present where they were. He hoped that they might afford, in conjunction with the results of further experiment, a basis for other deductions besides those already made.

Referring to Mr. Cummins's communication, he had to say that no test of the dryness of the steam was made. That was a point which was carefully considered in all its bearings, and in view of the fairly generally admitted fact that there existed no method which could be relied upon to give accurate and consistent information as to the moisture suspended in steam, and in view of the further fact that the trial results would be comparative and not absolute, it was decided not to fit any apparatus for making the test in question. No doubt one could not be sure that the quality of the steam received by the engines was uniform, when the conditions as to pressure and speed vary, and this must be recognised once for all, and taken as one of the conditions of the trials. The greatest care, however, was taken to thoroughly drain, first the steam pipe and second the high-pressure steam-chest. The water collecting in the latter was always kept in sight in the drain trap, so that if any water entered the cylinder it must have been suspended amongst the steam. And he did not think the variation in quantity thus suspended could possibly have been so great as to affect the comparative results to any appreciable extent. At low powers steam would be longer in the steam pipe, and therefore a greater proportion of it would condense than at higher powers. The resulting water would, however, be all drained away by the steam chest drain. If any more moisture remained suspended than was the case at higher powers it would of course enter the cylinder, and thus far the results would be affected. It must, however, be remembered that when power is low the boiler will probably produce drier steam than when it is forced and power is at a maximum. They therefore had such a condition of matters that when the pipe was likely to give moist steam the boiler was likely to give its driest steam, and *vice versa*. It would therefore appear that this question of steam-quality had not a very important bearing upon such trials as these, although of course it would certainly be desirable if the exact quality of the steam were known with certainty. The "contradictory results" referred to in the paper did not support Mr. Cummins's argument as to the probable importance of steam-moisture, because they were obtained at constant power, speed, and boiler pressure, in a series of trials undertaken with a view to determine the effect of intermediate or receiver expansion. In such circumstances the quality of the steam might be expected to be uniform from hour to hour. Superheating would no doubt serve as an

THE RESISTANCE AREAS OF TRANSVERSE SECTIONS.

BY A. E. SHARP.

[READ BEFORE THE INSTITUTION, IN NEWCASTLE-ON-TYNE, ON JANUARY 20TH, 1897.]

Considering the frequent occurrence of questions relating to beams and girders in the everyday routine of the engineer and shipbuilder, it is rather surprising that the literature on the subject is not of such a nature as to give those seeking information that grasp of the first principles necessary to a thorough knowledge and solution of the innumerable questions that are likely to arise.

If any apology is necessary for introducing what, perhaps, may be termed a threadbare subject, the writer can affirm from experience that it is a very difficult matter to obtain ideas which can be regarded with satisfaction, and he ventures to think that others have also felt this difficulty; hence a ventilation of the subject may be productive of much good.

It is very much to be regretted that there is often vexatious matter introduced, which can be of very little use whatever, even if it were true, and to those who have not been so situated as to have the subject definitely and forcibly impressed, or are inclined to waver between two opinions, such matter is a cause of much doubt and ambiguity; if the principles upon which the theories are based were kept more to the front, we would not be troubled with such statements as, "the position of the neutral axis varies as the square roots of the strengths in tension and compression," and other similar meaningless expressions.

It may appear rather alarming, though undoubtedly it is indisputable, that we are able to and often do make beams and girders of very complicated section, yet we are unable to say with any degree of certainty what load it will take to fracture them without having previously made one and tested it to destruction. It may be said that they are not intended to break, but the fact must not be overlooked that they do sometimes break, and the question is naturally asked, with what weight will they break?

In nine-tenths of the cases a calculation is made by means of a formula which was never intended to apply to breaking loads; and even when applied to working loads, there are certain assumptions which do not exist in practice. It may not be out of place to observe that the basis upon which the formulæ for determining the strengths of beams are founded is a purely theoretical one; that sufficient emphasis is not given to this, and the importance of it realised is apparent by the indiscriminate use made of the formulæ; in short, there does not appear to be that discernment in distinguishing between the working load of a beam and the breaking load. In almost every treatise dealing with the elements of structures tables are given, setting forth the resistances to be expected from each particular disposition of the material relatively to the neutral axis, but in very few instances indeed are there any qualifying statements that the deductions are strictly theoretical and true only within certain limits; and where restrictions are given, they are not, in the writer's opinion, given with that decisiveness which the subject requires. It is a very common occurrence in cases of direct tension or compression, when determining the load to be borne by various materials, to fix it at some fraction of the breaking load; hence, seeing that when a beam is subject to a transverse load causing a *combined* tensile and compressive stress, these stresses are frequently compared with and erroneously set down as being analogous to the former. That this is not so will be obvious from an inspection of the diagrams where the material is placed relatively to the neutral axis as may be found to be most convenient. We cannot speak with any accuracy as to its behaviour when about to rupture. It is not as if we were considering, say, two mild steel plates, placed at such a distance apart as to correspond to the depth of a

Expressed briefly, it is the summation of "*the area of the section divided into an infinite number of parts* multiplied by the *distance squared* of each from some axis," and called the moment of inertia relatively to that axis ; in transverse sections the axis is the neutral axis.

The propriety of calling the preceding definition a moment of inertia has been questioned, and very properly so, since an area can no more have a moment of inertia than an infinitely thin lamina can have weight ; when the term is applied to sectional areas it is essentially a mechanical magnitude reckoned by some writers in inch units. There is no doubt that the similarity of the processes is answerable for the same term being applied to such widely different subjects ; but however much it is misnamed, it is evident from a discussion elsewhere that it is not considered advisable to alter it ; probably the best course to pursue would be to discontinue the use of it, and substitute Unwin's *Modulus of the Section.*

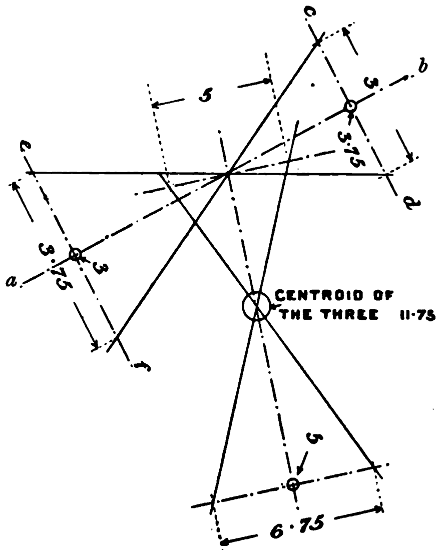
From the theories which are very generally accepted regarding the deflection of a beam, we know that the total stresses in tension are kept in equilibrium by the total stresses in compression, and it is therefore evident that to obtain such a result the neutral axis will be in the centre of the figure technically called the mass-centre and centroid ; the latter term will be used here. (This assumes that the moduli of elasticity in tension and compression are equal, the error introduced is so small that the difference can be neglected.)

Construction of Resistance Areas.

The method adopted in drawing the resistance areas, and a portion of the constructional lines, are shown in Fig. 10 (Plate XV.). In unsymmetrical sections the position of the neutral axis can be found by the "principle of moments," or from any of the methods usually employed for determining the centroid. The annexed figure A has been found to be very suitable for complicated figures the component parts of which are known.

Say the numbers 5, $3\frac{3}{4}$, and 3 (Fig. A) represent the centroids of pounds, square inches, or other convenient unit, it is required to find the resultant. Connect any pair by line *a b*, draw *c d* and *e f* at right angles, set off the distances at *opposite* ends, and the intersection of lines drawn through these points gives position of resultant, and the magnitude is the sum of the pair ; repeat the process, taking this resultant as found and the remaining centroid. The resultant of the latter pair is the centroid of the three quantities, and is correct for any number of pairs whose position and magnitude are known. In circular-shaped figures (Fig. B) we have the equation $R^2H - r^2h = (R^2 - r^2)\,C$, from which we obtain $C = \frac{R^3 - r^2h}{R^2 - r^2}$.

FIG. A.



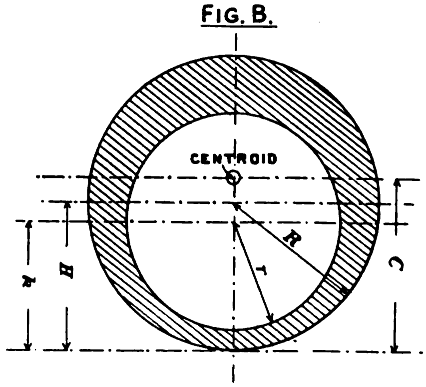
Having found the neutral axis, and determined the plane in which the bending is to take place, taking A B (Fig. 10 Plate XV.) as the plane of bending, draw C D and E F equi-distant from the neutral axis. These lines are termed boundary lines, one of them being tangent to that part of the section farthest from the neutral axis. Draw ordinates, and project the points where they cut the figure or section to boundary lines; intersect the ordinates by lines drawn from the points on boundary lines to centroid, and the intersections are the points from which the contour of the resistance area is formed. Having outlined the resistance area, find the centroid of each half; the distance between these two points constitutes the arm or leverage of the section.

Modulus of section = area of half resistance section × arm.

This is the modulus in unsymmetrical sections of that half which has material situated the more remote from the neutral axis.

The modulus of the other half is greater in the ratio of the distances of the remotest part of each from the neutral axis.

FIG. B.



It is a proof of the accuracy of the construction that in a figure of unsymmetrical section the resistance area above the neutral axis is exactly equal to that below it ; where this is not so the position of the neutral axis is incorrect, or possibly some error has been made in projecting the points to the wrong ordinates.

Figs. 1 to 13 (Plates XIV., XV., and XVI.) show the shapes of the resistance areas for some familiar sections, and Figs. 14, 15, and 16 (Plate XVII.) are the sections of a propeller blade near the boss. Fig. 14 is for the resistance to bending in a fore and aft direction, from which, knowing the amount of the thrust that is being exerted, and the resultant distance from the centre of the shaft at which it can be said to be concentrated, the stresses can be easily determined. Or, knowing the turning moment that is being put through the propeller, the same can be determined by means of Fig. 15, where the bending is at right angles to the motion of the ship, and Fig. 16 shows the least resistance offered by the section to bending, and is at right angles to the face of the blade at that particular point. In Figs. 17 and 18 (Plate XVIII.) we have a pipe the core of which is eccentric, the section of which has been selected to illustrate the usefulness of the graphic methods generally, and this one in particular.

As a numerical example, take the section in Fig. 17 (Plate XVIII.) to represent a cast iron tube 12 inches in diameter, having a 9 inch hole, the core of which has become displaced, with the result that it is $\frac{3}{4}$ inch at one side and $2\frac{1}{4}$ inches at the other; the span is 25 feet, and there is a load of 6 tons borne in the centre (weight of tube is not included in bending moment). The thin side is placed on the top, and it is required to find the greatest stress to which the material is subjected.

Each resistance area shown hatched is equal to 10·75 square inches. The length of the arm is 8·125 inches. Greatest distances of section from neutral axis are 6·95 and 5·05 inches.

Modulus of section for the half above the neutral axis, being that part which is in compression $10{\cdot}75 \times 8{\cdot}125 = 87{\cdot}3$.

Modulus of section for the half below the neutral, being for that part which is in tension is $\frac{87{\cdot}3 \times 6{\cdot}95}{5{\cdot}05} = 120$.

Greatest bending moment is $3 \times 150 = 450$ inch-tons.

Greatest intensity of stress in compression $\frac{450}{87{\cdot}3} = 5{\cdot}15$ tons per square inch.

Greatest intensity of stress in tension $\frac{450}{120} = 3{\cdot}75$ tons per square inch.

Should it be desired to have these intensities to correspond to some fraction of the ultimate elastic strengths of the material, this can be accomplished by placing the section, as in Fig. 18 (Plate XVIII.), which gives unity in tension to 1·33 in compression; or, in other words, in such a section we can almost make the intensities of stress in tension and compression anything we please.

If any doubt should exist as to the accuracy of the "arm" of the resistance areas, each centroid can be tested by a repetition of the process, that is, by drawing a second resistance area; the lower half of the resistance area in Fig. 18 (Plate XVIII.) is shown to an enlarged scale in the plain part of Figs. 19 and 20 (Plate XIX.), and the hatched portion represents the second resistance area; if these areas are measured the halves will be found to be equal, each to each.

It is not claimed for this graphic method of finding the resistance of sections, that it has not been previously dealt with by more able writers, that it is the quickest way of effecting a solution, or that it should supersede the integral calculus when the figure is bounded by curves the equations of which are known, and the investigator is capable of applying it; but it is the writer's experience that it is equally as accurate when the proper instruments are to hand (a planimeter being almost indispensable); and also that the average engineer does not have the use of the calculus sufficiently often to have confidence in the results obtained, however expert he may have been at it previously.

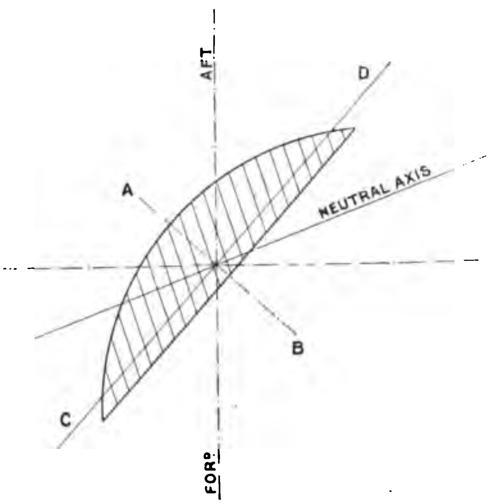
It is hoped for the reputation of the profession generally, and the benefit of those just about to enter upon their career, that in many instances the determination of the scantlings of details in connection with marine engineering will be placed on a better footing, and not be dependent on formulæ, which can only be regarded as empirical.

Sharp would perhaps correct him. He had often obtained the strength of beams by a graphical method by using Amsler's integrator, not the ordinary small planimeter, but the integrator which gave the moment of inertia. In doing so he used the moment of inertia of the section, and his calculation was open to exactly the same objection as if he had calculated the moment of inertia by the integral calculus.

Mr. ALEX. TAYLOR said they might consider him very bold to speak twice that night seeing he had not been at a meeting for years before; but, unfortunately for him, he had not been able to attend. Mr. Thomson wished to know how the figures were constructed. If he (Mr. Taylor) remembered aright he first saw these sections in Baker's book upon *Beams*. He had no doubt Mr. Sharp would fully describe the method of construction, but if any of the members wanted to see this, and the ordinary method of calculation compared, they would find them in the book mentioned. He would like to say it was many years since he had looked at this matter, and, therefore, he might be wrong in saying that Baker gave coefficients suitable for the form of section and material dealt with, but he was not aware that Mr. Sharp did so.

Prof. R. L. WEIGHTON said he should like to ask Mr. Sharp if he would kindly, when he replied—one could not expect him to do it that night—give a comparison between the results of the two methods of finding the moments of resistance. Like Mr. Thomson, he (Prof. Weighton) had not had the privilege of becoming acquainted with this method before. When he saw it at first he thought it very good indeed, as being some graphic method of integration. If it were really so for finding the moment of resistance, then it was subject to all the defects of the usual moment of inertia method, and the aspersions which the writer, in the first page, cast upon the accepted method applied equally to his own method. He could not see how the method could apply as far as the breaking strength without the use of an empirical coefficient. One could see how both methods applied up to the elastic limit, but beyond that it was well known that the moment of inertia method did not apply in its entirety; nor, as he understood it, could this method. If this method was not merely a graphic method of integration for finding out the moment of resistance of a section, one would like to know the results it gave as compared with the accepted method. The value of the paper would be very much increased if an illustration or two were appended, showing a comparison of the ordinary method of calculation with this method.

Mr. G. M. Brown thought they should all be very much obliged to Mr. Sharp for his paper, treating as it did of a subject not well known amongst engineers. There was one point about which he would like to make a remark. In Fig. 14 (Plate XVII.) they had a section of the propeller blade near the boss. The plane of the bending couple was supposed to be in the fore and aft direction, and Mr. Sharp took the neutral axis as coinciding with the axis of the bending couple. Now, in the case of unsymmetrical bending that was not so. The neutral axis did not coincide with the axis of the bending couple, and if any one wanted proof he would find it in Rankine or Cotterill's *Applied Mechanics*. He (Mr. Brown) thought the neutral axis (see sketch) should be inclined to the fore and aft line, not at a right angle, but at an angle rather less than a right angle.



Having found the neutral axis, and determined the moment of resistance about it, this example could be worked out in the usual way. It was, however, hardly worth while doing this, for before the neutral axis could be determined, the moments of inertia of the section about its two

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NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896–97.

PROCEEDINGS.

INSTITUTION DINNER.

The Institution Dinner of the North-East Coast Institution of Engineers and Shipbuilders was held on the evening of Monday, February 8th, 1897, in the Assembly Rooms, Westgate Road, Newcastle-upon-Tyne. The dinner, which was the first of its kind, was a pronounced success. There was a large and influential gathering of gentlemen connected with the shipbuilding and engineering industries. The chair was occupied by the President of the Institution (Colonel Henry F. Swan), on whose right hand sat Sir W. H. White, K.C.B., and on his left the Mayor and Sheriff of the city. In all 180 gentlemen were present, among whom were the following :—Past-Presidents—Messrs. W. Boyd, Robert Thompson, Thomas Richardson, M.P. Vice-Presidents—Messrs. E. W. De Rusett, J. R. Fothergill, Henry Fownes, John Gravell, D. B. Morison, James Patterson, Prof. R. L. Weighton, M.A. Members of Council—Messrs. R. P. Doxford, W. H. Dugdale, J. B. Furneaux, Summers Hunter, M. C. James, Joseph M. Rennoldson, H. B. Rowell, A. G. Schaeffer, W. G. Spence, R. Wallis, G. E. Macarthy (Hon. Treasurer), John Duckitt (Secretary). Guests—Sir W. H. White, K.C.B., Mayor and Sheriff of Newcastle, Mayor of Hartlepool, Mr. T. Westgarth (President of the Cleveland Institution of Engineers), Mr. J. B. Simpson (President of the local section of the Institute of Civil Engineers), Mr. G. T. Bootes (President of Newcastle Association of Foremen Engineers and Draughtsmen), Principal Gurney (Durham College of Science), Messrs. F. Gross (Sir John Brown & Co., Sheffield), R. Hedley, T. Mera (Naval Constructor I.J.N.), K. Mayeda (I.J.N.), C. J. Morch, W. H. Swenson, H. S. Arentz, Mera, Mayeda. Members—Sir B. C. Browne, Colonel A. Robson, Messrs.

John W. Spencer, John Tweedy, A. Coote, J. P. Wilson, R. S. White, C. H. Reynolds, T. Putnam, W. Putnam, J. D. Christie, C. D. Doxford, James Marr, W. Dobson, H. Charlton, G. Robson, G. Donkin, T. E. Smith, Andrew Laing, J. W. Dick, etc.

Apologies for absence were announced for Lord Hopetoun, Earl Ravensworth, Sir Andrew Noble, Mr. Cruddas, M.P. (whose illness was sympathetically referred to by the Chairman, the hope that he had turned the corner being cordially applauded), Sir Charles Hamond, M.P., Sir Matthew White Ridley, Bart., M.P., Mr. W. T. Doxford, M.P., Sir Christopher Furness, the Mayor of West Hartlepool, and Mr. A. J. Durston, Chief Engineer to the Navy.

After dinner, the CHAIRMAN gave the loyal toasts in an appropriate speech, in which he referred to the sixtieth year of the Queen's reign, and to the sterling qualities of the Prince of Wales.

Mr. ROBERT THOMPSON, in proposing "The Houses of Parliament," said he would like to re-echo the chairman's remarks respecting Mr. Cruddas, whom they all hoped would be long spared to represent Newcastle. With that toast there was coupled the name of Alderman Thomas Richardson, M.P., of Hartlepool, who was one of their Past-Presidents. He was glad to see that a number of engineers and shipbuilders were members of the House of Commons.

Alderman THOMAS RICHARDSON, M.P., in reply, said he had great pleasure in responding to the toast, and he thanked them heartily for the way in which they had drunk it. It would be a bad thing for this [redacted]

When they had fourteen engineering members and three admirals, that made seventeen, but the House of Commons consisted of many members who knew nothing about engineering and the navy, and the three admirals had the engineers at a considerable disadvantage, for they could refer to the share sailors had in the history of the past; while engineers in the navy had yet to prove their value in the history of the future, and they were trying to impress upon the Admiralty that the sailor's day was past, and engineering was the power they must look to in the future. They wanted as many members connected with naval architecture as possible. When they went back forty years their navy was manned by sailors, but now their fighting ships were a mass of machinery, and it was absolutely necessary that the engineers should be fully qualified; and they were continually urging upon the Admiralty the necessity of practising the engineering reserves in the work they would be called upon to perform in the event of their services being required. If it was necessary for sailors to be drilled, it was very much more necessary for the engineers to be drilled also. The day had gone by when they could take men off the mercantile marine and put them on board war ships and expect that they would be able to do their work right off the reel. This was utterly impossible. He believed, however, that by continually hammering at the matter, they would get the authorities to see that the engineers required more consideration than they were now getting. As engineers connected with naval architecture, they would deplore the fact very much, in the event of war, if it were the engineering branch of the navy which was found deficient in any way. They wanted to protect themselves against that. Mr. Richardson also referred to the social and scientific aspects of the Institution, and hoped that the dinner would become an annual affair.

Mr. WILLIAM BOYD proposed "The Army, Navy, and Auxiliary Forces." He said that the framers of that toast had been embodied with the true spirit of peace, for they had put words before deeds. It was one toast and one body of men whose health he asked them to drink. They were actuated by the same spirit, whether soldiers, sailors, or volunteers, and whether they served their country in the hills of Chitral, or in the deadly clime of the Gold Coast, or in a humbler fashion in the uniform of a Newcastle volunteer, they had the same spirit and patriotism, which was the mainspring of the military and naval services.

Colonel ROBSON, in response, said it was very pleasant to be able to congratulate the nation on its very satisfactory position. Never in its history had they had so perfect a fleet on the bosom of the ocean as now. The navy had always been good. Old-fashioned, perhaps, giving to doing all sorts of things the goody people did not like, but it could always fight. The British navy could still fight, and with the most perfect weapons. The weak spot was that whilst they had the ships, and almost unlimited facilities for turning them out in numbers and strength, they had not the means of manning them. They had not an efficient reserve. He advocated the training of more boys, who would help the mercantile marine by keeping up the supply of English born and bred sailors. The same remark in regard to the want of reserve applied to the army, and to a very much greater degree.

Sir W. H. White, K.C.B., then proposed "The Institution," and was received with hearty cheering. He said that it was a very agreeable duty to him to propose that toast, because it was always pleasant to be amongst old friends. He would never forget the time he spent in the north when he did a great deal of work and learnt much that was worth knowing, especially that the men of the north could be good friends to one of the south. The last time he was in that room was when that Institution did him the honour to ask him to attend and wish him God speed in beginning his work again at the Admiralty. Although it was quite true that that was the first dinner of the Institution he hoped it would be an annual dinner. He could not forget that the first time the Institution dined there it was to wish a man success in undertaking what was certainly no easy task, and which he filled from no personal motive. It was his duty to propose that toast, because when he went away and could no longer be an active member of the Institution, method in the shipyards of the North-East Coast had been remarkable. The Institution had been a foster father of an educational scheme which would always redound to the credit of the North-East Coast. And when one looked at their Past-Presidents, they might be assured that success had been attained, and would be continued so long as that Institution worked upon its present lines. Many of them there remembered the early days of that Institution. It was one of his most treasured memories that he had the honour of assisting in starting that Institution, as one of the members of the Council, and reading the first paper that was read before them. It was practical rather than scientific, but it had this good result, that out of it came at once something intensely practical—the Institution took steps and carried into effect a scheme for a proper measured mile, which they did not possess before. The Institution was first talked of by a number of young men who were in the position of chief draughtsmen and managers in the shipyards and engineering works of the district. When they had held their first meeting they wrote to him, saying that they had decided on the Institution, and asked him to become President. His hearers would feel for him when they remembered the self-denial he exercised when he advised them not to limit the scope of the Institution to the younger men, but to ask their employers and principals to join it, and also not to make the mistake of asking a new comer to become its first President, when they had so large a choice in the district. They consulted the employers, and received most hearty support from Mr. Boyd, their first President. So he had missed a great opportunity. He might have been their President, and who knew what else, for there was such a danger before their Presidents as becoming members of Parliament. What a gulf he had escaped! Their friend Mr. Richardson had been a President—had become a President before being made an M.P.—and Mr. Doxford was a Past-President. Other gentlemen had been asked to become M.P.'s, and perhaps Colonel Swan, as their President, would soon be added to the list. A feature of the Institution which was unique and had much to do with its success was this: the initiative in its formation was taken by young men who realised the enormous advantage of scientific method as applied to shipbuilding and engineering in days of great and earnest competition. In the Institution it had always been an essential point that the younger members should have a voice in the management, and be recognised in a way not usual in such institutions. He believed this had been a great element in their most remarkable success, and in looking over the papers read he found that much of the more valuable work had been done by the younger members. It was in the younger members that hope for the future chiefly resided. Altogether the past history of the Institution gave such happy auguries for the future that he had every confidence, in asking those present to drink its health, and couple with it the name of Colonel Swan.

The toast was received with cheers, and the PRESIDENT, in reply, said that although the Institution was a young one, it had shown considerable vigour. In the dozen years of its existence its membership had risen to over a thousand. The Institution was carrying on an educational work. The building of ships and engines nowadays had attained a degree of scientific excellence which a few years ago would never have been thought of, and it was absolutely necessary that the rising generation should be thoroughly and scientifically instructed in the rudiments of the profession. This education they were now able to get by means of such institutions as theirs.

Mr. J. R. FOTHERGILL, Vice-President and Chairman of the Dinner Committee, who occupied the vice-chair, proposed "Our Guests." He offered, on behalf of the members of the Institution, a hearty welcome to the guests. He expressed complete satisfaction at the number who were present, and had no hesitation in saying that a dinner would become an annual function of the Institution. He then referred to the advantages of such institutions, particularly as affecting junior members, and their advancement in their profession. He also referred to the great work the Institution had done associated with the Durham College of Science. They had founded and endowed for six years the chair of engineering and

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which had been carried out by the Tyne Improvement Commissioners, under the guidance of the late Mr. Ure, and their present head engineer (Mr. Messent). At the commencement of the reign of the Queen, and for long after, the Tyne was a narrow, tortuous river, full of shoals, with very little water on the bar at low tide, and dangerous to enter and navigate. Now, in the Queen's diamond jubilee year, the Tyne was one of the finest ports in the world, and a harbour of refuge on the stormy North-East Coast. When Queen Victoria ascended the throne the revenue of the port was under £20,000 a year. In 1895 the revenue of the Tyne Commission was £309,256. Sixty years ago the shipment of coal was under three million tons a year, whilst now the shipments amounted to between 12 and 13 million tons. Sixty years ago only the old-fashioned keels, for which the Tyne was so well known, could pass west of the old bridge. Now the Swing Bridge enabled large vessels to pass westward to load coal, and had also opened the upper reaches to the enterprise of the great Elswick firm, enabling them to build warships of the highest class. When the Queen began her reign the Corporation no doubt thought they were doing a great work when they dredged 20,000 tons a year from the Tyne; but under the Commissioners as much as 5½ million tons had been dredged in one year. During the sixty years of Her Majesty's reign nearly 100 million tons had been dredged from the Tyne. This wonderful change had been accomplished by an expenditure of between 11 and 12 millions of money; about 7 millions of which had been provided out of taxation on those using the river, and about 4½ millions had been borrowed. No branches of industry had benefited by these great improvements more than the engineering and shipbuilding. Most of the large firms had come into existence on the banks of the Tyne since the river came under the charge of the Commissioners. Only one of the principal shipbuilding firms now on the Tyne could boast of being in existence when the Queen ascended the throne—that of Thomas and William Smith, who in 1810 opened their works at St. Peter's, and in 1839 opened another establishment at North Shields, and the next oldest was the establishment of Messrs. Wigham Richardson & Co., at Low Walker, commenced in 1840 by Mr. Coutts. Great improvements had been carried out at other North-Eastern ports, and the members of the Institution had had much to do with the great advance in the prosperity of the North-East Coast—a prosperity and advancement which formed a leading feature in any retrospect of the achievements of the sixty years of Queen Victoria's reign.

Principal H. P. Gurney, M.A., whose name was also coupled with the toast, remarked that all acknowledged the value of technical education. No one more needed the fullest knowledge that science could give them, to none could it be more valuable, to be trained to the highest degree of technical skill, than masters and managers of the very important industries which his hearers presided over. Therefore they wished the Institution all success and prosperity. They were not merely a scientific body, for if they had done nothing else they had founded a school of engineering and naval architecture, the most complete in the kingdom.

The remaining toasts were "Trade and Commerce," proposed by Sir B. C. Browne, and acknowledged by the Sheriff of Newcastle and Mr. Summers Hunter; and "Kindred Institutions," proposed by Prof. R. L. Weighton, M.A., and responded to by Mr. T. Westgarth (President of the Cleveland Institution) and Mr. T. Mudd (Mayor of Hartlepool).

The following gentlemen were appointed by the Council to carry out the arrangements :—

Dinner Committee.

Mr. J. R. Fothergill (Chairmam).
„ Robert Thompson.
„ Hugh Macoll.
Mr. Henry Fowns.
„ A. G. Schaeffer.
„ John Duckitt (Secretary).

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896-97.

PROCEEDINGS.

THE FIFTH GENERAL MEETING OF THE SESSION WAS HELD IN THE LECTURE HALL OF THE MARINE SCHOOL, OCEAN ROAD, SOUTH SHIELDS, ON WEDNESDAY EVENING, 10TH FEBRUARY, 1897.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on January 20th, 1897, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, Messrs. R. P. Doxford and W. H. Atherton were appointed by the President to examine the ballot papers, and the following gentlemen were declared duly elected :—

MEMBERS.

Cleghorn, Alexander, Engineer, Datcha, Scotstounhill, near Glasgow.
Cuncliffe, Tom Arthur, Engineer, 12, Cresswell Terrace, Sunderland.
Nicholson, Joseph Cook, Mining Engineer, Collingwood Street, Newcastle-on-Tyne.
Staig, William Andrew, Draughtsman, Station Road, Wallsend-on-Tyne.

GRADUATES.

Buchanan, Samuel, Jun., Ship Draughtsman, 51, Welbeck Road, Walker-on-Tyne.
Doxford, Robert, Student in Naval Architecture, Silksworth Hall, Sunderland.
Mollard, James Percy, Electrical Engineer, 61, Elswick Road, Newcastle-on-Tyne.

WELCOME TO SOUTH SHIELDS.

Mr. J. M. RENNOLDSON said on behalf of the South Shields members he had very great pleasure indeed in welcoming the Institution on this, its first visit to that town. The Institution had now existed for something over twelve years, he believed, and this was the first occasion on which they had honoured them by holding the meeting in South Shields. He sincerely hoped that it would not be the last, and that they would be encouraged by the success that night to hold meetings there again. He was sorry that the meeting was not a larger one. There were some members of the Shields contingent who would have been present but for other functions going on that prevented them. At this time of the year there were such a variety of things doing, it was impossible to get a clear night for a meeting. Still, he thought, more members would turn up, and that the meeting would not be a discreditable one, in the matter of attendance, for South Shields members. They welcomed the Institution heartily, and hoped the meeting would be encouraging and successful.

The PRESIDENT, on behalf of the Institution, thanked Mr. Rennoldson very cordially for the reception given to them on their first visit to South Shields, and they would have been glad if it had been a larger meeting. One of the objects in having meetings away from Newcastle was to meet the convenience of those of their members living in the various towns. They had already held meetings at Hartlepool and Sunderland, and he should be glad if, at these meetings, the attendance was such as to justify them being held in these towns in future. He hoped the meeting that [redacted]

SESSIONAL AWARDS.

The PRESIDENT announced that the Council had awarded the engineering gold medal of the twelfth session of the Institution to Mr. J. Denholm Young for his paper "On the Application of the Law of Similarity to Marine Propellers."

The amount (£7 11s.) which lay at the disposal of the Council to be given as prizes for the best papers, read before the Graduate section, had been awarded by the Council to be equally divided between Mr. J. B. Bent for his paper on "Alternating Current Motors for use on Single Phase Mains," and Mr. R. G. Thomas for his paper on "Some Notes on the Methods of Generating and Distributing Electric Power."

This money, it was explained, was not given in cash, but was at the disposal of the recipients to be spent upon books, instruments, etc., which would serve in after years to remind them of their earlier efforts.

The discussion on Mr. A. E. Sharp's paper on "The Resistance Areas of Transverse Sections" was resumed.

Mr. R. WALLIS, Wh. Sc., read a paper on "Liquid Fuel."

ADJOURNED DISCUSSION ON MR. A. E. SHARP'S PAPER ON "THE RESISTANCE AREAS OF TRANSVERSE SECTIONS."

Mr. W. H. Atherton resumed the discussion on Mr. Sharp's paper. He said that Mr. Sharp deserved the gratitude of the Institution for bringing before it a matter of some interest to scientific designers, and for the trouble he must have taken in the preparation of so many excellent diagrams. At the same time the paper as a whole might have been fuller, with advantage, and in places less obscure. The first point which Mr. Sharp emphasized was that the ordinary formulæ for the strength of beams "go out of gear when the limits of elasticity are exceeded," and were never intended to apply to breaking loads: a fact that was perhaps not so well known as its importance demanded. He next reminded them that it was very usual to fix the safe load as some fraction of the breaking load by the use of a factor of safety, and personally he (Mr. Atherton) failed to see how they could do anything else, though Mr. Sharp apparently objected to the method. With regard to the much-abused term moment of inertia, he quite agreed with Mr. Sharp that, when used with reference to an area, it was most misleading and unfortunate, because an area had no inertia, and therefore, properly speaking, no inertia moment. But the name was conventional and universally used, like many other faulty names, and any new one that might be proposed would not be generally adopted. Further, when they desired to be particularly explicit, they could always distinguish between the true and the fictitious quantities of the same name by calling the one the dynamical or mass moment of inertia and the other the geometrical or area moment of inertia, though one must admit that these terms were rather cumbrous. Mr. Sharp, however, thought that it would be best to discontinue the use of moment of inertia altogether, and to substitute Unwin's "modulus of the section," but he (Mr. Atherton) did not wholly agree with him there. He was quite willing to admit that, in an elementary treatment of the strength of beams, it was simplest to say nothing about the moment of inertia, but to define the moment of resistance of a section as the product of the stress on the material into the strength modulus of the section, the values of the latter being taken from the tables in Unwin's *Machine Design* or other such book. But, allowing all this, it was very certain that, in a complete scientific treatment of the strength and deflection of beams, the moment of inertia was bound to come in and figure prominently. It was hardly right, either, to imply that Unwin ignored the moment of inertia. The fact was he defined the moment of inertia first of all, and afterwards deduced the moduli of the section from it, giving also tables of both functions. To prevent misconception, one should remember that the strength modulus of a section was a geometrical quantity of the nature of $(\text{length})^3$, like volume, while the moment of inertia was of the nature of $(\text{length})^4$, or one dimension higher. The former might, therefore, be called the third dimensional function of the section, and the latter the fourth power function of the section, or briefly the *cubic* and the *quartic* respectively.

Rather strangely, Mr. Sharp, although going out of his way to discuss the term moment of inertia, had neglected to define what he meant by a "resistance area," leaving it to be gathered from the context. In fact, he had used that term in a sense different from the usual sense, and confused it with "equivalent area." The resistance area of a transverse section of a beam was defined as follows:—"Assuming that the position of the neutral axis of a section is known, and that the stress on the material is proportional to the distance from this axis, then a figure can be drawn which represents in intensity and distribution the varying stress over the section when the extreme fibres on one side are stressed to their greatest safe load. Such a figure is termed the "safe resistance area of the section." In drawing a figure of this kind, some chosen force scale must be worked to, and when so drawn the half resistance area multiplied by the resistance arm gave the moment of resistance of the section. The equivalent area of the section, on the other hand, was the [redacted] by distances from certain assumed datum lines or axes. Of such co-ordinate axes, however, Mr. Sharp made no mention whatever, and therefore he (Mr. Atherton) was quite at a loss to know what he really meant by the sentence quoted. In order to test the practicability of the method of resistance areas he had taken the trouble to draw down the eccentric pipe section shown in Fig. 17 (Plate XVIII.), and to determine its equivalent area in the manner described by Mr. Sharp. Having done so, the next step was to find the centroids of the top and bottom parts separately, from which to get the resistance arm. This promised to be a rather lengthy operation, so instead of proceeding in that way he took up his slide rule and tables and figured out the required moduli by their aid in about twenty minutes. (The calculation is appended.) The results arrived at, it would be seen, differed very slightly from those given by Mr. Sharp, and were probably a trifle more accurate. He doubted whether the results could be arrived at by the graphic method in less than two hours. The resistance area itself was not difficult to draw, but it was troublesome to find the centre of gravity of the peculiar figures thus obtained. Mr. Sharp disposed of the matter much too briefly in the words, "having outlined the resistance area, find the centroid of each half." Of course the centroid of any area, no matter how irregular, could be found, given plenty of time and patience, but it was a decidedly slow process. Herein, then, lay one serious drawback to the method, that in applying it, it was necessary to determine the centroids of extremely awkward figures. Another objection was that it required so much apparatus, viz., all the ordinary drawing instruments, and, in addition, a planimeter. He thought it would be generally agreed that the method which needed the least apparatus was, other things being equal, the best. In favour of the graphic method it might be said that it gave them a picture showing at a glance the relative resisting power of the different parts of the section, and especially the comparative uselessness of metal near the neutral axis; further, it was applicable to any shape of section, however irregular. He doubted, however, whether it was superior in point of generality to the method of dividing up the section into a series of rectangles and finding the approximate moment of inertia about the neutral axis of the upper and lower parts. For standard sections, whose moments of inertia were known, the graphic method was not needed at all, because they had formula at their command, which could be applied much more rapidly. In short, the method of resistance areas was of greater scientific interest and educational value than practical utility. Nor was there anything novel in it, for it was fully and accurately described in Clarke's treatise on graphic statics written twenty years ago. He supposed the reason why it had not become widely used was that it was too slow for practical work.

Finally, Mr. Sharp, both in his introductory and concluding remarks, would appear to be labouring under a singular illusion. He had rightly emphasized the fact that formulæ were of restricted application, and have to be used with caution; but he had also, perhaps unintentionally, implicitly led them to suppose that beams would be more scientifically or correctly designed by the graphic method than by the use of the regular formulæ. As a matter of fact, the two methods were identical in principle, and were equally erroneous beyond certain limits; they both proceeded on the same hypothesis that strain was proportional to stress, and they gave exactly the same results.

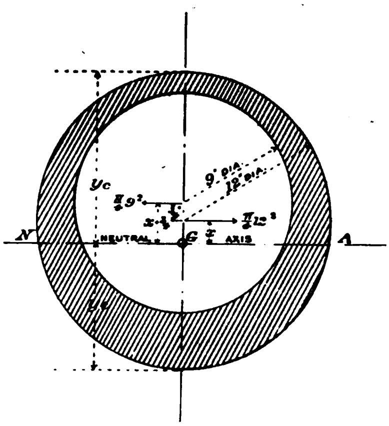

Fig. 17a.

Calculation of Stress on Eccentric Pipe Section.

1.—To find the position of the neutral axis they had, by the principle of moments (see Fig. 17*a*)—

[redacted]

Thus, for the 12 inch circle, they had—

$$I_{NA} = \frac{\pi}{64} D^4 + \frac{\pi}{4} D^2 . x^2;$$

$$= \frac{\pi}{4} \times 12^2 \left(\frac{144}{16} + \cdot 964^2\right); \qquad \text{(From 1)}$$

$$= 113 \cdot 1 \ (9 + \cdot 93);$$

$$= 113 \cdot 1 \times 9 \cdot 93 = 1{,}123;$$

and for the 9 inch hole they had—

$$I_{NA} = \frac{\pi}{4} 9^2 \left(\frac{81}{16} + 1 \cdot 714^2\right); \qquad \text{(From 1)}$$

$$= 63 \cdot 6 \ (5 \cdot 06 + 2 \cdot 94);$$

$$= 63 \cdot 6 \times 8 = 509, \text{ say.}$$

Hence the moment of inertia of the whole section about the neutral axis is 1,123 — 509 = 614 inch units.

3.—The strength modulus of the section, with respect to compression, is therefore, from the figure,

$$\frac{I}{y_c} = \frac{614}{6 \cdot 964} = 88 \cdot 1 \text{ inch units;}$$

and with respect to tension, is :—

$$\frac{I}{y_t} = \frac{614}{5 \cdot 036} = 122 \text{ inch units.}$$

4.—As the bending moment at the centre of the beam is 450 inch-tons, the greatest stress on the material is

$$\frac{450}{88 \cdot 1} = 5 \cdot 11 \text{ tons per square inch in compression,}$$

and

$$\frac{450}{122} = 3 \cdot 68 \text{ tons per square inch in tension.}$$

The discussion was again adjourned.

LIQUID FUEL.

By R. WALLIS, Wh. Sc.

[Read before the Institution, in South Shields, on February 10th, 1897.]

The writer's experiences with this form of fuel has principally been with petroleum residues on board of steamships, and the contents of this paper may, therefore, be taken as applying more particularly to its use in this direction.

The application of liquid fuel for the purpose of raising steam in boilers is now no longer in the experimental stage, a large number of boilers, both on board ship and ashore, being fired with this fuel, and there is no doubt that as the numerous oil-fields in the various parts of the world develop, its application will rapidly extend.

In addition to the oil wells of Southern Russia and Pennsylvania, oil has been found in varying quantities in most countries all over the globe. The late Mr. B. G. Nichol, in his paper on this subject before this Institution in 1886, mentions the countries in which petroleum had then been discovered. Since that time several of these oil-fields have been developed, and are now producing petroleum in considerable quantities, especially those of Peru, Burmah, Sumatra, and Beluchistan.

The principal source of *fuel oil* is Russian petroleum residuum or "astatki:" this is the oil remaining in the distillery apparatus after the lighter naphthas and paraffins have been distilled over. Russian crude petroleum yields a very much smaller percentage of burning oils than American crude oil, as is shown in Table I., but fuel oil in Russia, where astatki is used for this purpose, is cheaper than in America, where crude oil is used.

The percentages of the various oils that, with the perfected process of distillation now used, could be obtained from Caucasian naphtha are as follows :—

TABLE I.

		Density at 17 degs. Centigrade.	Per-centage.
Light oils ...		0·725	3
Illuminating oil ...	Kerosene...	0·822	30
	Solar oil ...	0·863	14
Lubricating oils ...	Spindle oil	0·895	10
	Machine oil	0·908	16
	Cylinder oil	0·915	5
Oil fuel ...		0·93	17
Loss ...		—	5
			100

American oils contain a very much higher percentage of burning oils, about 80 to 90 per cent., instead of only about 50 per cent., as above.

The first steamer to use liquid fuel was the s.s. "Constantine" on the Caspian Sea in 1870, and in America it was used on the steamer "Thoroughfare" in 1885. The first steamer to cross the Atlantic burning oil as fuel was the s.s. "Baku Standard" in January, 1894.

In addition to the petroleum oils the following oils have also been used as fuels :—shale oil, blast furnace oil, creosote, green, and other tar oils.

On the table are examples of Russian astatki, American crude petroleum ; crude petroleum, which has been exposed in a lake to the influence of the atmosphere for twelve months ; creosote oil ; heavy and light tar oils.

Comparing the value of coal and oil as fuel, it will be found to vary considerably according to the quality of the fuel, and the circumstances under which each are burnt, oil doing from $1\frac{1}{2}$ to $2\frac{1}{2}$ times the work of an equal weight of coal ; taking the average conditions, the results of

TABLE II.

	Specific Gravity.	Chemical Composition.						Heating Power. British Thermal Units.	Theoretical Evaporation.		Evaporation in lbs. from and at 212° Fahr. by Experiment.
		Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.		Lbs. from and at 212.	Lbs. Air required per lb. 23% O.	
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.				
Petroleum—											
Pennsylvanian heavy crude	·886	84·9	13·7	—	—	1·4	—	20,736	21·48	14·56	—
Caucasian light crude	·884	86·3	13·6	—	—	0·1	—	22,027	22·79	14·74	—
„ heavy „	·938	86·6	12·3	—	—	1·1	—	20,138	20·85	14·28	—
Refuse	·928	87·1	11·7	—	—	1·2	—	19,832	20·53	14·12	16
Crude average, 15 samples	·870	84·7	13·1	—	—	2·2	—	20,233	20·94	14·29	—
Refined average ...	·760	72·6	27·4	—	—	—	—	27,531	28·5	17·93	—
Scotch blast furnace oil	·920	83·6	10·6	—	0·1	9·4	—	18,590	19·2	—	—
Coal—											
Welsh, 37 samples ...	1·315	83·8	4·8	1·0	1·4	4·1	4·9	14,470	14·98	—	9·05
Newcastle, 18 samples	1·256	82·1	5·3	1·3	1·2	5·7	3·8	14,432	14·94	—	8·01
Derbyshire and Yorkshire, 7 samples ...	1·292	79·7	4·9	1·4	1·0	10·3	2·6	13,582	14·06	—	7·58
Lancashire, 28 samples	1·273	77·9	5·3	1·3	1·4	9·5	4·9	13,552	14·03	—	7·94
Scotch, 8 samples ..	1·260	78·5	5·6	1·0	1·1	9·7	4·0	13,804	14·29	—	7·70
Average British, 98 samples	1·279	80·4	5·2	1·2	1·25	7·87	4·0	13,968	14·46	11·34	8·13

2. There are no ashes or clinkers, and consequently no fires to clean, with the accompanying loss of heat and drop in the steam pressure. The steam pressure and revolutions of the engines being maintained at one point throughout the voyage.

3. The boiler tubes are always free from soot and clean, and therefore always in the best condition for transmitting the heat from gases passing through them to the water of the boiler.

4. The temperature of the escaping gases may be considerably lower than is required to create the necessary draught for coal firing. With coal, the air has to be drawn through the bars and the fire in the furnaces; by natural draught this requires a temperature of the escaping gases about 600 degs. to 700 degs. Fahr. But in the case of liquid fuel there are no bars or thick fire for the air to force its way through, and the required amount of air can be drawn through the furnaces by a much lower uptake temperature—about 400 degs. to 450 degs. Fahr. being in most cases sufficient.

5. The admission of air to the furnace being under complete control, and the fuel being burnt in fine particles in close contact with the oxygen of the air, only a very small excess of air above that actually necessary

for the complete combustion of the fuel is required. With coal, in order to ensure as complete combustion as possible, a very much larger excess of air is required.

In addition to its higher calorific value, liquid fuel has many other advantages, especially on board ship.

Stowage.—A ton of coal will occupy about 45 cubic feet of bunker space, and a ton of oil will require about 40 to 45 cubic feet. Assuming that both coal and oil will require the same bunker space per ton, then, since one ton of oil fuel is equal to two tons of coal, the bunker space necessary to steam the same distance at the same speed is only one-half. In addition to this, there is no lost space caused by the projection of frames, stringers, or beams. Also, portions of the ship which, if used as coal bunkers, would be inaccessible can be utilised for the stowage of oil.

Trimming.—This is altogether dispensed with, the oil being run or pumped into the fuel tanks through a deck connection, and beyond the opening and closing of the distributing valves no other attention or labour is necessary for the shipment of the fuel; this makes a considerable reduction in the labour cost and the time occupied. When at sea the oil either gravitates to the furnaces, if the tanks are above them, or is pumped up if below, and no trimmers are required.

Stoking.—The sprayers require very little attention after they are once adjusted, and one man can attend to a large number of furnaces, and there being no ashes or dirt to remove the stokehold staff can be reduced to a single man for each watch in any ordinary vessel, or in a small vessel the sprayers can be attended to by the engineer on watch in the engine room, as is done in many of the vessels on the Caspian Sea.

There are also no firing tools to repair, or firebars and floor plates to

Figs. 2 and 3 (Plate XX.).—The pan furnace of Biddle used in North America in 1862.

Fig. 4 (Plate XXI.).—Richardson furnace, patented in 1864. The bottom of this furnace is covered with ordinary slacked lime, which is kept saturated with the oil to be burned.

Fig. 4*a* (Plate XXII.).—Audouin furnace, first tried in 1865, consists of a large number of small tubes, from which the oil is constantly dripping, and is carried into the furnace and burnt by the draught through the openings in the front.

The furnaces of St. Claire-Deville, 1868, Wagenknecht, 1870, Kamenske, 1869, MacKine, 1865, Verstraët, 1868, and Paterson, 1878, are all similar to one or the other of the above furnaces. The defect in all these is that the air is not brought in close contact with the burning fuel, with the result of imperfect combustion, accompanied by dense black smoke.

2. Fig. 5 (Plate XXII.) illustrates Shaw and Linton's gas furnace, patented in America in 1862.

Fig. 6 (Plate XXII.).—Dorsett and Blythe gas furnace, tried in England in 1868 on board the steamer "Retriever." It may be observed that the disadvantage of all gas furnaces is that when using heavy residual oils the tarry deposits rapidly stop up the passages and pipes.

3. The furnaces into which the fuel is sprayed can be divided into three distinct classes :—

a.—Flat slit sprayers.

b.—Sprayers in which a jet of steam or air meets a jet of oil at an angle.

c.—Circular sprayers.

a.—Flat Sprayers.

Fig. 7 (Plate XXII.) shows the first sprayer, which was constructed by Lenz in 1870, who commenced experimenting with oil as a fuel in 1868.

Fig. 8 (Plate XXIII.) shows the later form of Lenz sprayer.

Fig. 9 (Plate XXIII.).—Korting's flat-mouthed sprayer of 1872.

Fig. 10 (Plate XXIII.).—Artemeff sprayer, 1878. A large number of these sprayers are used in ships on the Caspian Sea and the Volga.

Figs. 11 and 12 (Plate XXIV.).—Karapetoff sprayer, 1880.

Fig. 13 (Plate XXIV.).—Brandt's flat sprayer, 1880. The opening for both steam and oil in this sprayer are circular; it was designed for use in locomotive boilers, and was placed in the centre of the firebox at the level usually occupied by the firebars.

Fig. 14 (Plate XXIV).—Bloomer and Korebutt-Dachkeveich, 1886.

Fig. 15 (Plate XXV.).—Kauffmann's flat sprayer.

Fig. 16 (Plate XXV.).—Chippournoff's sprayer.

Fig. 17 (Plate XXV.).—Berseneff's sprayer, 1891. This very much resembles Brandt's sprayer (Fig. 13), with the addition of a second steam opening.

b.—Jet Sprayers.

Fig. 18 (Plate XXV.).—The sprayer of Wise, Field, and Aydon was patented in 1865, and is one of the oldest methods of spraying fuel oils. It was first used on a Cornish boiler in 1866 in South Lambeth. Admiral Selwyn also experimented with this sprayer.

Fig. 19 (Plate XXVI.).—Aydon and Selwyn, 1867. This sprayer was tried by the Admiralty in 1868 at Greenwich, heavy tar oil being used as fuel and the steam superheated.

Fig. 20 (Plate XXVI.).—Benkston, 1874. This sprayer consists of two pipes flattened at one end, the oil pipe being bent over, and is the most simple form of sprayer.

Fig 21 (Plate XXVI.).—Korting, 1876. This sprayer shows an attempt to carry in air with the steam jet before it reached the oil jet, but the spraying was found to be imperfect. Since 1886 Korting has used a sprayer very closely resembling that of Aydon and Selwyn (Fig.19).

Dickey's jet sprayer, 1878, is illustrated in the paper by the late Mr. B. G. Nichol.

c.—Circular Sprayers.

Fig. 22 (Plate XXVI.).—Spakovski, 1870. This sprayer was fitted to the boilers of the steamship "Ivan," on the Caspian Sea, in 1870.

Fig. 23 (Plate XXVII.).—Lenz, 1872.

Fig. 31 (Plate XXIX.).—Dunder's sprayer. The steam and oil passages in this sprayer it will be noticed are reversible.

Fig. 32 (Plate XXX.).—Stewart and Farmer, 1894. This sprayer is constructed for the use of compressed air.

Fig. 33 (Plate XXXI.).—Rusden and Eeles, 1896.

Several attempts have been made to spray the oil by other means than that of the steam jet, in order to overcome the difficulty of making up the fresh water drawn from the boilers in the form of steam.

Air under pressure, especially if heated, has been found to give good results, but the flame is shorter, giving a more intense heat for a short distance than the flame from a steam sprayer. More air than steam is required for the spraying of the oil, and the air jets are more noisy than the steam. The danger of an explosion of oil gas in the furnace and combustion chamber when lighting up, especially if the furnace has been stopped for a short time only, is very much greater with air than with steam sprayers.

Comparing the economy of air and steam sprayers (notwithstanding the drawback of having to make up the water lost in steam used by the sprayers), the steam sprayers appear to be the most economical, and are certainly the type mostly in use. The arrangement of the whole of the steam sprayer installation is exceedingly simple and not liable to derangement or breakdown, whereas the compressed air system is complicated and the risk of breakdown increased by the addition of the air compressor.

The essential requirements in a sprayer are :—

1. The oil and steam openings must be so arranged that the oil can be sprayed in the finest particles possible.

2. The steam consumption of the burner must be as low as possible.

3. The sprayer must be constructed in such a manner that it can be easily and quickly taken apart for cleaning and quickly replaced.

4. The noise should be reduced to a minimum.

During the writer's experience and tests with a large number of sprayers, he has found that the "Rusden-Eeles" sprayer (Fig. 33, Plate XXXI.) conforms more nearly to these requirements than any other. The spray is very fine; in fact, with astatki the flame can be regulated so as to have the appearance and character of a gas flame. The steam consumption is low, and the construction allows it to be quickly and easily cleaned.

In the latter sprayers the blow-through cock, shown in Fig. 33, is omitted, it being found easier and more effective to take the tube out and clean it than to blow the oil space through with the steam.

Fig. 34 (Plate XXXII.) shows the arrangement of the complete installation as applied to a two-furnaced marine boiler.

In arranging an installation, the principal points are: (1) the superheating of the steam; (2) ample area in the fuel pipes, especially if heavy oil is used, and in the case of very heavy oils they may be required to be heated; (3) the supply tank should be placed in such a position as to ensure a constant and steady supply to the burner.

Brickwork in the furnaces should be arranged in a manner so as to ensure the complete combustion of the fuel in the furnace, and to prevent the too rapid cooling of the furnace after the flame is extinguished.

In some cases, where the boiler is placed in a confined space, or there is not height enough to obtain a steady pressure on the burners from the supply tank, the oil may be pumped direct to the burners if a controlling valve is connected to the steam pipe of the pump; a valve of this character is illustrated in Fig. 35 (Plate XXXIII.). This valve will regulate the speed of the pump automatically, and maintain a constant pressure in the oil supply pipes, no matter how many sprayers may be in use.

In relighting a furnace which has been extinguished for a short time lies the greatest danger of explosion of oil gas and the accompanying back flash from the furnace doors. Any small leakage or drip of oil finding its way into the heated furnace gasifies and forms an explosive mixture with the air, and if the lighting-up torch is introduced into a furnace under these conditions an explosion is sure to take place, and the person introducing the torch is very possibly burnt. Before lighting a furnace, it should be well blown through with steam, and care taken to see that the steam jet is open first and the torch placed in the furnace average data from some experiment with a Rusden and Eeles sprayer, and a heat account from the same data :—

Kind of Liquid Fuel.	Russian Astatki.
Specific gravity	·9
Chemical analysis (approximate) :—	
Carbon	87 per cent.
Hydrogen	12 ,,
Oxygen	1 ,,
Temperature of stokehold	60° Fahr.
,, escaping gases	450° ,,
Weight of steam required to spray 1 lb. of oil ...	·3 lbs.

Assuming that the air contained 23 per cent. of oxygen, and that the excess of air over that required for complete combustion passing into the furnace was 20 per cent., which would be about correct, because the slighest reduction of air caused smoke to issue from the chimney.

		Heat Units.		Equivalent Evaporation from and at 212° Fahr.
Total heat from combustion of 1 lb. of oil—				
Carbon ·87 × 14,500	=	12,615		
Hydrogen ·12 × 62,032	=	7,444		
			20,059	20·7
Heat lost in waste gases at 450° Fahr.—				
Carbonic acid gas	3·19 lbs.	269		
Nitrogen	10·72 ,,	909		
Water vapour from combustion ...	1·08 ,,	1,452		
,, ,, sprayer ...	·30 ,,	29		
Surplus air, 20 per cent.	2·78 ,,	257		
			2,916	3·0
			17,143	17·7
Heat lost in radiant heat, etc.			1,687	1·7
Heat absorbed by water in boiler			15,456	16

In addition to the firing of boilers, liquid fuel has been used for various other purposes. Mr. Urquhart, in his paper before the Institution of Mechanical Engineers, shows how he has successfully applied it to scrap welding furnaces.

Fig. 36 (Plate XXX.) shows its application to a smith's hearth.

Fig. 37 (Plate XXX.) shows it applied to a brass melting furnace. It will be observed the furnace has two flues leading from it, one carries off the products of combustion and the other the fumes given off from the molten metal; this forms a convenient method of recovering a valuable bye-product.

A furnace, with an arrangement somewhat similar to Fig. 1 (Plate XX.), has been used for the melting of wrought iron for the production of Mitis casting, the temperature of the furnace being about 4,000 degs. Fahr.

In conclusion, the writer expresses his indebtedness to the works of Gulishambaroff, Carew, Brayley Hodgetts, Col. Soliani, Urquhart, and many others, for a great deal of the matter contained in this paper.

DISCUSSION.

Mr. G. D. Weir said he was sure they all felt deeply thankful to Mr. Wallis for his very interesting and able paper. It appeared to him to supply a long felt want among engineers, some of whom had a very hazy notion as to what sort of a machine an oil burner was, or if perchance they had examined the construction of some oil burners that were illustrated in the plates that were attached to Mr. Wallis's paper, which, perhaps, few of them present ever thought were in existence. The second paragraph on the first page of the paper seemed to be one of the points which it would be well to thoroughly ventilate, and he should feel extremely pleased if any member or friend present, who had practical experience in the running of ships using liquid fuel would give the result of such experiences. For himself he felt that anyone having read or listened to Mr. Wallis's paper would think that it was high time vessels crossed the Atlantic with their bunkers full of oil instead of coal, and only a slight grey-coloured gas rising from their funnels in place of the dense volumes of jet black smoke which they so often saw, and the problem of the smoke nuisance solved for ever. But would this state of affairs ever come to pass? He hardly thought so, and they might almost take for granted that they never would so long as the relation between the price of coal and the price of oil remained as at present, even if they

[redacted]

8s. 6d. per ton, for the same money, and they got theoretically for the same money value 19,832 units of heat from the oil, and 57,728 units of heat from the coal, or if they turned to the end column of Table II., they could evaporate for the same cost twice as much water by using coal than if they had used oil, on condition that they bought the fuel in this country.

TABLE III.

Coal.	£	Oil.	£
600 tons of coal at 8s. 6d.... ...	255	300 tons of oil at 34s. per ton ...	510
6 men at £4 per month	24	2 men at £6 per month	12
Repairs to fire tools	10		
	£289		£522
	372	300 tons of cargo at 10s. per ton...	150
Gain by using coal	£83		£372

In Table III. were figures showing the amount of money which it would cost to run sister vessels, say with engines indicating 1,200 to 1,300 horse-power, one of the vessels fitted to burn oil as fuel, and the other to burn coal.

He had taken as an average consumption 20 tons of coal per day, and he had for the sake of argument taken the duration of the voyage from the United Kingdom to be, say, thirty days or one month. He took Mr. Wallis's figures, viz., that it required twice the weight of coal compared with oil to give the same amount of steam, and as Mr. Wallis in his paper takes account of the cost of repairing fire irons, etc., he (Mr. Weir) had debited the vessel burning coal with £10, which he thought was an ample allowance. From these figures they saw at a glance that the vessel using the coal was by far the less costly to run. He had not taken any account of the amount of fuel required for raising steam, nor of the amount of steam which would be used to drive the donkey for pumping the oil, so that the method of comparison was practically in favour of the oil, if anything. Perhaps, also, Mr. Wallis could say if the premium for insurance would be greatly increased in the vessel using oil, owing to the combustible contents of her bunkers. He should also be glad if Mr. Wallis could tell him if the wear and tear on the boilers was not greater when using oil than when using coal, owing to the intense heat concentrated in a practically small part of the furnace; and regarding this latter question he understood that there was a great deal of brickwork built into the furnaces, and perhaps Mr. Wallis would favour them with a sketch showing the method of arranging the brickwork, which he had found from his experience to give the best results. Of course, he did not wish it to be understood that it was not considerably cheaper to run vessels with liquid fuel when they were trading on, say, the Caspian or Black Seas, or even where vessels were trading regularly between such ports where the price of liquid fuel was less than the price of coal or even if the price of oil was 60 per cent. greater than coal; then in such cases it would be found more economical to use oil, but unless the relative prices of the two fuels underwent a very considerable change, he did not think that they should ever see oil as fuel adopted by shipowners in this country. If, however, they turned from the stokehold of steam vessels and went to some of the large ironworks in the world, he thought that at no very distant date they should find petroleum displacing coal. Some time ago when looking into this question he came across some very interesting statements, which perhaps would be of interest to them. At Woolwich, under ordinary circumstances, the armour plate bending furnace was lighted some four or five hours before the plate was put in, the time occupied in heating the plate for bending depended upon its thickness, one hour per inch of thickness being allowed. Taking a 6 inch plate, they got from ten to eleven hours from the time of starting till the plate was ready for bending. Let them now see what liquid fuel would do. The cold furnace was lighted, and after one hour it was found to be sufficiently heated, and a 6 inch armour plate, 7 feet 6 inches by 3 feet, was put in the furnace, and after one hour or an hour and a half it was ready for bending. Thus in two hours and a half they had the work of ten or eleven hours completely and satisfactorily performed. Nor did the advantages of this system stop there. The plate was remarkably free from scale, which could only be accounted for by the absence of the deterioratory influence of the products of combustion in the ordinary furnace. As proof of this it was said that

TABLE IV.

	Lbs.		Lbs.
Total amount of iron in furnace	26,378	Iron put in scrap furnace ...	7,950
Amount taken out after being rolled	24,524	Taken out...	7,751
Loss	1,854	Loss	199
Loss in same amount of iron in coal furnace	2,901	Loss with coal	1,192
Saving in iron by using gas ...	1,017	Saving by using oil gas as fuel...	993

operation was less than one-half of that required by the ordinary method when using coal, and besides the economy manifested in these instances, the cleanliness and freedom from smoke and cinders were important considerations.

In conclusion, it must be conceded by everybody that, weight for weight, petroleum was a more valuable fuel than the best coal ; but it could only be used in competition with coal when the value in £ s. d. of the manufactured article more than counterbalanced the difference in the price of the two kinds of fuel ; and for steam raising in this country, he thought coal would always hold its own.

Again, he thanked Mr. Wallis for his interesting paper.

Mr. E. W. DE RUSETT said he would like to ask the author a few questions. Could the oil be carried in the ordinary double bottom of the vessel ? Also, would there be any danger of the oil firing ? Was it necessary to make any special provision to prevent such an accident ? Could Mr. Wallis also tell them what the flashing point would be of this crude oil ? Another question he would like to ask was, whether, in the comparisons of the work done by oil and coal, the amount of power absorbed in the evaporator in making up the steam used in spraying the oil was included ? for a large amount of steam was necessarily used for this purpose, viz., ·3 lb. of steam to every 1 lb. of oil consumed.

Mr. J. H. HECK said he had listened to Mr. Wallis's paper with a good deal of interest and attention. He thought the paper was a very good one, and an addition to the literature on the subject. He had not had very much experience in the use of liquid fuel ; but had paid a good deal of attention to the transport question. While it was true, as Mr. Weir said, that oil could not at its present price compete with coal, there was no knowing what they might get in the future owing to the rapid development in new oil-fields. If the supply ever increased to a great extent, then he thought the amount of information given in the paper would be valuable. He believed the total production of petroleum per annum in the world was about 8,000,000 tons, and the oil refuse only about 2,000,000 tons, while the output of the world's coal was 400,000,000 tons. The quantity of oil produced, even if they used it all, would hardly be enough for the steamships at present in existence. Petroleum was too valuable as an illuminant to be used for fuel, and there were only some countries where it could be used for steamers. As to the use of liquid fuel he could say there was no danger in using astatki or even crude oil, if suitable arrangements were made. There was one thing he should mention. In the past he believed they had over-estimated the dangers that attended the transport of refined oil, and at the same time under-estimated the danger and attention required in carrying crude oil. He wished to express his thanks to Mr. Wallis for his very valuable paper.

Mr. C. J. Seaman said he had heard that the great difficulty with any oil burner was to keep it clean. Could Mr. Wallis tell them what was the best way to clean burners? He noticed between the lines of the paper a hint not to blow the steam through the burner, but rather to take it out and deal with it in some other way. With the ordinary Wells light he had found it difficult to keep the burner clean. Perhaps Mr. Wallis might enlighten them on that matter? As one of the advantages of oil Mr. Wallis claimed that the boiler tubes were always free and clean, and therefore always in the best condition to transmit the heat from the gas to the water in the boiler. He (Mr. Seaman) had expected lamp black and spray being part of the difficulties of oil burning, and was rather pleased to find he was mistaken. With reference to the statement that there subject. He might say that twelve years ago, when manager with Messrs. Wigham Richardson & Co., he fitted up three steamers for the Caspian Sea that were to be fueled by oil. They received the drawings in the usual way, and he must confess he was a little confused at first how to go about the work. The furnaces was lined with bricks. He could not quite remember what class of burner they were using, and he could not say whether the steam or the oil was at the top. At the first trial they had the usual commotion, with a certain amount of fear in the stokehold when the thing had to be lighted; he opened the tank valves and the steam valves, and away went the oil for 2¼ hours; but they got nothing but huge volumes of black smoke. Everyone was surprised. They could have got steam up with coal in half the time. But as soon as the bricks got into a white heat, they saw through the peepholes the smoke diminish, and things went all right. He had the data of the evaporation trials at home. The name of the first steamer, he thought, was the "Flora;" she went out to the Black Sea, and he heard nothing more about her. They fitted up two after that, and he believed they were greater successes than the first. The tanks were fitted above the boiler. They had a large tank on the lower side of the boiler, a storage tank, with a small donkey engine fitted to keep up the supply. The difficulty they had was to keep the burners clean. That was overcome by a universal joint, as it were; and when one was supposed to be blocked up they took it off, cleaned it out, and put it back in its place.

The PRESIDENT—What kind of oil did you burn?

Mr. WHITFIELD—Crude oil, brought purposely from Russia. The vessels were for the Black Sea, and the stuff was brought over for the experiment.

Mr. WEIR—Could you give us the exact date of what was probably the first experiment, to be included in the *Transactions?*

The PRESIDENT—And the dates of the trials?

Mr. WHITFIELD—Yes; I can get them quite easily.

Mr. H. FOWNES confessed that he knew little about oil burning; but one of the advantages of an institution like this was that papers were read which raised an interest in questions that the majority of them possibly did not know much about. It led them to think about the subject and apply the information to their own business. He had nothing to do with burning oil in steamers; but he had in the matter ventilated by Mr. Weir —the saving of iron shown in Table IV., page 143. The saving of iron, or any other material in course of manufacture, was an important matter. Still, it did not amount to a great deal from what appeared on the face of it, for in the manufacture of iron there was 40 per cent. of waste from the scrap to the manufactured article: take that at 50s. the ton, it came to 20s. according to that table. He saw they saved 10 per cent. of that waste by using oil fuel, which would mean a saving of 2s., so it would require a very considerable saving in other ways to make up for coal; and as Mr. Weir had kindly offered before the next meeting to let them have a sketch of this furnace he was sure to those, such as himself, engaged in that particular business, it would prove of interest, and one they should certainly study with a view to economy in their manufacture.

Mr. J. M. Rennoldson thought they might in South Shields congratulate themselves upon having such an interesting subject treated as they had that night. He did not know that they, as north countrymen, would be likely to congratulate themselves upon the discovery of any system by which liquid fuel would supersede the burning of coal, although they were told from time to time by various prophets that the days of their coal supply were numbered. He did not think it would happen in this generation, nor yet in the next. So far as they were personally concerned they had not much to fear. The time might come when the production of oil would be very much greater than coal, and, consequently, cheaper than coal. When that day came there was no doubt that this balancing of accounts, these comparisons, would be very greatly statement they could all endorse, for, with the exception of one or two firms on the river, no one in marine engineering had had much to do with the carrying out of liquid burning furnaces. Such an explanation, therefore, of the diagram would make the paper more interesting and intelligible generally. He hoped Mr. Wallis would be able to do something to clear up this point. He must thank Mr. Wallis for the very great trouble he had taken in the preparation of this paper; it was one of intense interest and certainly great satisfaction to them at that meeting.

Mr. F. W. GARBUTT said there had been a question raised whether it was safe to use crude oil or astatki. He had been in Russia for the last two years, and had supplied most of the fuel oil to the Northern Caucasus Railway Company, who have over 250 locomotives at work. During the last year they had carried out a great many exhaustive experiments; also the Italian and German navies, and from the result of these trials they had come to the conclusion that it was not advisable to use oil fuel under a flashing point of 130 degs. C. = 266 degs. Fahr.—and crude oil had a flashing point usually under 50 degs. C. = 120 degs. Fahr.—and North Caucasian crudes of ·870 to ·878 specific gravity. Flashed below zero, mazoot or crude oil which had been exposed in open reservoirs long enough to allow the lighter and more volatile substances to evaporate was, however, mostly used on the Russian railways and Caspian Sea for fuel and lubricating purposes with very good results, and it was found after an exposure of about three months to have a flashing point of 235 to 245 degs. Fahr. He quite agreed that oil fuel would never entirely take the place of coal in England, although the supply from Russia was almost unlimited, as the extra cost and transport charges debarred the use outside the limits where a regular and cheap supply could be obtained. He had been negotiating with the German government, who had replied that, although they were highly satisfied with their experiments and the adoption of oil fuel, they could not leave themselves dependent upon a foreign country for the supply of fuel for their navy.

Mr. J. H. HECK said with reference to the use of crude oil as fuel, they could use it quite safely on a plan suggested by an English engineer residing in Italy. He (Mr. Heck) believed that gentleman was connected with some of the experiments made by the Italian government. If his system were adopted it was impossible to have an explosion in the oil bunkers, and that was simply always to keep the oil bunkers completely full. The way to ensure this was that as the oil was used for consumption to allow water to go in, and so keep the oil bunkers completely full.

Mr. Garbutt said he referred only to the use of oil in locomotives, not for marine boilers.

The President said he was afraid they would have no option now but to postpone consideration of the paper till the next meeting, at West Hartlepool, on 13th March. The subject was one which bristled with points of interest. To him it was especially interesting, as he had paid very great attention to everything concerning the carrying of petroleum and the burning of it, and there were a great many points which had not been touched upon, but which had an important bearing upon the subject. The comparison in Mr. Weir's table was taken with coal at 8s. 6d., that was the price of coal at their own doors, and probably did not even include getting them into the bunkers. Even in London the price of coal would be very different from that; but going further afield, as Mr. Rennoldson remarked, the further from the coal supply and the nearer the oil supply, so would the advantage come in, and for war purposes, he believed, there was a great future in oil burning. One way in which it could always be utilised was for the smaller class of torpedo boats. There was a difficulty in coaling them at sea, but in time of war there would be no difficulty in having a large tank steamer anchored in a known latitude and longitude where these vessels could go and get a supply of oil fuel at any time without going to port for coals. Moreover, the transfer of oil from the supply steamer to the small vessels through pipes would be much more easily accomplished in a seaway than would the handling of coals. This was merely one incident in the matter. However, at their next meeting he hoped they would have a number of questions asked on this subject.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896-97.

PROCEEDINGS.

SIXTH GENERAL MEETING OF THE SESSION, HELD IN THE ATHENÆUM, WEST HARTLEPOOL, ON SATURDAY EVENING, MARCH 13TH, 1897.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in South Shields, on February 10th, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. R. Harkness and G. Jones to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Brigham, Robert F., Engineer, 72, Linskill Terrace, North Shields.
Carney, J. H., Engineer, Messrs. Mordey & Carney, 48, Mount Stuart Square, Cardiff.
Clarke, Harry, Lloyd's Engineer Surveyor, 23, West Parade, Newcastle-on-Tyne.
Dale, John, Engineer, 26, Whitehall Terrace, Hylton Road, Sunderland.
Edwards, Guy W., Engineer, 89, Holly Avenue, Newcastle-on-Tyne.
Garbutt, Frederic W., Consulting and Marine Engineer, Messrs. Eeles & Garbutt, Hansa Haus, Hamburg.
McLean, John H. K., Dry Dock Manager, 3, Windsor Terrace, South Shields.
Orr, John, B.Sc., Engineer Draughtsman, 2, Albany Terrace, Whitley, Northumberland.
Scott, Walter, Naval Architect, Jamesfield Villa, Glasgow Road, Dumbarton.
Scurfield, George G., Engineer, 15, Nelson Street, Sunderland.

GRADUATES.

Fleet, Herbert A., Engineer, Coney House, Birtley, Durhamshire.
Routledge, Herbert J., Electrical Engineer, Stapleton House, Jarrow-on-Tyne.

ADJOURNED DISCUSSION ON MR. A. E. SHARP'S PAPER ON "THE RESISTANCE AREAS OF TRANSVERSE SECTIONS."

Further discussion was invited on Mr. A. E. Sharp's paper on "The Resistance Areas of Transverse Sections;" none, however, being offered. Mr. Sharp, moreover, was not present to reply.

The SECRETARY said he had written to Mr. Sharp, but had got no response; he might be away from home.

The PRESIDENT said that at the last two meetings Mr. Sharp's paper was criticised in a very intelligent way by some of the speakers, and he thought the feeling was that the criticisms did away with a good deal of the value of the paper. Two letters had been written to Mr. Sharp asking him to be present that evening, and no reply had been received, but meanwhile they could only record the fact of his non-attendance, and therefore if no one had anything further to say on the paper they must consider the discussion upon the paper closed.

ADJOURNED DISCUSSION ON MR. R. WALLIS'S PAPER ON "LIQUID FUEL."

Discussion was invited on Mr. Robert Wallis's paper on "Liquid Fuel."

The SECRETARY read the following communication on the subject from Mr. L. Rusden, Newcastle-on-Tyne, who regretted his inability to be present :—

NEWCASTLE-ON-TYNE,
March 12*th*, 1897.

DEAR MR. DUCKITT,

I am very much indebted to the writer of this paper for the kindly reference to the oil burners that I am intimately connected with. Although oil burners of a different type were made long before the writer of this paper had anything to do with them, it was not until Mr. Alfred Suart gave the order to fit the s.s. "Baku Standard" for burning oil as fuel that serious attention was given to using oil in place of coal on English-owned steamers. The s.s. "Baku Standard" was the first steamer fitted for burning liquid fuel that crossed the Atlantic, and the result of the trial was anxiously awaited by many, as doubts were expressed about the use of this fuel as being unpractical. However, the use of liquid fuel in the s.s. "Baku Standard" was a marked success, and the owner (Mr. Alfred Suart) may be congratulated on the result; but, like many other things, owing to the exigencies of the trade, it had to be abandoned. If oil fuel could be supplied to meet the demands, and could also be secured at a reasonable price, we should then begin another era in ocean steam navigation. The saving of oil fuel will be very considerable as compared with coal, more especially regarding labour and cleanliness, but I am afraid the day is far distant when oil will supersede coal, though on the Caspian Sea and district immediately surrounding it for some years have been using liquid fuel. The boiler for burning liquid fuel needs to be specially designed for economical results, although it can be used in an ordinary boiler. For instance, a boiler containing a certain number of square feet of heating surface requires to be less in diameter and of a greater length for using oil fuel than for coal, the furnaces and tubes being proportionably smaller. The brickwork in the furnace also needs careful attention. After the oil burner has been under-way the brick arch built inside the furnace serves not only to break the force of the injected oil, but it serves in its heated state to assist the combustion, and to prevent too rapid cooling of the furnace when burners are put out. The heat being more uniform around the furnaces, the fire-bricks at the bottom cause a better circulation in the boiler. The writer of the paper has had considerable experience of the use of oil as fuel, he having carried out all the experiments with the oil burning for the firm he so ably represents.

Yours faithfully,

L. RUSDEN.

Mr. J. R. FOTHERGILL said that Mr. Wallis's paper treated upon a subject of very great interest. The consumption of liquid fuel instead of coal for general use in steamers had been frequently advocated, and no doubt was in certain districts, such for instance as the Caspian Sea, most advantageous, but there were considerations in its general application to steamers trading from this country which prevented its use. He apprehended there would be some difficulty in carrying petroleum in bulk. Mr. Wallis proposed utilising the present bunkers, but he was afraid it would be found a very difficult matter to make the bunkers absolutely tight.

Mr. R. HARKNESS—Not at all.

Mr. FOTHERGILL said he deferred to the experience of Mr. Harkness, and was glad to hear such was the case. Possibly it might be more advantageous to use the ballast tanks in preference to the bunkers. There was of course no question as to the greater evaporative efficiency readily vaporise or gasify petroleum oil, such vapour could be burnt to the best and highest evaporative efficiency, but they would be dealing with an article that was very dangerous, almost as explosive as gunpowder, and when dealing with it in large quantities, such as would be required for marine consumption, it was exceedingly dangerous and to be avoided. Experience proved that spraying was the most practicable and applicable to marine boilers. Mr. Wallis also classed under three heads various methods of spraying. In deciding the class of sprayer, consideration must be given to the kind of oil to be used. Although for marine purposes the use of steam might be objected to, yet there was one great advantage in using high-pressure steam, and particularly when superheated, that compressed air did not offer. Steam under such conditions had the power of breaking up the oil—it literally pulverised it—to the greatest advantage and efficiency in combustion; and there was another important feature in connection with the use of steam, and that was that it very materially reduced the carbonised deposit, which, under ordinary circumstances, formed on the lips of the sprayer, choking it up. When air was used in the sprayer instead of steam, it was productive of greater local heating, certainly to be avoided. Many users of petroleum found it necessary to introduce heavy brickwork to prevent damage by intense local heating, but such brickwork, particularly in a marine boiler, was an objectionable feature, and to be avoided when possible. Some eight or nine years ago, he fitted to a steamer having two single-ended boilers, an apparatus to supply vaporised petroleum through tubes in the back of the boilers direct into the combustion chambers, in conjunction with his system of forced draught. An illustration, showing a part of this arrangement, was given at the end of the paper on "Combustion," etc., which he read before the Institution, November, 1892. Petroleum oil passed from a closed reservoir in an elevated position through a coil in the uptake or funnel, where it was gasified or vaporised by the heat of the waste gases, and under its own pressure entered the combustion chamber at considerable velocity, in combination with air supplied under pressure. For this purpose refined petroleum had to be used, as refuse petroleum would have given a carbonised deposit in the vaporising pipes and soon have choked them up. Petroleum was a mechanical combination of several oils whose specific gravity varied considerably, and likewise their evaporative temperature: this had a strong bearing upon vaporising in pipes, and materially added to the danger in using such vapour. For instance, the slightest joint leak gave a gas which immediately fired, and it was extremely difficult to make and maintain tight joints under petroleum vapour under pressure. Scientifically and mechanically, petroleum as a fuel was a perfect success, but the whole question resolved itself into a commercial question, and he failed to see that it was possible to use petroleum instead of coals in the number of steamers trading from this country. Petroleum could not in this country be bought at a price that would compete with coal, and if there was any great demand for it the price would enormously increase, although there was abundance of oil in many parts of America and Russia. In conclusion, he begged to thank Mr. Wallis for his paper, which he thought was one of value to the Institution.

Mr. J. DUCKITT (Secretary) explained that at the last meeting Mr. Weir was asked to submit a drawing of the furnace to which he alluded in the manufacture of iron, following upon a question by Mr. Seaman. Mr. Weir had not been able to prepare the drawing for that meeting, but a sketch of it would be found in a paper read by Harrison Aydon before the Institution of Civil Engineers in 1878, and included in vol. 52 of the *Transactions* of that society. Mr. Whitfield also was asked for details of some experiments with liquid fuel steamers. He found it impossible to be with them that evening, but he (the Secretary) hoped to receive the promised details at a later period, when they would be included in the *Transactions*.*

MR. WALLIS'S REPLY.

Weir's £24; the repair of fire tools, if it were worked out, would come out rather more than the £10—£15 per month would be more like the figure—a total of £405. Take Mr. Weir's price for oil, etc., £524; then they made on 300 tons of extra cargo at 10s. a ton, £150, which gave the comparative cost, £374—a difference of £31 per month in favour of oil burning.

Mr. Fothergill—But if oil was used, the price would go up to double its present cost.

Mr. Wallis—They were dealing with things as they were; but the whole question of cost of oil and coal depended upon where the ship was trading. If the ship was trading to a port where oil could be obtained, then, undoubtedly, the oil was cheapest; if the vessel was trading from such a country as England, where coal was cheap, then, in the present state of supply and cost, coal would be the cheapest without any doubt. Mr. Weir mentioned the amount of steam required to drive the donkey for the service. He thought he would find if he tested one of these donkeys that the amount to drive it would be so small as to be practically neglected, for the donkey all through would exhaust to the condenser, and a very small quantity of steam would suffice to drive it—merely the vacuum in the cylinders. The matter of insurance was another question raised in connection with the carrying of petroleum in place of coal. He (Mr. Wallis) did not think, when the whole thing settled down, that would be greater than at present, for the fear of explosions from oil gas was not so much to be dreaded as might be imagined. The character of the oil which was used as a fuel was one with a very high flash point, and consequently the amount of gas generated from oil of this character was very small. Members would see the differences in the specimens on the platform. Wear and tear of the boilers was another question raised; but wear and tear with liquid fuel was less than when using coal, for, when using the sprayer, the heat generated in the furnace was a constant one, and the amount of air admitted was only slightly above that required for combustion, and there was no cooling down of any part of the furnace by the opening of fire doors as there was in the coal system. Then the wear and tear on the boiler would be less than that of coal. The arrangement of the brickwork was raised by Mr. Weir and several other gentlemen. Well, the arrangement of brickwork depended to a great extent upon the size of furnace they were using and also the character of the boiler. Mr. Urquhart, in his paper before the Institution of

Mechanical Engineers, described several methods of brickwork as adopted in locomotives, and the Baldwin Company, of America, showed several forms of brickwork in locomotive work. He found the brickwork did not vary very much from that of the ordinary brick arch, with the exception that it had an additional wall. In the case of the ordinary marine boilers, what was required was to place the brickwork so as to baffle the flame and prevent it striking through to the combustion chamber. The exact pattern of that brickwork would vary under various circumstances and special requirements of any particular boiler. The lining of the bottom of the furnace enabled the circulation at the bottom of the boiler to be improved, and at the same time, if their burner was working badly, any drop of oil not sprayed fell quite finely on the bottom, it was at once burnt on the hot bricks, without which they would have an accumulation of coke on their furnace bottom. Mr. De Rusett asked if the oil could be carried in the ordinary double bottom of a vessel. He did not see any reason why it should not, and one vessel which they had fitted with oil-burning appliances went out to Peru and carried her bunkers in the double bottom. As far as he could learn they found no disadvantage or trouble in that arrangement. Mr. De Rusett also asked the question as to the flashing point of crude oil. It varied considerably. They might get it as low as 30 or 40 degs., or it might go up to 400 or 500 degs. It depended upon where the oil came from and the density of any particular well. He also asked about the power absorbed by the evaporator in making up the water lost in steam for the sprayers. The loss of water in the boilers was not a great deal if, as recommended by a great many people, the vapour from their evaporator was carried to the hot well and they used their evaporator practically as a feed-

[redacted]

gas. Using commercial petroleum would, he dared say, some day or other, cause an explosion. There would be some danger attached to it, but evaporating petroleum refuse would possibly work out all right as long as their appliances kept free from heavy tar deposit and carbon, which would inevitably follow, the apparatus would then get clogged up, and the trouble would be to clean it. In some experiments they tried evaporation—partial evaporation—sufficient to make gas to drive their burners in place of steam, and as far as their experiments went it was successful, but it was not a thing he should like to go to sea with; the whole thing got uncomfortably hot, there was the trouble with the tarry deposits, the oil they were using was a heavy oil to commence with, and there was always a tendency, with a tarry heavy deposit, to form coke in the furnace. The effect of high-pressure steam was mentioned by Mr. Fothergill, and was very clearly evidenced in their experiments. The cubic capacity of air required to spray a given quantity of oil they found very much greater than the cubical capacity of steam to do the same work. The steam seemed to pulverise the oil easier and more perfectly than air, and that was what led him to make the statement he did in the paper, that the amount of air required to spray oil was very much more than the amount of steam; consequently, when using compressed air, the air compressing plant, with a steamer of any dimensions or any number of boilers, would be considerable. Mr. Fothergill mentioned the brickwork in a furnace, and its bad effect. In an oil fire furnace the brickwork had a very good effect in that it retained a certain amount of heat in the furnace after the burners were extinguished, and so allowed the whole boiler cooling down gradually, and preventing any undue stress upon any part. The carbonising of the oil at the mouth of the burners was another point raised. That took place in all burners, more or less, less in the steam than in air burners; but still it took place, and that was the greatest difficulty in the cleaning. Where a burner or sprayer was not readily taken apart there they would have the most trouble. Consequently, it was essential, as pointed out, that burners or sprayers should be easily taken apart for cleaning, and then they could get over this difficulty of carbonised oil. It gave them little trouble if they could take their sprayer apart for half a minute, and put it together again at once, and in the one shown the furnace would not be stopped for more than four or five minutes. In concluding, he thanked those gentlemen who had said so many flattering things regarding the paper, and for the interest taken in regard to oil fuel.

The PRESIDENT thought the only thing that remained for them was to accord a very hearty vote of thanks to Mr. Wallis for his very able paper. He should have wished very much that there had been more speakers to deal with such an important subject as the burning or use of liquid fuel. It had now reached a stage beyond that of mere conjecture. There was not a doubt that if liquid fuel could be had at a reasonable price there was no difficulty whatever in burning it in a thoroughly efficient and economical manner. This was clearly demonstrated on the Caspian Sea, where there was not such a thing as a steamer burning anything else than the refuse of petroleum (astatki). Mr. Fothergill had referred to different kinds of oil, and the great danger attached to their use. There was a difference, of course, between the kinds of oil. There were three kinds. Firstly, refined petroleum, scarcely used at all, and that was the kind with which there was, perhaps, the greatest danger. Then they had the crude petroleum, just as it came out of the earth, which would be dangerous because it contained all the naphthas, benzenes, and so on, very light and highly inflammable; but the custom in hot countries, where the oil was usually found, was to expose the crude oil in open tanks and let the sun evaporate the lighter carbons, so that the resultant could be used with perfect safety. As regarded the third kind of fuel (astatki), exclusively used on the Caspian Sea, it was of a heavy, treacly description, and not at all dangerous. It could be carried in any part of the vessel, so to speak, either in cross bunkers or side bunkers, or in the double bottom; and it had been suggested in some cases, where there was a large compartment, to prevent the oil coursing about when half full, to allow the sea water to flow in and keep the tank always full. There was no difficulty about that if circumstances required it. Mr.

they had often put the bunkers above the level of the furnaces, and had no difficulty. Among other advantages, they eliminated the firemen, they minimised manual labour, and altogether there could not be a doubt that the use of liquid fuel was one that would surely come in wherever the supply of the oil could be had at a reasonable price. He now asked them to carry by acclamation a hearty vote of thanks to Mr. Wallis for his very able paper.

The resolution was passed accordingly.

ON THE MACHINE-CUTTING OF ACCURATE BEVEL AND WORM GEARS.

By J. H. GIBSON.

[Read before the Institution, in West Hartlepool, on Saturday, March 13th, 1897.]

Machine-cut gearing, considered an extravagance a few years ago, is now become a necessity in all high-class engineering practice.

Even the glamour which the term "machine-moulded" suggested is fast fading away, and the Admiralty specification, "Teeth of all wheels to be machine-cut, accurately shaped and well-fitted, so as to reduce backlash to a minimum," is rapidly becoming the general rule. Lest it should still be considered that there is nothing to beat machine-moulded cast wheels (an opinion tenaciously held by many old-fashioned wheelwrights—strengthened, no doubt, by having come across some of the too usual abortions rejoicing in the name of machine-cut wheels) the following extract is quoted from an article which appeared in *Engineering* of 15th January, 1897:—

"To advertise machine-moulded gears is considered a guarantee of their absolute accuracy. This is a popular delusion. Such gears ought to be, for all practical purposes, true; in many instances they are so; but very often also they are not. Everything depends upon the amount of personal care bestowed upon the manufacture . . . . The mere fact that a wheel is machine-moulded carries no weight, therefore, to a practical engineer."

This disposes of the accuracy of machine-moulded wheels; but even assuming that they are accurate, it is surely a barbarous thing to have two cast surfaces sliding on one another; for all toothed gears *must* slide as well as roll. It is commonly supposed that the hard skin of a cast tooth prolongs its life; but the sand and grit in the skin itself soon wears away the surface and inevitably produces backlash. One of the peculiarities of toothed gearing is that however badly shaped the teeth may be to start with, they always tend to correct themselves as they wear; and were it not for the chatter, and weakness due to the wearing away of the teeth, one could wish for nothing better than the harmonious union of a pair of old toothed wheels which, during years of hard work, have rubbed away all inequalities, each accommodating itself to the peculiarities of the other. Mortice teeth are used for this very reason. The iron wheel soon impresses the correct curves on the soft wood teeth; and, barring the natural results of wear, with very satisfactory results.

Nearly all the machine-cut gears of the present time, especially bevel and worm gears, suffer from a most serious defect—*the teeth are not properly shaped.* True, the wheels "mesh" all right when new; and the teeth, though equally bad, are at any rate equally spaced, being machine divided; but the bearing part is a *point*—perhaps only *one point*—between a pair of teeth, instead of several *lines* the full breadth. Even if a single tooth is able to stand the whole working load concentrated at one end, the bearing point soon wears away, the pressure being so severe; and, therefore, if such deterioration is to ensue so soon, the cheaper cast wheels might just as well be fitted.

The configuration of wheel teeth is a matter of pure solid geometry; and it is generally recognised that there is no impossibility in making a machine that will follow, or faithfully reproduce any purely geometrical design. The first essential is to grasp the principles involved, then lay down the construction lines, and clothe this skeleton with a combination of mechanical parts that shall be constrained to follow the prearranged plan.

The writer had long held this view with reference to the machine-cutting of bevel and worm gears, when some time ago opportunities occurred of putting it to a practical test.

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contact between the two cones is therefore a straight line passing though the common apex. Each cone is provided with teeth which engage with corresponding spaces in the other, and not only prevent slipping, but transmit power. On the exact shape of these teeth depends the efficiency of the gear. Too often the points and flanks are simply struck with a radius to suit the eye, without any regard to the smooth rolling of the pitch cones ; and the pair of wheels being meshed, each tooth has to be eased until they gear all round.

In setting out a pair of spur wheels, the profile of the tooth should be first obtained by rolling circles in the usual way, and then each and every cut made *parallel* to the axis of the wheel for the whole breadth of the tooth.

A spur wheel is but a bevel wheel whose pitch cone apex is at an infinite distance ; and so it may be said that each cut actually *converges* to a point—the apex of a pitch cone at infinity.

The same construction applies to the setting out of bevel wheel teeth : the profile being described at the large end, on a development of the outer conical bounding surface (Fig. 1, Plate XXXIV.), the tooth is shaped by directing *each cut* towards the pitch cone apex.

These are elementary details, but it is necessary to keep them clearly in mind to appreciate the principles of construction in a bevel gear cutter.

It will be seen that the section of tooth constantly and uniformly diminishes towards the apex of the pitch cone, and that, assuming the curves of points and flanks to be arcs of circles, their radii at the inner end of tooth are relatively much shorter than at the outer end.

Obviously then, for a given number of teeth in a wheel, the further away one gets from the apex of pitch cone the larger the tooth and space will become, and by choosing a suitable distance an enlarged profile may be set out of any required size. The pitch and rolling circles being determined this can readily be done in the pattern shop, as shown in Fig. 1 (Plate XXXIV.) at B.

Fig 2 (Plate XXXIV.) is a bird's eye view, showing the essential features of a bevel wheel tooth. Suppose the wheel blank C to be made of butter, and a "space template," mounted at the appropriate relative position thereto as at D.

Suppose also that an extremely thin and rigid knitting needle is pivoted by one end at the apex of the pitch cone, and the other end guided over the enlarged profile D ; the needle must needs sweep out of the blank a perfect bevel wheel space, and every peculiarity of the profile would be faithfully reproduced in ever-decreasing miniature as the pivot is approached.

By bringing the sides of the space template together the pitch could be reduced to suit any required number of teeth in a wheel.

Compare this tooth with Figs. 3 and 4 (Plate XXXV.), which represent spaces in bevel wheels cut out by rotary cutters whose sides are radiused to approximate to the curves of point and flank. In Fig. 3 the spaces are gapped out by angling the wheel, first to one side and then to the other of the median plane, and running the cutter through, as shown by the tool marks A A.

Then another rotary cutter is mounted—the finishing tool: the vertical angle of wheel axis is altered so as to bring the cuts about parallel to the *tips* of teeth, and the wheel is wobbled a bit extra on either side of the median plane, while the finishing cuts B B are run through.

The result is as shown. A cycloidal tooth at the outer end, merging into a mongrel involute at the other. These teeth usually mesh at one point only E. There is not a single position where a pair of teeth bear along their whole length.

Fig. 4 shows the involute form of bevel wheel tooth. Its chief beauty lies in the fact that the error is not so manifest, but it is there all the same.

Two cuts, C and D, suffice, and each cut is parallel to the *root* of the tooth: consequently too much metal is generally cut off the points at the outer end, and the wheels mesh only at F. It is a favourite dodge in wheels of this description to deliberately mutilate the proper proportions of teeth as shown by dotted lines, it being rightly recognised that the pitches, and in cases where but little power is transmitted and the wear slight, it may not matter very much; the teeth may be mere stumps, and by some judicious hit-and-miss practice it may be possible to get the bearing point somewhat near the middle of the breadth.

But the writer of a recent paper on this subject was about right when he said that, as usually practised, the cutting of bevel gears with rotary cutters is generally so much time wasted.* No amount of "dodging" will produce a perfect tooth, and for heavy work such a method is, as it should be, entirely out of the question.

Coming now to the machine illustrated by Figs. 5, 6, and 7 (Plates XXXVI. and XXXVII.) it will be observed that the true principles laid down in Fig. 1 (Plate XXXIV.) are rigidly adhered to. The bevel wheel to be cut (1) is mounted on a mandril (2), one end of which pivots in a small trunnion bearing (3) at the apex of pitch cone. The other end is capable of movement in a vertical plane, and can be fixed on a graduated quadrant (4) at any required angle. A dividing gear (5) turns the blank into successive positions for cutting the required number of teeth, and while each tooth is being cut a pinching screw (6) helps the dividing wheel to hold the wheel blank securely in place.

A slider arm (7), carrying the ram (8) and tool box (9), is also pivoted so as to have a *universal* motion about the apex of pitch cone. Its outer end connects to the feed gear, and carries a roller (10), the centre of which is constrained to trace out the enlarged profile of tooth as set out in Fig. 1, by means of the space template (11), feed gear (12), and spring (13). The ram can be set to reciprocate in a position according to the size and angle of wheel to be cut, and the slot bracket (14) pinched to it by bolts. The stroke can be varied to suit breadth of tooth by altering the radius of crank pin (15).

The tool box (9) is capable of *lateral* adjustment by the screw (17), so as to bring the *cutting corner* of the tool (18) on to the straight line or "radian" joining the centre of roller to apex of pitch cone.

Thus, if the *left* side of a space is to be cut, the roller is made to roll down the *left-hand* profile, and the *left* corner of tool is brought on to the radian (Figs. 8 and 11, Plate XXXVII.). A simple depth and side gauge enables the corner of the tool to be set with ease and accuracy.

The outer end of slider arm terminates in a socket (20), and engages a ball, which is one with the feed nut (21). To the upper end of the feed nut is keyed a ratchet wheel (22), which is actuated by the tappet

* *Engineering*, January 15th, 1897.

rod (23), so that by adjusting the tappets (24) any desired feed can be imparted to the outer end of slider arm by the motion of the ram. On the tool reaching the root of tooth, the pawl engages the adjustable rod (25) and stops the feed, when the hand wheel (26) enables the attendant to bring the nut to the top of the feed screw again. The wheel blank is turned through another pitch, the pawl sprung into gear with the ratchet again, and the next tooth is operated upon.

The bottom end of feed screw terminates in a ball and socket joint (27), which allows it to accommodate itself to any position taken up by the end of slider arm. The space templates are mounted on an arc plate (28), which is struck from the same centre as the development of the pitch circle (29), and the templates themselves are pitched so that the distance between them measured on the pitch line is equal to ·5 pitch + diameter of roller (+ ·01 inch for clearance). The same templates are right for the same angle of wheel, whatever its diameter and pitch, provided the same generating circles are adopted to roll the curves.

If it be required to gap out the spaces in the wheel blank by the machine, the vertical roller guide (30) is lifted up, clamped in position by set bolts (31), and the gaps cut as in Fig. 10 (Plate XXXVII.), the width of tool being not greater than the root space at inner end. But it is much better to cast the gaps as shown in dotted lines (32), leaving the machine to shape the teeth only. Of course, this gap casting is out of the question when using expensive rotary cutters; but a shaping tool does not cost much to renew; besides, the cutting *corners*, which actually shape the teeth, do not touch the skin of the casting, as the outer and inner ends and tips of teeth are already machined in the lathe.

Figs. 8 and 11 (Plate XXXVII.) show the operation of shaping the [redacted]

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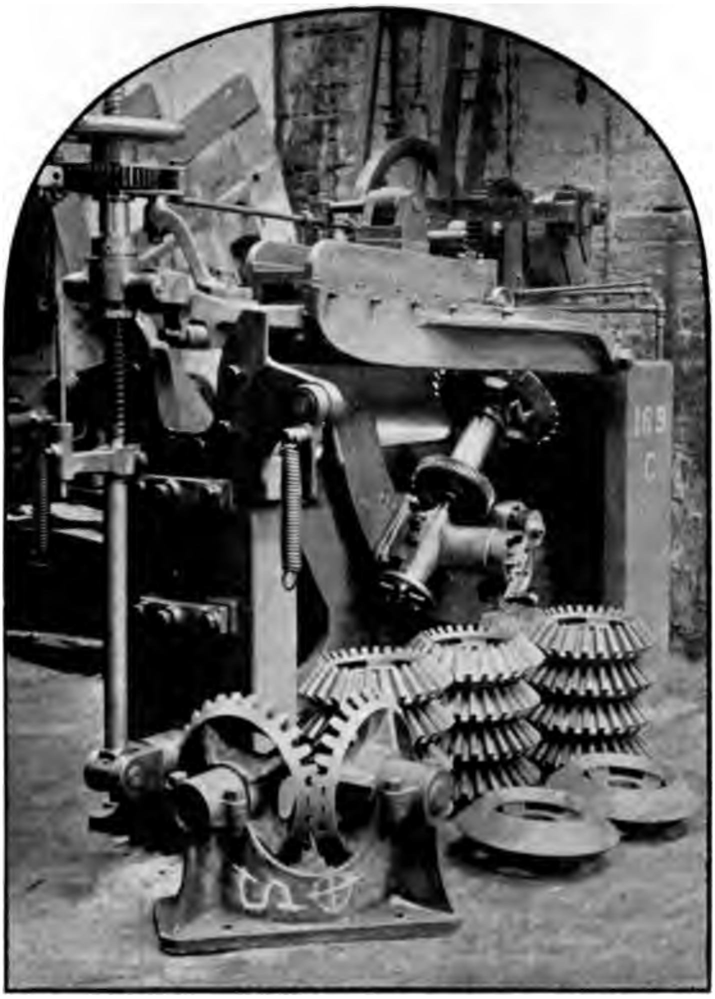

FIG. 20.

Next in importance to the efficiency of a machine comes simplicity of working, and the writer claims for this bevel wheel cutter that it is extremely simple to understand. Any mechanic of ordinary intelligence can readily manipulate it, and he is not dependent on a long list of instructions and rules as to how to "set" it, which the man usually knows as much about as the master mariner does about the nautical almanack.

The writer has in mind an American bevel wheel cutter, which was so complicated that the purchaser, an eminent machine-tool maker in this country, had to go over to the States to get practical instruction from the inventor. A convenient bench was fitted up near at hand, where the wheels were mounted and filed up as they came off the machine. In the case of another machine, the owner thereof could not explain it, as the independent and intelligent mechanic who worked it was off on the spree.

II.—Worm wheels are so called from having teeth specially adapted to gear with an endless screw or worm.

The worm is a comparatively simple mechanical contrivance, consisting, as it does, of a few threads of somewhat V-shaped section, which can be turned in an ordinary screw-cutting lathe, and which can be drawn by any elementary machine-construction student. Not so the wheel, however. The problem of drawing a correct worm wheel is extremely complicated, and there are few draughtsmen who could do so off-hand without getting tied in a knot. This accounts for much of the ignorance that prevails as to the right contour of worm wheel teeth, and explains the ease with which so many atrocities are palmed off as machine-cut worm wheels.

It is news to many people to be told that the end tips of worm wheel teeth are thinner than at the middle, especially in coarse pitches, and that the angle of tooth at the tip is greater than at the root. The writer has known quadruple threaded worm wheels ordered with parallel teeth; and with the inevitable result—days and weeks of chipping to get the twist and thin the ends, so as to gear with the worm.

Some engineers are more wary—perhaps bitter experience has taught them. They turn a worm first and then pare the pattern until it gears. But the expense of patterns and moulding is great, and the wheel when finished requires much dressing; also the loss by friction in imperfect worm gears is so excessive that their use is often abandoned in favour of a train of spurs and bevels. It may be that this last fact accounts for the fearful and wonderful collection of cog wheels in the tiller rooms of our first class battle-ships. They are perhaps to be preferred to some of the machine-cut worm wheels that it has been the writer's sad lot to behold. As a sample, look for a moment at the worm wheel teeth, illustrated by Fig. 13 (Plate XXXVIII.). This picture is no nightmare; the wheels are actually fitted in the capstan gears of some of H.M. new battle-ships not yet in commission.

The teeth had unmistakably been cut by a rotary cutter, and naturally the teeth were parallel, as shown at A; and naturally even a worm would not look at the wheel in that condition, and so the teeth had to be "humoured." In the first place the thick ends were very much in the way, so to save thinning them separately they were cut away bodily, as shown by dotted lines at B, then by chipping and filing each tooth at C, it was found just possible to jam the worm into gear, when, no doubt, running them together and grinding the worm well in would complete the "job."

Machine-cut wheels forsooth! Who would like to say when and where the worm gears with the wheel just described? Better say they fit where they touch, and pass on to consider "hobbed" worm wheels.

Before describing the process of "hobbing," it will be as well to revert to our analogy, and imagine a worm wheel blank made of butter. The spaces are already roughed out: the finished worm is brought into full gear; and worm and wheel rotated together at their appropriate relative angular velocities.

The result would clearly be a perfect worm wheel, for the worm-threads would mould the teeth to the theoretically correct shape.

The practice of hobbing worm wheels is based on these same lines.

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and is fed in until it occupies the same relative position to the wheel, as will the worm itself eventually. The hob, engaging with the spaces already gapped out, revolves the wheel.

This makes a fairly perfect worm wheel; it would be quite perfect had the hob an infinite number of teeth, were it long enough axially, and could it be arranged that all the teeth were dead on the helix.

The first condition it is impossible to fulfil because of practical considerations of clearance, etc.; the second condition would double or triple the number of teeth, each one of which has to be carefully backed off on top and sides; and the third condition is difficult of attainment, because, however carefully the hob is grooved and backed off and "got up" generally, you don't know where you are, so to speak, after tempering. It has been well said that a good hob is worth its weight in gold; it certainly costs that to purchase from some of the swell machine-tool firms.

But there are other objections to the use of the hob in these enlightened days. In the first place it is utterly unscientific; it is as barbarous a proceeding as the cutting of a screw thread on a round bar with stocks and dies, and for exactly the same reason, viz., the difference of angle between the tips and roots. Again, hobs can only be used for cutting wheels having worms exactly similar; and so it often happens that, after a turning or reversing gear, a capstan or crane has been carefully calculated and designed—perhaps half made—it is suddenly found there is no hob in stock that will cut the particular wheel required; and then heaven and earth are raised to make a stock hob "work in" and save the expense and time of making a new one. Perhaps the hob that is thus "worked in" is bigger in diameter, or of coarser pitch than that required, and so your elaborate calculation goes for naught, and the efficiency of the whole arrangement impaired.

Evidently, therefore, a simple machine that will cut perfect worm wheels out of the solid at one operation with an ordinary "fly" cutter, that requires only an outfit of standard screws and nuts of equal pitch to the worms usually fitted, and can, moreover, be put to other uses when not engaged in wheel cutting, should commend itself to all engaged in high-class heavy engineering work.

Such a machine the writer will now proceed to describe, referring to Figs. 16 and 19 (Plates XXXIX. and XL.). A standard worm wheel (1), operated by a driving worm (2) on the driving shaft (3), is adapted to rotate a face plate (4), to which the wheel to be cut (5) is secured. A rotable tool box (6), carried in bearings (7) secured to a carriage (8), is capable of adjustment to suit the size of wheel to be cut, by moving the slide (9), which can be clamped down by the side strips. The carriage can also slide freely in the direction of the axis of the cutter shaft.

The driving shaft and cutter shaft are geared together by the change wheels (11), which give the required velocity ratio between the turntable and cutter to suit the number of teeth in the wheel to be cut.

The last change wheel (12) is not attached directly to the cutter shaft, but to a nut (13), which forms a journal and thrust bearing (14) for the standard screw shaft (15). This nut has a wheel (16) securely keyed to it, having 40 teeth, which drives another wheel (17) of equal diameter, but having 42 teeth, by means of the pinions (18), which engage both differential wheels at opposite sides. The wheel (17) rides on the standard screw shaft (15), but cannot rotate on it because of the feathers (19) which slide in the feather ways (20).

It will be seen, then, that the rotation of the pinion by the star wheel (21) causes relative movement between the differential wheels (16 and 17), and constrains the standard screw to thread itself through the nut; but while the star wheel remains inoperative the whole mass revolves together and maintains a rigid connection between the last change wheel and the cutter (22).

The star wheel is operated automatically each time the worm wheel blank makes a complete turn by means of a cam (23), which engages the lever (24) and pushes the rod (25) to the right; the spring (26) brings the rod out of gear when the cam passes the pin (27).

The operation of cutting is as follows:—The tool is brought over to the left until it just touches the worm wheel blank at (28). The machine is then started, and the tool nibbles away until the blank has [redacted]

threaded worm, three cutters at 120 degs. to each other, and so on. A left-handed screw and nut (15 and 13) must be used in cutting left-handed worm wheels; in which case the tool, starting at (30), finishes at (28). In cutting wheels of large diameter a roller is fitted under the rim at (31) to take the pressure off the cut. The machine can conveniently be converted into a vertical lathe suitable for turning pistons, gun pivot plates and the like, by substituting one or more ordinary slide rests for the fly cutter, carriage, and slide.

The photograph (Fig. 21) shows the first machine erected, and also a number of reversing and turning wheels cut and ready to be cut for main engines of some 30 knot destroyers building on the premises. The wheel blank in the machine has just been started. This machine was made up from parts of ordinary shop tools, a boring head being adapted for the standard worm wheel, and some wheels from a large screw-cutting lathe forming the change wheel train.

The machine has cut about 70 worm wheels, some of which were double-threaded, with most satisfactory results—the wheels being simply perfect, and exhibiting all the peculiar characteristics of accurate worm gear teeth. Two reversing wheels, which were urgently needed for the erection of the first set of engines, were sent to Manchester to be cut whilst the machine was being put together. When they arrived and were tried over, it was found that there was $\frac{1}{16}$ of an inch difference in mean diameter between them, and that the centres of worm shafts, instead of being in the plane of the wheel, were considerably out of it. It transpired that to save time the wheels had been cut with a hob of the wrong diameter, thus altering the angle of teeth, and that an attempt had then been made to get the right twist in the teeth by applying a wooden pattern of the finished worm and easing off the corners that fouled with a universal rotary cutter manipulated by hand. There was nothing for it but to "chuck" the wheels in the new worm gear cutter and to run a finishing cut through them; the amount of metal that came off *some* of the teeth was surprising. The wheel-cutting firms may well advise, as they generally do, that worms should not be turned until after receipt of the wheels. This appears to throw the onus of error on the man who cuts the worm, and so the wheel is chipped and humoured, generally on the quiet, sooner than have any bother with the wheel cutter, who, of course, is an authority on such a matter, and must not be criticised.

When the teeth of a worm wheel are inaccurately shaped the whole load may come on one tooth—perhaps only on one point of one tooth—

just as described in the case of bevel wheels. Then the pressure per unit of area becomes almost infinite, and no amount of lubricant will do any good.

During a heavy capstan trial the steel worm galled the gun-metal wheel and projected splinters of gun-metal 2 to 3 inches long in all directions, that stuck in the wood-work and the deck overhead like so many darts. Oil bath, tallow, and water service were useless. Had the teeth been white metalled they would perhaps have been squeezed into shape like the butter blank; but a gun-metal surface once galled is done for, and this particular wheel was soon irretrievably ruined. The mischief was entirely due to the inaccuracy of the worm wheel teeth, the bearing pressure per square inch of surface in contact being simply unbearable!

So it comes about that worm wheels of 3 to 4 inch pitch are often used when 1½ to 2 inch pitch would be ample. The draughtsman must assume that one end of one tooth is going to get all the load, and he designs the teeth accordingly (see Unwin on strength of wheel teeth); whilst if it could be known for certain beforehand that several teeth would gear at once, the pitch could be reduced to correspond, and the total load distributed as in a marine engine thrust block. Besides which, the fine pitched wheel will work much sweeter and with much less frictional loss than one of coarser pitch; this is especially noticeable in electric lifts driven by a worm motor, where the coarse pitched and often imperfect wheel gives rise to the unpleasant pulsating sensation which doubtless most passengers have experienced and noted.

As to the cost of machine-cut bevels and worm gears, the writer is of opinion that the general adoption of proper machinery will so cheapen production as soon to render cast wheels a relic of the past.

This is already the case with spur gearing; good machine-cut wheels can be had at prices very little more than for wheels with cast teeth; and the time saved in fitting up soon repays the extra cost.

Bevel and worm wheel patterns are much more expensive than spur wheel patterns, as every tooth has, of necessity, to be shaped separately. Add to this the cost of moulding and the final fitting; and it will be found that in the long run machine-cut wheels are the cheapest as well as the best. A pair of 12 inch cast iron mitre wheels, 1¼ inch pitch, can be cut in 9 to 10 hours; it would require a remarkably good fitter to satisfactorily gear the cast teeth of similar wheels in the same time.

A 30 inch gun-metal worm wheel, $1\frac{3}{4}$ inch pitch, takes no more than a day to cut out of the solid. Can the cast wheel successfully compete with this ?

It would be looked upon as something worse than crime in these days to cast a screw thread, or to chip and face a slide valve by hand, with the screw-cutting lathe and planing machine in existence ; and the same reasoning will apply to all classes of toothed gearing—bevel and worm wheels included—in the near future.

There are some peculiar types of bevel and worm gears which have not been touched upon, notably skew bevel wheels and screw gears.

Skew bevel wheels are used to transmit motion between shafts whose axes do not quite intersect. The pitch surface is a cross between a cylinder and a cone, viz., a hyperboloid of revolution.

When the axes are not parallel and are a good distance apart, screw gears are often adopted, the wheels consisting simply of a pair of very coarse—pitched, multiple—threaded worms gearing into one another at a pitch point.

It is not now proposed to go into the question of machining these special gears ; but it is certainly quite practicable, proceeding on the lines laid down in this paper.

It is interesting, however, to note how naturally the geometry of the various gears merge into each other. Spur wheels are merely bevel wheels whose common apex of pitch cones is so far away as to make cylinders of them.

Skew bevels are only so called because their pitch surfaces just miss being cones.

And as screw gears can be used interchangeably with skew bevels to obtain the same result, the transition from cones to cylinders again comes quite naturally. Finally, we have the particular type of screw gear termed worm gearing ; and all direct-driven wheel gears have then passed in review.

The writer confidently recommends the study of wheel gearing as an intellectual treat to all mechanical engineers who can appreciate the beauties of the geometry of motion.

DISCUSSION.

The PRESIDENT, at the conclusion of the paper, after an inspection of the samples of the machine-cut wheels, said he was sure they were very much indebted to Mr. Gibson for his very interesting paper, and he would be very glad if anyone would make some remarks upon it.

Mr. J. R. FOTHERGILL said he felt certain he was only expressing the feeling of the meeting in extending a hearty welcome to Mr. Gibson. They appreciated the trouble he had taken in travelling from Liverpool that he might read to them his paper. Not only did they appreciate this, but they fully realised they had before them a most interesting and valuable paper, and for which he desired to express to Mr. Gibson his thanks. That portion of the paper which interested him most had reference to the cutting of worm wheels. He thought if there was any class of gear more barbarous than another, particularly in the contour and fitting of the teeth, it was the worm wheel. No doubt many of them present had experienced, in the turning of marine engines with worm gear, the grinding and cutting that took place, and the absurd amount of power required. Worm gear offered some advantages that ordinary toothed gear did not. It was most advantageous in sustaining weights, and in obtaining direct leads; he thus thought if worm wheels could be produced with the accuracy predicted by Mr. Gibson, the friction would be so reduced as to admit of their use being more general. He hoped the paper would produce a good discussion, which it certainly deserved.

Mr. A. M. HENDERSON said no one listening to the paper, having to do with machinery or cutting tools, but must be forced to the conclusion that it was unanswerable. There was no negative to it. The subject was dealt with in a plain, practical, straightforward way, and dealt with the causes of troubles which they, as mechanics, were experiencing every day. The proposed improvement was bound to come. Mr. Gibson said the machine cuts wheels of all shapes. There was one shape not mentioned, which he (Mr. Henderson) found they had in practice, viz., the helical tooth, the form of which for certain reasons, such as when a high driving power was wanted in a narrow space, was found strong and lasting. Perhaps Mr. Gibson would show how these could be machine-cut. With regard to worm-wheel cutting by the hob, this was the nearest approach to perfection. In ordinary practice they got a machine-moulded worm wheel with not too much left on the teeth, and they were able to get the hob well housed into the bottom before it began to cut, and thus got the nearest true wheel possible. He must say they had had very good results from wheels cut in that way compared with what they got with the teeth moulded and fixed together in segments. That was no doubt what caused the machine moulding to be introduced, which suited fairly well. Mr. Gibson had mentioned a certain firm which had produced a wheel-cutting machine—Messrs. Hulse. Perhaps the question might arise—Why did not they use it themselves? In all cases he (Mr. Henderson) thought it came to this—machine-cut wheels of all descriptions rate very high in the market at the present time, and people would not pay for a high-priced tool if they could get another one to do the work. But the paper fully and fairly described what would come to pass, no doubt. They found high-class machines, that cost a long price, with machine-cut teeth, running for three years, and at the present time no appreciable wear was observable. It would run as sweetly the one way as the other, and there was no doubt that it would be a good thing, if he might put it that way, to turn out all machines in that style. It would mean a saving of a large percentage in machine-finished work. At the present time one might have a large diameter spur wheel running into a small pinion—a very difficult matter for the pattern-makers and all concerned to make it gear properly. The outcome was that in finishing a piece of work they had it chattered and marked all over from end to end; while with machine-cut gearing that would be saved; and if purchasers would give the price, machine makers no doubt would provide them, and they would soon reach the millennium in machining. He thought the paper one which every engineer should study, as the practical hints could be put into use, even although not going the length of a cutting machine.

Mr. C. J. Seaman said that in his opinion the paper as a paper was so near to perfection as to be only equalled by the wheels cut with such accuracy by the machines so ably described by the writer. He had to confess that in the past he had advocated the use of the machine-moulded wheel as superior to the machine-cut wheel, not because the former was perfect, but on account of the many imperfections of the latter. In one case he had two multiple drills running side by side on similar work, and owing solely to the bad shape of the worm wheels on the one machine their life was not one-third that of the better designed wheels on the other machine. He would like to know whether these machines were likely to be in the market soon, or if wheels cut by them would be readily obtainable, for he thought they only required to be known for them to be extensively adopted, even although there was a little additional first cost? He was sure the reduction in wear and tear and the saving in power owing to reduced friction would amply repay any additional outlay.

Mr. Jas. Wilson said there was one point he would like to mention; in cases where they had very heavy wheels to deal with in reversing gears for large cruisers, when they used ordinary wheels they could not place very great reliance upon the teeth, hence they had to adopt a very large factor of safety; but when they had machine-cut wheels they could come down with the factor of safety; and in getting out an entire gear for reversing some of these very large engines, with compound gear throughout, they found they could use smaller gear, which minimised the cost; and the parts, starting from the reversing shaft, were very much smaller, which brought down the weight, and that was a consideration in naval work. So, taken altogether, the cost, although they were machine-cut, was generally less than in the usual form. That was why these gears were being introduced into Admiralty work and high-class machinery.

The President, in adjourning the discussion to the next meeting at Sunderland, entirely concurred with all Mr. Fothergill had said as to their thanks being due to Mr. Gibson for the very valuable paper he had given, and he had put the subject before them in such a lucid way that anyone could understand it. He had not only read the paper, but brought interesting examples of what the machine could do as compared with work which had been done in the ordinary manner, making his subject all the more intelligible.

The meeting was then adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896–97.

PROCEEDINGS.

SEVENTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, SUNDERLAND, ON WEDNESDAY EVENING, APRIL 14TH, 1897.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in West Hartlepool, on March 13th, 1897, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. W. R. Cummins and W. G. Spence to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Hemphill, Henry, Mechanical Engineer, 15, North View, Heaton, Newcastle-on-Tyne.
Henry, William P., Marine Engineer, Cragside, St. Aidan's Road, South Shields.
Paulin, William J., Engineer, 47, Clarence Crescent, Shieldfield, Newcastle-on-Tyne.

GRADUATE TO MEMBER.

Laing, Hugh, Naval Architect, Deptford Shipyard, Sunderland.

ASSOCIATE.

Donkin, George, Jun., Accountant, St. Andrew's Works, Newcastle-on-Tyne.

GRADUATE.

Coulson, Richard H. A., Apprentice Engineer, 12, East View, South Shields.

NOMINATIONS FOR THE EXECUTIVE.

The SECRETARY (Mr. Duckitt) reported that, in accordance with Article X. of the Constitution, the following gentlemen retired from the Council :—President—Col. Henry F. Swan (eligible for re-election); Vice-Presidents—Mr. J. R. Fothergill, Mr. Hugh Macoll, and Prof. R. L. Weighton (eligible for re-election); Hon. Treasurer—Mr. G. E. Macarthy (eligible for re-election); Ordinary Members of Council—Mr. J. M. Rennoldson, Mr. H. Rowell, Mr. A. G. Schaeffer, Mr. G. W. Sivewright, and Mr. J. E. Stoddart. (These are *not* eligible for re-election.)

The PRESIDENT, in accordance with Bye-law 11, on behalf of the Council, nominated the following gentlemen, to be balloted for, to fill up the vacancies :—President—Col. Henry F. Swan; Vice-Presidents (three to be elected)—Mr. J. R. Fothergill, Mr. Hugh Macoll, Mr. J. M. Rennoldson, and Prof. R. L. Weighton; Hon. Treasurer—Mr. G. E. Macarthy; Ordinary Members of Council (five to be elected)—Messrs. F. Caws (Associate), J. H. Heck, R. H. Muir, P. Phorson, C. Rennoldson, and M. Sandison.

There were no further nominations.

The PRESIDENT, on behalf of the Council, gave notice that at the Closing Business Meeting, to be held in Newcastle-upon-Tyne, on May 12th, he would move that Bye-law 40, be altered to read as follows :—"The *Transactions* shall not be supplied free to members whose subscriptions are unpaid."

The discussion on Mr. J. H. Gibson's paper "On the Machine-cutting of Accurate and Bevel and Worm Gears" was resumed and closed.

Mr. W. R. CUMMINS read a paper on "High Pressures for Marine Engines."

ADJOURNED DISCUSSION ON MR. J. H. GIBSON'S PAPER "ON THE MACHINE-CUTTING OF ACCURATE BEVEL AND WORM GEARS.

CLOSE OF DISCUSSION.

Mr. W. H. ATHERTON, in the further discussion of Mr. J. H. Gibson's paper, said it was an interesting one to mechanical engineers, and especially to those who had had much to do with wheel gearing. The matter was clearly put, and formed a valuable contribution to the literature of the subject. Having himself had a fair amount of experience with wheels of all kinds, he ventured to make a few criticisms on the paper. The quotation on page 161 from *Engineering* asserted more than Mr. Gibson would have them believe, for if they substituted the words "cut gears" in place of "machine-moulded gears" the paragraph still applied with almost equal force. The fact that a wheel was cut was no guarantee of its excellence. Given an accurate wheel-cutting machine, properly shaped cutters, the best accessories, and also a careful and competent workman, excellent wheels could be cut. Similarly, with an accurate moulding machine, well shaped tooth blocks, a good man, and perfect appliances generally, it was possible to mould gears true enough for most practical purposes. In the absence of these conditions it was, of course, easy by either method to produce very inferior specimens of work; though one must admit that machine shop results were less uncertain than those of the foundry. Cast wheels had some advantages over their rivals. They were rather cheaper, especially if heavy; it was also possible to materially increase their strength by shrouding; and they admitted of such parts as clutches being cast in one piece with them. Double-helical wheels, whether spur or bevel, could not be cut at all. He doubted, therefore, whether large cast steel wheels were ever likely to be wholly displaced by cut gearing for such heavy work as rolling mill trains, though for small and medium-sized work cut gearing was preferable. For Admiralty work, however, even the heaviest gearing must be cut, such as the turret training gear of battleships. At the top of page 162 Mr. Gibson remarked that mortice wheel teeth were used to enable each of a pair of wheels to accommodate itself to the peculiarities of the other. He had the impression that they were used merely to diminish noise. At least he remembered one particularly noisy shop, containing a pair of large bevels running at a good speed, which was rendered very much pleasanter to work in by the substitution of a mortice wheel for one of the iron wheels. As regarded the shape of wheel teeth, it was rather surprising to learn nowadays that "too often the points and flanks are simply struck with a radius to suit the eye." In his experience, most firms of repute used Willis's *odontograph* for setting out teeth. No simpler or handier method could be desired where whole sets of wheels had to run together, as in change gears. But if preferred, it was easy enough to draw true cycloidal curves corresponding to any desired diameter of rolling circle, by manipulating a piece of tracing paper on which the rolling circle was drawn and pricking through it any required number of points on the curve.

On page 164 Mr. Gibson clearly brought out the impossibility of cutting reasonably accurate bevels by means of rotary cutters. His remarks called to mind the manœuvring he used to have some years ago in cutting small bevel pinions on an ordinary wheel-cutting machine. The best that could be done was to make the two ends roughly to shape, and finish the job by hand in the vice. In the shops of a well-known northern engineering firm he had seen dozens of bevel wheels produced by the excessively slow method of first setting out every tooth by dividers and centre-punch, then slotting out the spaces nearly to shape on a slotting machine carrying an angled dividing head on its table, and finally filing up each tooth to two gauges shaped to suit the thick and thin ends of the teeth. This process made a fair job, and might be defensible for an occasional wheel; but it could be hardly recommended as an economical method, and certainly ought not to be adopted for manufacturing large numbers of wheels, when such excellent machines as Mr. Gibson's could be had.

In the description of the bevel wheel cutter it was stated that the same templates were right, for the same angle of pitch cone and same rolling circle, no matter what might be the diameter of the pitch circle or pitch of teeth. This seemed an important feature, because it effected a great saving of templates. In comparing the simplicity of this machine with the complexity of some others, it should be remarked that the Bilgram bevel cutter, to which Mr. Gibson probably alluded, did not merely copy the tooth form, but evolved it mechanically.

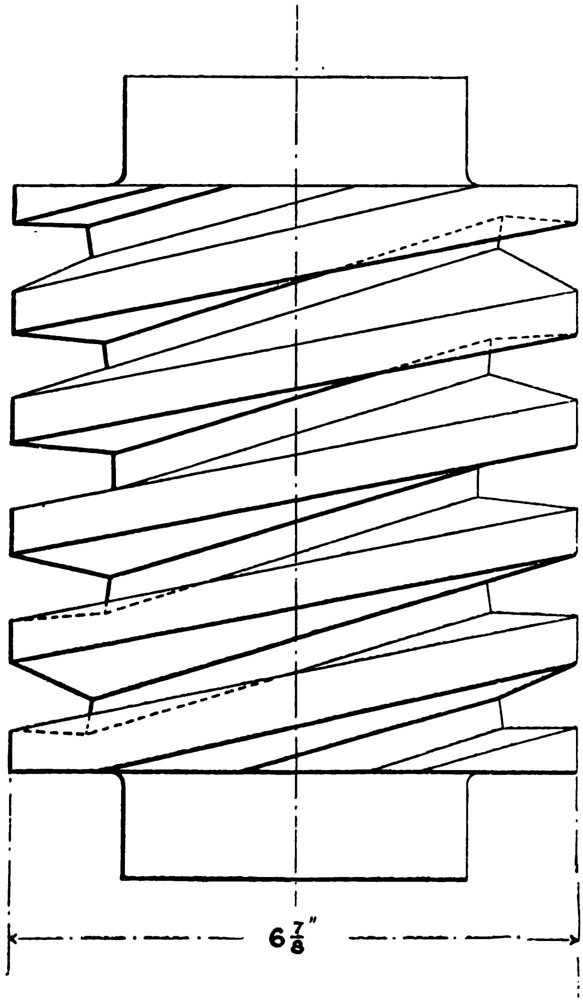
The attempt to cut bevel wheels absolutely correct by planing the teeth with a point-tool was by no means new. He had brought with him a drawing, nearly thirty years old, of a machine for cutting bevel and spur gearing mathematically correct, which might be of interest to some members (see Plate XLI.). It represented a larger machine than Mr. Gibson's, from which it did not differ greatly in principle, though quite different in design and detail. The following is a description of the machine :—

Fig. 1 shows the front elevation of the machine as fixed for cutting a bevel wheel. Fig. 2 shows the plan view of the same.

A is a planed cast iron bed, 12 feet long, which carries a saddle or slide, B, which can be moved on any part of the bed to suit the diameter of the wheel to be cut. The said saddle carries a slide, G, at right angles to the long bed, upon which is another slide, H, to which is connected a spindle, the bottom end of which spindle rests upon a form the shape of the tooth to be cut, and which spindle is connected to a casting, C ; and as the slide is made to traverse (by the crank motion and ratchet wheel) over the form, that end of the casting is made to rise or fall, according to the shape of the tooth to be cut. It will be observed that the other portion of the casting, C, is made in the form of a slide or bed, the extreme end of which swings upon a ball-joint, I ; and the centre of that ball-joint is in the line of the axis of the wheel, F, which is to be cut. In the plan (Fig. 2) the movable bed, C, is shown in its proper oblique position for cutting the bevel wheel, F ; but in the elevation (Fig. 1) it is shown in a side view, in order that the mechanism which it carries may be more distinctly seen. The block or standard, E, which carries the ball-joint is fixed upon a base plate, J, set at right angles to the bed, A. The standard can be fixed at any part of the base plate so as to give the proper angle to the slide, C, parallel with that of the bevel of the wheel to be cut. K is a saddle which carries the tool-box, to which a reciprocating motion is communicated by connecting rod and crank pin, driven by suitable gearing mounted on the end of the casting, C. It will be observed that the tool box carries an ordinary planing chisel suitable for either wood or iron. When the machine is used for cutting spur wheels the standard, E, and a portion of the casting, C, are dispensed with, and the other end of the slide, C, is bolted firmly to the slide, G. The form of the tooth, in the case of spur wheels, is obtained by the tool box working loosely in a socket, one end of which is connected to a form or template of the teeth to be cut, as shown at M. The screw, N, is for traversing the saddle, K, by hand (when disconnected from crank arm) for turning up the wheel pattern in the face plate, thereby answering the purpose of a lathe, which can be easily done, by disconnecting the worm and worm wheel and putting a pulley on the main spindle carrying the wheel to be cut.

Much might be said about worm wheels, did time permit. From the rapid development of electric driving, and the need for a compact reducing gear, such wheels were becoming increasingly important, and yet of all machine details they were, as a rule, the most badly made. It was really surprising how few entirely satisfactory worm wheels were to be seen. He had in mind some large gun lathes, whose loose head-stocks were fitted with the most wretched apologies for worm wheels, and a certain 100-ton testing machine was in no better plight. These wheels had been cast from patterns cut in the same manner as a spur wheel, except that the machine slide had been angled to suit the inclination of the worm thread. It was impossible to produce decent worm wheels in this way, though wheels could be made to answer the purpose at the least initial cost, regardless, however, of mechanical efficiency. There was some slight excuse for such makeshifts in the case of the adjustments of machine tools, where the motion was only intermittent; but he had also seen scores of wheels of like construction fitted to rope-power travelling cranes, running almost continuously at high speed, where their use was certainly not legitimate. It was true these particular wheels were cast in gun-metal, and there had been some little attempt to make them look like real worm wheels by turning off the corners off the teeth and hollowing out the face a trifle; but, after all, they were only slightly modified spur wheels, and should be called angle wheels. He supposed one reason why such wheels were so largely used in machine tool work was that they were easier to get into place and disconnect than true worm wheels, which latter often necessitated steps and caps where plain bosses would otherwise suffice.

Some of the nicest worm gearing he had ever seen had been that fitted for training quick-firing guns, which had to be handled with the utmost despatch and the greatest economy of hand power. These wheels [redacted] one or two teeth was made without much labour by the patternmaker, while for a worm wheel the tooth-block was first cut with a fly-cutter on a wheel-cutting machine, and the corners then trimmed to gear with the previously cut worm. This pattern was not at all costly. Some years ago he made several large worm wheels by this method, which gave no trouble.



THE HINDLEY WORM.

Lastly, Mr. Gibson had made no mention of the most perfect type of worm gearing extant, the so-called Hindley gear. The peculiarity of the Hindley worm was that its pitch line was not straight, but an arc of a circle coincident with part of the pitch circle of the worm wheel. The worm thus assumed a slightly hour-glass shape. It was cut with a tool which travelled in a circle and truly represented a tooth of the wheel which the worm had to drive. The worm wheel also was cut by a special hob which truly represented the worm. The advantage of this gear was that the surface of contact was far greater than that possible with an ordinary worm. The method of cutting such a worm and wheel was described in detail in the *American Machinist* for March 25th and April 1st of the current year, copies of which he had brought with him for the sake of the diagrams. The process was rather complicated, however, and required a good deal of expensive apparatus, so that it was not likely to come into vogue for general work. For exceptionally high-speed worms it might perhaps be applied with advantage. Mr. Gibson's views on the Hindley gear would be interesting.

47, Clarence Crescent, Newcastle,

Dear Mr. Duckitt, *April 22nd*, 1897.

At the resumed discussion of Mr. Gibson's paper "On the Machine-cutting of Accurate Bevel and Worm Gears," at the last meeting of the Institution at Sunderland on the 14th inst., I unfortunately missed the opportunity of putting the following question, and should feel obliged if you could see your way to bring it under Mr. Gibson's notice, so that he may make some observation on the point in his reply:—"Does Mr. Gibson find any difficulty in setting the fly-cutters with perfect accuracy and rigidity, so that they revolve in the same plane at right angles with the axis of the arbor, when cutting double or triple threaded worm wheels, so as to ensure a uniform section of wheel teeth?"

HIGH PRESSURES FOR MARINE ENGINES.

By W. R. CUMMINS.

[Read before the Institution, in Sunderland, on April 14th, 1897.]

In 1890 the writer had the honour of reading a paper before this Institution on "Increased Boiler Pressure and Increased Piston Speed for Marine Engines."

The paper advocated the adoption of a working pressure of 250 lbs. per square inch, and a considerable increase in the piston speed for engines of the mercantile marine, over that obtaining in the three cylinder three-crank engine.

It was suggested that the best means of carrying out these proposals was by a four-crank four cylinder engine, the steam being expanded successively in each cylinder. It was also suggested that the cylindrical return-tube boiler was unsuitable fòr such a high pressure, and that a modification of boiler design was desirable. Since that date the use of four cranks has been growing in favour, especially for high-speed engines; but the boiler of 150 lbs. to 180 lbs. pressure remains as it was six years ago.

These six years have nevertheless seen the introduction of the water-tube boiler in various forms, and in many cases accompanied with an increase of working pressure.

The writer believes that there is only one case of cylindrical return-tube boilers working at a higher pressure than 250 lbs., viz., those of the s.s. "Inchmona," built by the Central Marine Engine Works, which have a working pressure of 255 lbs. per square inch.

In this paper the writer proposes first to recapitulate the arguments of the former paper as to the economy to be expected from the proposed increase of pressure, and to touch upon the commercial aspect of the question; secondly, to consider what type of boiler will best suit the new conditions; and, thirdly, to make some suggestions as to the design of an engine most suitable for this increased pressure.

The coal economy effected by substituting the triple expansion engine with boilers working at 150 lbs. pressure for the compound engine with boilers working at 80 lbs. was, generally speaking, about 25 per cent. Let it be assumed that in the case of the compound the mean pressure referred to the low-pressure cylinder would be $21\frac{1}{2}$ lbs. The total number of expansions requisite to obtain this mean pressure would be $6\frac{3}{4}$. (See Appendix, Calculation A, page 215.)

For the sake of simplicity the term "expansions" in this paper will mean the "valve" expansions, that is to say, the ratio of expansion neglecting the effect of clearance space, etc., on that ratio.

Then, if an economy of 25 per cent. is obtained by using a boiler pressure of 150 lbs., the mean pressure referred to the low-pressure cylinder of the triple expansion engine will be $21\frac{1}{2}$ plus 25 per cent.—say $26\frac{1}{2}$ lbs. The total expansions necessary to obtain this mean pressure will be $11\frac{3}{4}$. (See Appendix, Calculation B, page 216.) Thus we have in the case of the compound 95 lbs. absolute pressure in the boiler, $6\frac{3}{4}$ expansions and $21\frac{1}{2}$ lbs. mean pressure referred to the low-pressure cylinder, and in the triple expansion engine 165 lbs. absolute pressure in the boiler, $11\frac{3}{4}$ expansions, and $26\frac{1}{2}$ lbs. mean pressure referred to the low-pressure cylinder.

These, it may be stated, are average voyage figures, with the compound using about $2\frac{1}{4}$ lbs. coal per indicated horse-power per hour, and the triple about $1\frac{5}{8}$ lbs. per indicated horse-power per hour.

We have next to determine the theoretical economy of steam of 165 lbs. absolute pressure over steam of 95 lbs. absolute pressure, under the above conditions.

In the first place, Carnot's formula :—

$$T_1 = 827 \text{ degs. Fahr.};$$

$$\frac{827 - 541}{827} = \cdot 345 \text{ efficiency};$$

$$\frac{\cdot 345 - \cdot 310}{\cdot 310} \times 100 = 11 \text{ per cent.}$$

economy of steam of 165 lbs. absolute pressure over steam of 95 lbs. absolute pressure, according to Carnot's formula.

As will be shown further on, the actual theoretical economy is considerably more than this figure. It is probably owing to the misapplication of this formula that the triple expansion engine has had the credit of its economy put down to the fact of it expanding the steam in three stages instead of in two, as in the compound; the argument being that the initial condensation is diminished owing to a lessened range of temperature in each cylinder.

It is well known that when dry saturated steam expands adiabatically doing external work, that a portion of the steam is liquefied, and to calculate the amount of this external work we must know how much of the steam is liquefied during expansion. Prof. Rankine gives the following formula for the proportion of steam liquefied during expansion :—

$$\text{Proportion} = 1 - \frac{T_2}{L_2}\left(J \ \log_e \frac{T_1}{T_2} + \frac{L_1}{T_1}\right).$$

(See *Steam Engine*, by Prof. Rankine.)

Where T_1 = absolute temperature at beginning of expansion in degs. Fahr.

T_2 = absolute temperature at end of expansion in degs. Fahr.

L_1 = latent heat in ft.-lbs. per lb. of steam at beginning of expansion.

L_2 = latent heat in ft.-lbs. per lb. of steam at end of expansion.

Prof. Cotterill gives the same formula in another form (see *Steam Engine*, by Prof. Cotterill).

Rankine's formula does not give the liquefaction for any definite number of expansions, hence the temperature at end of expansion must be determined by trial and error to suit the given expansions. This has been done in the following calculations :—

For steam of 95 lbs. absolute pressure, $6\frac{3}{4}$ adiabatic expansions, and terminal pressure 11 lbs. absolute :—

$$T_1 = 785 \cdot 084 \text{ degs. Fahr.},$$
$$T_2 = 658 \cdot 968 \text{ degs. Fahr.},$$
$$L_1 = 683{,}674 \text{ ft.-lbs.},$$
$$L_2 = 753{,}288 \text{ ft.-lbs.},$$

and the proportion of steam liquefied at end of expansion = 12·21 per cent.

Thus we have, at the beginning of expansion, 1 lb. of steam at 95 lbs. absolute pressure, and at the end of expansion ·8779 lbs. steam at 11 lbs. pressure and ·1221 lbs. water.

V_1 = volume of 1 lb. steam at 95 lbs. absolute pressure = 4·494 cubic feet.

V_2 = volume of ·8779 lbs. steam at 11 lbs. absolute pressure + volume of ·1221 lbs. water = 30·379 cubic feet.

Ratio of expansion $= \frac{V_2}{V_1} = 6{\cdot}76.$

Then, assuming that the above proportions of steam and water do not vary during the exhaust period, and that the back pressure = 4 lbs. absolute, we have :—

Heat received = total heat of 1 lb. steam at 95 lbs. absolute pressure = 1212·729 thermal units. Heat rejected = total heat of ·8779 lbs. steam at 4 lbs. absolute pressure = 1018·912 + heat of ·1221 lbs. water at the corresponding temperature = 18·729 thermal units. Heat utilised = heat received − heat rejected = 1212·724 − (1018·912 + 18·729) = 175·082 thermal units.

For steam of 165 lbs. absolute pressure, $11\frac{3}{4}$ expansions, and terminal pressure 10 lbs. :—

$T_1 = 826{\cdot}944$ degs. Fahr.,

$T_2 = 654{\cdot}440$ degs. Fahr.,

$L_1 = 660{,}110$ ft.-lbs.,

$L_2 = 755{,}755$ ft.-lbs.,

and the proportion of steam liquefied at end of expansion = 15·24 per

Heat received = total heat of ·9895 lbs. steam at 165 lbs. pressure = 1212·724 thermal units. Heat rejected = total heat of ·8387 lbs. steam at 4 lbs. pressure = 973·416 thermal units + heat of ·1508 lbs. water at corresponding temperature = 23·132 thermal units. Heat utilised = 1212·724 − (973·416 + 23·132) = 216·176 thermal units.

Then, $$\frac{216 \cdot 176 - 175 \cdot 082}{175 \cdot 082} \times 100 = 23 \cdot 47 \text{ per cent.}$$

economy of steam of 150 lbs. boiler pressure over steam of 80 lbs. boiler pressure.

To show that this economy is not due to mere expansions, take the case of steam of 95 lbs. absolute pressure expanded the same number of times as the steam of 165 lbs. absolute pressure, viz., 11¾ times; the terminal pressure in this case will be 6 lbs., and

T_1 = 785·084 degs. Fahr.,
T_2 = 631·323 degs. Fahr.,
L_1 = 683,674 ft.-lbs.,
L_2 = 768,332 ft.-lbs.

The proportion of steam liquefied at end of expansion = 13·71 per cent. Thus we have, at beginning of expansion, 1 lb. of steam at 95 lbs. absolute, and at end of expansion ·8629 lbs. steam at 6 lbs. absolute, and ·1371 lbs. water.

V_1 = volume of 1 lb. steam at 95 lbs. absolute = 4·494 cubic feet.

V_2 = volume of ·8629 lbs. steam at 6 lbs. absolute + volume of ·1371 lbs. water = 52·939 cubic feet.

Ratio of expansion $= \frac{V_2}{V_1} = 11 \cdot 77.$

Heat received = total heat of 1 lb. steam at 95 lbs. absolute = 1212·724 thermal units.

Heat rejected = total heat of ·8629 lbs. steam at 4 lbs. absolute = 1001·503 thermal units + heat of ·1371 lbs. water at corresponding temperature = 21·030 thermal units.

Heat utilised = 1212·724 − (1001·503 + 21·030) = 190·200 thermal units.

$$\frac{216 \cdot 176 - 190 \cdot 200}{190 \cdot 200} \times 100 = 13 \cdot 65 \text{ per cent.}$$

economy of steam of 150 lbs. boiler pressure expanded 11¾ times over steam of 80 lbs. boiler pressure expanded 11¾ times.

It is thus seen that the mere fact of raising the boiler pressure from

80 lbs. to 150 lbs., and expanding the same number of times, causes an economy of about 13½ per cent.

The lessons to be learnt from this fact are: first, that "thermal units should be used while they are hot;" that is to say, every opportunity should be taken when designing cylinders, steam ports, and passages, to prevent steam of higher pressure giving up its heat to steam of lower pressure; and, secondly, that unless we can obtain direct proof to the contrary, there is no appreciable coal economy in expanding steam in several stages.

For steam of 220 lbs. absolute pressure, 15¾ expansions, 30 lbs. mean pressure, referred to the low-pressure cylinder, and theoretical terminal pressure 9 lbs. :—

$$T_1 = 851{\cdot}04 \text{ degs. Fahr.},$$
$$T_2 = 649{\cdot}516 \text{ degs. Fahr.},$$
$$L_1 = 646{,}422 \text{ ft.-lbs.},$$
$$L_2 = 758{,}439 \text{ ft.-lbs.}$$

and the proportion of steam liquefied at end of expansion = 17·10 per cent.

Thus we have at the beginning of expansion ·9836 lbs. steam at 220 lbs. absolute pressure, and at the end of expansion ·8154 lbs. steam at 9 lbs. absolute pressure, and ·1682 lbs. water.

V_1 = volume of ·9836 lbs. steam at 220 lbs. = 2·141 cubic feet.

V_2 = volume of ·8154 lbs. steam at 9 lbs. absolute pressure + volume of ·1682 lbs. water = 34·112 cubic feet.

$$\text{Ratio of expansion} = \frac{V_2}{V_1} = 15{\cdot}80.$$

Heat received = total heat of ·9836 lbs. steam at 220 lbs. absolute

[redacted]

$T_1 = 867{\cdot}040$ degs. Fahr.,
$T_2 = 649{\cdot}516$ degs. Fahr.,
$L_1 = 637{,}186$ ft.-lbs.,
$L_2 = 758{,}439$ ft.-lbs.,

and the proportion of steam liquefied at end of expansion = 18·16 per cent.

Thus we have at the beginning of expansion :—

$$1 \times \frac{\text{total heat of steam at 95 lbs.}}{\text{total heat of steam at 265 lbs.}} = {\cdot}9798 \text{ lbs.}$$

steam at 265 lbs. absolute pressure, and at the end of expansion ·8019 lbs. steam at 9 lbs. absolute pressure and ·1779 lbs. water.

V_1 = volume of ·9798 lbs. steam at 265 lbs. pressure = 1·833 cubic feet.

V_2 = volume of ·8019 lbs. steam at 9 lbs. absolute pressure + volume of ·1779 lbs. water = 33·592 cubic feet.

Ratio of expansion $= \frac{V_2}{V_1} = 18{\cdot}32$.

Heat received = total heat of ·9798 lbs. steam at 265 lbs. absolute pressure = 1212·724 thermal units. Heat rejected = total heat of ·8019 lbs. steam at 4 lbs. absolute pressure = 930·705 thermal units + heat of ·1779 lbs. water at corresponding temperature = 27·289 thermal units. Heat utilised = 1212·724 − (930·705 + 27·289) = 254·730 thermal units.

$$\frac{254{\cdot}730 - 216{\cdot}176}{216{\cdot}176} = 18 \text{ per cent.}$$

economy of steam of 250 lbs. boiler pressure over steam of 150 lbs. boiler pressure.

The following table shows the relative economy of the different pressures and expansions :—

Pressure	80	80	150	205	250
Mean pressure on low-pressure cylinder	21½	—	26½	30	31½
Expansions	6¾	11¾	11¾	15¾	18½
Relative economy	100	108	123	137	145

Thus we see that by increasing the boiler pressure to 205 lbs. we may expect a saving in the coal consumption of 11 per cent., and by still further increasing it to 250 lbs. we may expect a saving of 18 per cent.

The first question to be answered is : Will it pay the shipowner to go in for this increase of pressure and consequent saving in the coal bill ? In the first place, a substantial gain must be guaranteed to compensate for the extra care and attention required for higher pressures, so that if the pressure is increased at all, it should be increased to at least 250 lbs., thus ensuring an economy of at least 18 per cent.

For purposes of comparison take a boat 310 × 40 × 21, carrying 3,500 tons deadweight and 4,000 tons measurement on 19′ — 6′ draught, fitted with triple expansion engines,

$$\frac{23'' \times 35'' \times 60''}{42''},$$

running at 65 revolutions per minute, and indicating about 1,000 indicated horse-power, with 26½ lbs. mean pressure referred to the low-pressure cylinder.

The coal consumption at 1·6 lbs. per indicated horse-power per hour would be 17·14 tons per day, which, with a bunker capacity of 540 tons, gives 31 days' steaming.

Supposing that engines and boilers working at 250 lbs. pressure and indicating the same power as the triple were substituted, and that they occupied the same space, and cost the same money as the triple, the shipowner would effect a saving in—first, cost of bunker coal; second, less bunker capacity required, and consequently more space available for cargo, or with same bunker capacity ability to steam longer without coaling. With engines working at 250 lbs. boiler pressure and an estimated economy of 18 per cent., the consumption would be reduced to 14 tons per day. The number of steaming days will average about 190 in the year and the saving on the bunkers at, say, 8s. per ton, would be

$$\frac{8 \times 190 \times 3}{20} = £228 \text{ per annum.}$$

ing at the higher pressure costs the same and occupies the same space as the triple expansion machinery, also that the cost of repairs, engine room stores, and wages are the same in both cases.

Suppose, however, that the higher pressure machinery costs £1,500 more than the triple expansion machinery, still occupying the same space, then the above saving will be reduced by the interest on £1,500 at, say, 8 per cent. = £120, and the saving to the shipowner will be only £8,602 − £8,184 = £418 = 5 per cent. of total expenses.

Or, suppose that the higher pressure machinery occupies a frame space more than the triple engines, but costs the same money, then the above saving will be reduced by the value of one frame space = 1,776 cubic feet = 45 tons cargo at, say, 48s. per ton per annum = £108, and the saving to the shipowner will be only £8,602 − £8,172 = £430 = 5 per cent. on total expenses. If the machinery were to cost £1,500 more, and occupy one frame space more, the saving would be only £8,602 − £8,292 = £310 = 3½ per cent. of total expenses.

From this it will be seen that if the higher pressure is to be adopted it is very essential that the new machinery should not cost any more, nor occupy more space, than the triple expansion machinery.

We can now pass on to consider the boiler question. The first question which arises is: How will the new conditions affect the transmission of the heat through the heating surface?

From Peclet's experiments and deductions it would appear that the quantity of heat transmitted through a plate varied as (1) the surface exposed, (2) as the difference of temperature of the plate on the fire side and on the water side, and (3) inversely as the thickness of the plate, or

$$M = (t_1 - t_2)\,\frac{C}{E}$$

where M = thermal units transmitted,

t_1 = temperature of plate on fire side,

t_2 = ,, ,, water side,

C = constant depending on material and state of surface,

E = thickness of plate.

Peclet's experiments, however, were carried out by steam heat only, and are thus not applicable to the case of fire heat.

Rankine is of opinion that the transmission by fire heat to water varies as the square of the difference of temperature between the fire and the water, and the experiments carried out by Mr. Blechynden apparently confirm this theory.

Mr. Hudson, in a paper reviewing experiments on heat transmission, is of opinion that in all probability the difference of temperature between the two surfaces of a plate, transmitting the same quantity of heat, will be the same whether the transmitting medium be fire heat or steam heat, but that a much higher temperature of medium is required in the case of fire heat to keep up the temperature of the hotter side of the transmitting plate; that is to say, the internal resistance of the plate is the same whatever the transmitting medium may be.

This theory reconciles the apparently contradictory results obtained by experiments with fire heat and steam heat.

Plate XLII. shows the results of one set of Mr. Blechynden's experiments on a plate of varying thickness. From it, it will be seen that for thicknesses, varying from $\frac{1}{2}$ inch to $1\frac{1}{8}$ inches, the transmission for any given difference of temperature varies approximately as the square root of the thickness. Below $\frac{1}{2}$ inch thickness, however, the transmission varies apparently as some higher root of the thickness.

It should be remembered that these experiments deal chiefly with the effects of radiant heat, and it may be that for convective heat the thinner plates may transmit heat varying as the square root of the thickness.

In Dr. Kirk's experiments, it will be remembered that with thick plates the heat transmission was so small that the plate next the fire became red-hot, the plate next the water being only at 212 degs. Fahr. From this it would appear that for plates above $1\frac{1}{8}$ inches, say, the transmission would vary inversely as the thickness. Hence, in default of more experiments, we may assume in the meantime that the transmission varies as the square of the difference of temperature between the fire and the water, inversely as the thickness of the plate for thick plates, inversely as quantity of heat we would require 9 per cent. more heating surface. With the same quantity of heat received we may expect an increase of steam economy of 18 per cent. Hence the higher pressure boiler to develop the same power should have 18 per cent. less grate surface but only 9 per cent. less heating surface than the lower pressure boiler, provided the thickness of the heating surface remains the same in both cases.

The importance of keeping down the cost and the space occupied by the higher pressure machinery has been insisted upon above, and since the cost of the engines will certainly not be less, and the space occupied if four cranks are adopted may be more, then the whole of the saving must be made in the boiler space. This should be a very important factor in deciding upon the best type of boiler for the increased pressure.

A satisfactory boiler for 250 lbs. working pressure suitable for the mercantile marine should have the following qualifications :—

First—The design should be such that the pressure may be carried safely with the minimum thickness of the material forming the heating surfaces.

Second—It should have a large and free combustion chamber to allow the gases to combine properly before they lose any of their heat by contact with any of the heating surface.

Third—After leaving the combustion chamber the gases should be split up into small streams and well distributed over the heating surface.

Fourth—Sufficient time should be given to allow the gases to give up the desired amount of their heat before they pass away to the uptake.

Fifth—There should be a sufficiently large body of water over the highest heating surface to allow the boiler to run some time with the feed shut off.

Sixth—Every part of the boiler, both inside and out, should be accessible for examination, cleaning, and repairs, and every part exposed to the heat of the furnace or hot gases should be renewable without interfering with the main structure of the boiler. Also, all tubes should be straight, of fairly large diameter, and of the same length.

Seventh—The lower part of the boiler should be so arranged that if any mud or grease collects there it can do no harm by causing over-heating.

Eighth—The circulation of water should be active and natural.

Finally—The cost of construction and the space occupied should not be more, and if possible should be less, than the present return-tube boiler.

As regards the first point, viz., the thickness of the material forming the heating surface, this is a most important point, as the increased temperature of the water will decrease the efficiency of the heating surface, and if, in addition, the plates have to be made thicker for the increased pressure, we shall still further decrease the efficieney. For instance, the thickness of circular furnaces would be increased for the higher pressure, unless the diameter were decreased. The thickness of the plates forming flat stayed surfaces would also need to be increased, the alternative being to decrease the pitch of the stays.

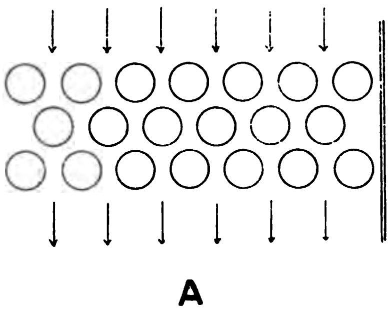
The thickness of plain tubes would not need to be increased to any appreciable extent, but stay tubes would need to be thicker or closer pitched. Hence, to satisfy this first condition, preference should be given to a boiler in which the greater part of the heating surface consists of plain tubes.

As regards the second point, viz., the size and disposition of the combustion chamber, this has a well-known bearing on fuel economy.

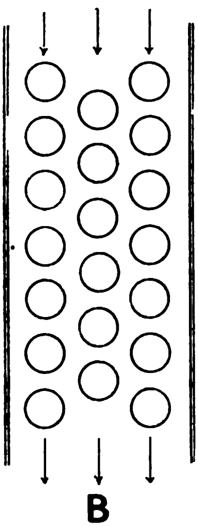
It is of the utmost importance to have a large combustion chamber where the furnace gases may combine before they part with their heat, and where unconsumed gases may have room to pick up more oxygen or more heat, as if their temperature is not raised to the combining temperature they will pass away to the funnel unburnt, entailing a serious loss of heat. The ideal combustion chamber would be a large free space directly over the furnace.

As regards the third and fourth points, viz., the distribution of the tion. The area for the passage of the gases is the same in both cases, hence the velocity of the latter will be the same, but with the tubes arranged as in sketch B the gases will take more than twice the time to traverse the heating surface than when arranged as in sketch A.

Now, it might be that the time occupied in case A would not be sufficient to extract the desired quantity of heat from the gases, and this would place the arrangement A at a distinct disadvantage, although it has the same heating surface as B.



Hence, preference should be given to a boiler which splits up the gases leaving the combustion chamber into small streams, and compels them to travel some considerable distance in contact with the heating surface before they pass away to the uptake.



As regards the fifth point, viz., the amount of water over the highest heating surface, the weight of water should be such as to allow the engines to run some little time with the feed shut off, as it will contribute a great deal to the comfort and peace of mind of the engineer if he knows that in case of a failure of the feed pumps he can run the engines some time without burning the boiler.

As regards the sixth point, viz., accessibility for cleaning and repairs, and facilities for renewing damaged or defective parts, this is perhaps the most important point affecting the good working of the boiler. Absolute cleanliness of the heating surface is a necessity even for 150 lbs. pressure, and in spite of feed filters and evaporators a certain amount of sediment and scale will find its way into a boiler, so that it is very necessary to have every facility for cleaning. It is also very desirable that all parts of the boiler exposed to the heat of the furnace gases should be arranged to be conveniently renewed.

All boilers are arranged to allow of re-tubing, but very few are arranged to allow of new furnaces being fitted, and in most cases a new combustion chamber means a new boiler.

It is also desirable that the boiler should be arranged to allow of recaulking all over, both inside and outside. All tubes should be straight, or nearly straight, and of the same length, otherwise a great number of spare tubes must be carried. They should also be of fairly large diameter, say not less than 2 inches. This permits them to be examined from end to end.

As regards the seventh point, viz., provision at the bottom of the boiler of a quiet place where mud and grease may collect: a certain amount of mud and grease will get into a boiler, and it is well known that this is the most fruitful cause of collapsed furnaces. Hence, surfaces at the bottom of the boiler where grease could lodge should not, if possible, be exposed to heat.

As regards the eighth point, viz., the water circulation, this affects not only the good working of the boiler, but also the efficiency of the heating surface. In the first place, the circulation should be natural, *i.e.*, there should be no necessity for a pump or hydrokineter or other complications to compel the water to circulate.

A free and natural circulation is especially valuable when raising steam, so that the whole of the water in the boiler may be at practically the same temperature, and thus avoid racking strains on the boiler through unequal expansion.

A good circulation on the water side of a heating surface is just as essential, and perhaps more efficient than a good circulation of the gases on the fire side. The most effective combination would be a moderate velocity of the gases and a great velocity of the water, and the water and gases moving in opposite directions.

The best means of securing a maximum velocity of the water will be by vertical water tubes, as the entraining action of the steam bubbles

That it is capable of being worked at 250 lbs. pressure has already been demonstrated in the case of the s.s. "Inchmona." For this pressure, however, it is absolutely necessary to keep the diameter of the furnace as small as possible, hence some system of assisted draught is a necessity in order to burn the requisite amount of coal.

The thickness of the material composing the heating surface will be considerably increased over the thickness required for 150 lbs. pressure, viz., the furnaces by about 25 per cent., fireboxes and tube plates by about 10 per cent., and the stay tubes by about 50 per cent.

To estimate the combined effect of all these different increases of thickness, as well as the effect due to increase of temperature of the water, it is assumed that for the furnace and firebox heating surface the heat transmission varies as the square root of the thickness of plate, and that the increase of thickness of the stay tubes has no appreciable effect upon the heat transmission.

The temperature in the furnace may be taken at 2,500 degs. Fahr., in the firebox at 1,800 degs. Fahr., and the mean temperature in the tubes at 1,250 degs. Fahr.

Then for the furnaces we have:—

$$\frac{(2{,}500 - 366)^2}{(2{,}500 - 406)^2} \times \sqrt{1{\cdot}25} = 1{\cdot}16,$$

i.e., 16 per cent. less efficiency than under the lower pressure conditions.

For the fireboxes:—

$$\frac{(1{,}800 - 366)^2}{(1{,}800 - 406)^2} \times \sqrt{1{\cdot}10} = 1{\cdot}10,$$

i.e., 10 per cent. less efficiency than under the lower pressure conditions

For the tubes:—

$$\frac{(1{,}250 - 366)^2}{(1{,}250 - 406)^2} = 1{\cdot}09,$$

i.e., 9 per cent. less efficiency than under the low pressure conditions.

Taking the usual proportions of heating surface in an ordinary return-tube boiler and debiting each part with its own deficiency, the decrease of efficiency amounts to 9½ per cent. on the total surface. That is to say, assuming a steam economy of 18 per cent. for 250 lbs. pressure, the boilers, if of the ordinary return-tube type, could have 18 per cent. less grate, but only 8½ per cent. less heating surface than the lower pressure boilers.

As regards the combustion chamber, the return-tube boiler is very well off. The furnace crown, however, especially with small furnaces, is apt to cool down the gases given off by green fuel, but the firebrick bridge acts as an equaliser of temperature and tends to counteract the cooling effect.

In order to institute a means of comparison between different types of boilers in the matter of combustion chambers take, say, two single-ended boilers 14 feet 6 inches by 10 feet 6 inches, with a heating surface of 3,750 feet, and a grate surface of 118 feet. We may take one-half the volume of the furnaces above the bars as forming part of the combustion chamber.

This, together with the fireboxes, gives a total capacity of 480 cubic feet for the two boilers.

Nothing better in the way of dividing up the gases into small streams, and ensuring their distribution over the heating surface, could be desired, than the arrangement of fire tubes of the present boiler.

The distance travelled by the gases from the firebars to the uptake also allows ample time for the heating surfaces to absorb the desired amount of heat. In the boilers we have taken above as an example the mean distance travelled by the gases from the firebars to the uptake is 17 feet.

As regards the quantity of water over the highest heating surface the boiler under question is perhaps superior to any other.

Take the same two boilers as above indicating, say, 1,000 indicated horse-power, the weight of water, 6 inches over the highest heating surface, would be 8,788 lbs. Then if the engine were using 16 lbs. water per indicated horse-power per hour, the feed could be shut off for 30 minutes without exposing the heating surface.

The return-tube boiler is fairly accessible for cleaning. All parts are lating the water in the boiler is essential, otherwise it may easily happen that the body of water under the line of firebars remains quite cold even when steam is being generated above, thus causing serious racking stresses in the boiler.

Finally, as regards the cost of the return-tube boiler, it will certainly not cost less than a boiler working at 150 lbs. pressure and doing the same work, as, owing to the increased thickness of the heating surface and the increased temperature of the water, the higher pressure boiler will need to have almost as much surface as the lower pressure one, consequently its size cannot be reduced to any extent. This, added to the extra scantlings required for the higher pressure, will undoubtedly bring up the cost to that of the lower pressure boiler.

The other types of boiler which have been used on board ship are the locomotive type and the navy type. These have, however, been discarded for various reasons, hence we need not discuss them further.

Passing on to the water-tube types, these can be divided roughly into two classes, viz., those with vertical water tubes, and those with horizontal water tubes, or, more correctly, those whose tubes are more nearly vertical than horizontal, and those whose tubes are more nearly horizontal than vertical. To the former class belong the haystack boiler, Yarrow's, Thorneycroft's, Normand's, Fleming and Ferguson's. Reed's, Blechynden's, and others; and to the latter class belong Belleville's, Babcock and Wilcox's, Niclausse's, Anderson and Lyall's, and others.

The haystack boiler is totally unsuited for 250 lbs. pressure, although it is lighter and occupies less space than any of the shell boilers.

For purposes of comparison we may take as one class the Yarrow, Thorneycroft, Normand, Reed, and Blechynden boilers.

As regards thickness of heating surface, these boilers are very favourably situated, as almost the whole of the surface, including that surface which takes up the radiant heat of the fuel, is composed of tubes of small diameter, and being exposed to internal pressure, may consequently be made very thin. The combustion chambers of these boilers are almost ideal, viz., a large free space over the firebars. To compare the volume of the combustion chambers of these boilers with that of the Scotch boiler, take for example three of any of the above types, having the same grate surface as the two Scotch boilers, viz., 118 square feet. The volume of the combustion chambers for the three boilers will be about 525 cubic feet, which is more than that of the two Scotch boilers. Hence, this class of water-tube boiler, as regards combustion, should be superior to the Scotch boiler, provided the same quantity of coal were burnt per square foot of grate, as the volume of the combustion chamber should be determined by the weight of coal burnt.

In the boilers under question the gases, after leaving the combustion chamber, are well split up and distributed over the heating surface, but the distance travelled by the gases before they pass into the uptake is so small that it will be impossible to lower the temperature of the gases to an economical point. For instance, the mean distance travelled by the gases from the firebars to the uptake is only about 5 feet in the Yarrow boiler, and somewhat more in the other varieties, against 17 feet in the Scotch boiler. As regards weight of water over the highest heating surface, these boilers are so deficient that an automatic feed arrangement is desirable.

For instance, in the three boilers taken as an example the weight of water at 6 inches over the highest heating surface is about 2,625 lbs.; that is to say, the surface would be exposed if the feed were shut off for only ten minutes.

These boilers are very accessible for cleaning, examination, and repairs, except those with curved tubes. As the whole of the surface exposed is composed of tubes, it is an easy matter to renew the whole or any part of them.

All these boilers have lower drums shielded from the heat of the furnace, where grease and mud may collect without doing harm.

The circulation of water in these boilers is natural and leaves nothing to be desired. This, combined with their form, renders straining from unequal temperatures impossible, and allows steam to be raised in a very short time without the trouble of mechanical circulation.

As regards the thickness of the heating surface, these boilers are under the same favourable conditions as the other class of water-tube boilers. As regards size of combustion chamber, they are, generally speaking, deficient. For instance, take three Belleville boilers of same grate surface (118 square feet) as the two Scotch boilers we have been using as examples. The volume of the combustion chambers for these three boilers amounts to only 255 cubic feet, against 480 cubic feet for the Scotch boiler, and 525 cubic feet for the other class of water-tube boilers. Besides the deficiency in volume, they are of insufficient height, the consequence being that whenever fresh fuel is put on some of the liberated gases reach the lower row of tubes before they have time to get heated up and combined. They pass among the tubes unconsumed until they reach the uptake. If they meet a hot current of gases from another boiler they will burn in the uptake, if not they will pass up the funnel unconsumed. The former event is probably what happened during the first trials of H.M.S. "Powerful," when the base of the funnel became red-hot. The evils of a shallow combustion chamber are aggravated by a thick fire, and to get good results with a combustion chamber of this type needs a thin fire and firing little and often.

One of the features of the Belleville boiler is the arrangement of air jets above the firebars. These jets serve two purposes : first, they tend to secure a better combustion than would otherwise be possible ; and secondly, they tend to protect the lower row of water tubes, which apparently sometimes suffer from overheating. As regards the splitting up of the gases after leaving the combustion chamber, and their distribution over the heating surface, the boilers of the type we are considering are quite equal to any of the types before considered, and as regards the distance travelled by the gases, before they pass away to the uptake, they are very superior to the other class of water-tube boiler. For instance, in the three Belleville boilers used as before for comparison, the mean distance travelled by the gases from the firebars to the uptake is about 9 feet compared with about 5 feet in the Yarrow boiler.

As regards the weight of water carried above the highest heating surface, this type of boiler is provided with a drum connected with the front and back headers, and if the drum is of sufficient capacity, a large weight of water can be carried over the highest heating surface. The Belleville boiler is, however, worked in a special manner and requires a feed regulator.

As regards accessibility and convenience for repairs this class of boiler is very well off, except perhaps in the matter of cleaning the tubes externally, especially in cases where deflectors are placed on the tubes.

The tubes are all straight, of large diameter, and uniform length, thus dispensing with the necessity of carrying a great number of spare tubes and allowing for internal inspection of each tube.

The majority of these boilers are provided with a mud drum at the bottom, where sediment may collect and be removed at intervals. The circulation of water in this class of boiler is satisfactory, provided the tubes are of sufficiently large diameter, and the fires are not much forced. With small tubes and forced draught there is a risk of burning the lower tubes owing to failure of the circulation. If there is any risk of this, and the headers are in one piece from top to bottom, they should be sufficiently flexible to allow for the unequal expansion of the top and bottom rows of tubes, as cases have happened of cracked headers due to this cause. As regards cost of construction and space occupied, this class of boiler is inferior to the other class of water-tube boiler, but much superior to the Scotch boiler.

Summing up, we may say that the Scotch boiler working at 250 lbs. pressure would burn the fuel well and utilise the heat satisfactorily, it would contain plenty of water to allow for irregularity in the feed, it would be not quite so accessible as the lower pressure boilers of the same type, and would have the same defects as to repairs of the internals. The danger from the presence of grease would certainly not be less, and the circulation would not be better. Extra care would be needed in raising and letting down steam to avoid straining from unequal temperature. Finally, the cost of construction would be more than that of the lower pressure boiler, and the space occupied only very little less.

The water-tube boilers of the Thorneycroft, Yarrow, Normand, etc., type would burn the fuel well, but would not utilise the heat satis-

There are, up to the present, very few published trials of water-tube boilers on which any reliance can be placed, as the majority of them have been carried out by measuring the feed-water pumped into the boiler, but how much of this has been turned into steam is not known. The coal consumption trials of H.M.S. "Sharpshooter" and H.M.S. "Powerful" give the combined efficiency of the engines and boilers, which is very satisfactory compared with similar trials of the Scotch boiler, but how much this good result depends upon the higher boiler pressure and how much on the boiler itself is not known.

We can now pass on to discuss questions as to the best design for an engine suitable for 250 lbs. working pressure. The first question which arises is: Into how many stages should the expansion be divided? When the triple expansion engine was first introduced, and effected a saving of 25 per cent. in the coal consumption, its main source of economy was attributed to the use of three stages in the expansion, giving a small temperature range in each individual cylinder. This theory has, of late years, been to some extent discredited. The only method of getting at the truth would be to carry out a scientific experiment with engines indicating about the same power, with same boiler pressure and number of expansions, one with two cylinders and two stage expansion, and the other with three cylinders and three stage expansion. No amount of theorising will lead to any reliable conclusion, and Prof. Weighton's experiments on this subject will be awaited with interest.

As pointed out in the beginning of this paper, the economy due to raising the boiler pressure from 80 lbs. to 150 lbs. is theoretically about 23 per cent. As the maximum economy claimed by the triple expansion engine over the compound is not more than 25 per cent., there is no need to call in the three stage expansion to account for the economy.

The total temperature range for steam of 80 lbs. boiler pressure is 171 degs. Fahr.: this, divided into two equal stages, gives a range of 85½ degs. Fahr. for each cylinder. The total temperature range for 150 lbs. boiler pressure is 213 degs. Fahr.: this, divided into three equal stages, gives a range of 71 degs. Fahr. in each cylinder. That is to say, there is only a difference of 14 degs. Fahr., under the most favourable conditions, between the temperature range of the compound and the triple expansion. Hence, in default of experiments on temperature range, we need not tie ourselves down to multiple expansion stages on account of steam economy.

The next question is that of number of cranks. The three-crank engine has now almost displaced the two-crank engine, on account of its more equable turning and balance, and four-crank engines are now coming into favour.

The four cranks offer great facility for balancing the moving parts, and should, therefore, be adopted for a high number of revolutions, and where absence of vibration is of importance. They will, however, occupy more space fore and aft, thus necessitating a longer engine room, unless special means are taken to make the engine short.

The next point is the arrangement of cylinders.

In the first place, tandem cylinders should only be used in cases of absolute necessity, owing to the inconvenience of overhauling the lower cylinder.

Then, with three cranks, we may have two arrangements of cylinders, viz., (1) one high pressure and two low pressure; (2) one high pressure, one intermediate, and one low pressure.

With four cranks three arrangements are possible, viz., (1) two high pressure and two low pressure; (2) one high pressure, one intermediate, and two low pressure; and (3) one high pressure, one first intermediate, one second intermediate, and one low pressure.

The most important qualifications for economy of design and working are :—

First, the initial loads in each cylinder should be equal.

Second, the cuts-off should be as late as possible, and practically equal in each cylinder, and so arranged that when working at the maximum voyage power the valve gear will be operating at its maximum efficiency.

Third, the "drop" between the cylinders should be as small as possible consistent with economy of size of cylinders.

initial loads; in fact, the total weight of engines of the same type should vary directly as the sum of the initial loads and some power of the stroke.

Plate XLIII. shows this relation for three-crank triple expansion mercantile engines.

It is also an advantage to have the cuts-off in each cylinder as nearly equal as possible.

With the link motion there is a particular point of cut-off where the maximum efficiency is attained, that is to say, where the mean speed of steam during the admission is a maximum with a given travel of value.

Plate XLIV. has been constructed to show this.

It will be seen that the later the cut-off the better the result, and that the efficiency falls off rapidly for cuts-off at less than 50 per cent.

The cut-off in the high-pressure cylinder should not be much less than 50 per cent. when linked up, as the later the cut-off the less is the proportionate loss from clearance, and an earlier cut-off than this in the other cylinders would mean a large increase of admission speed in the very cylinders where it is most difficult to get sufficient steam opening.

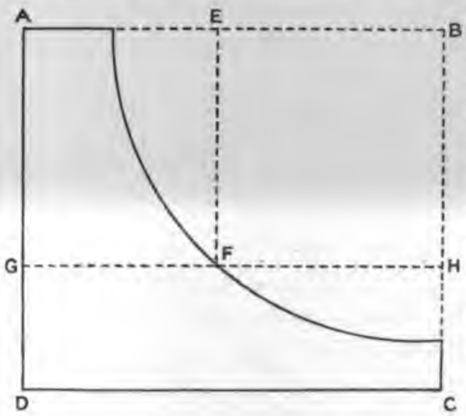
The diagrams have been constructed by dividing the engine stroke into a number of small intervals, getting the mean opening during each interval from the valve diagram, and calculating the speed of steam due to this mean opening and the mean velocity of the piston during the said interval. The curve represents the mean of both ends of the cylinder.

The best conditions as regards "drop" will be obtained if there is no "drop," or a "drop" of a few pounds at the minimum voyage power (*i.e.*, ship in ballast), which will give a reasonable drop for the loaded ship horse-power.

Initial Load.

Although, as pointed out above, we need not tie ourselves to multiple expansion stages on account of any expected economy due to lessened temperature range, yet the use of more than one stage has the important effect of diminishing the sum total of the initial load, and, generally speaking, the more stages we use the less will be the total loss from "drop." The above sketch shows the effect of single and double expansion stages on the initial load.

If only one cylinder were used, the initial load would be represented by the rectangle A B C D, vertical ordinates representing pressures, and horizontal ordinates areas of cylinder: or taking a cylinder 49 inches in diameter, with 4 lbs. back pressure and 250 lbs. initial pressure in the cylinder, the total initial load would be 463,700 lbs. If, however, the expansion were divided into two stages, the total initial load would be represented by the two rectangles A E F G and G H C D, or with



cylinders $15\frac{1}{2}$ inches by 49 inches, the combined initial load would equal 85,200 lbs., a reduction of no less than 80 per cent. on the single stage load. Of course the actual reduction in weight would not be so much as this, as the weight of one engine with a certain initial load will be less than the combined weight of two engines with the same combined initial load.

For two stage three-crank engines with cylinders $15\frac{1}{2} \times 34\frac{1}{2} \times 34\frac{1}{2}$ the combined initial loads = 115,415 lbs., an increase of 35 per cent. over the combined loads for the two stage two cylinder arrangement. For the three stage three cylinder engine, with cylinders $15\frac{1}{2} \times 26\frac{1}{2} \times 49$ the combined initial load = 95,700, rather more than with the two stage two cylinder arrangement.

For the three stage four cylinder arrangement, with cylinders $15\frac{1}{2} \times 25\frac{1}{2} \times 34\frac{1}{2} \times 34\frac{1}{2}$, the combined initial load = 118,900 lbs., an increase of 24 per cent. over the three stage three cylinder arrangement.

For the four stage four cylinder arrangement, with cylinders

From which it will be seen that the worst results after the single stage arrangement is attained by the divided low-pressure cylinder arrangements.

Cut-off.

The following table shows the cuts-off in each cylinder to give equal initial loads with the above cylinder ratios :—

Two stage, 2 cylinders or, two stage, 4 cylinders	Cylinders	15½	49	—	—
	Cuts-off, per cent.	54	42	—	—
Two stage, 3 cylinders	Cylinders ...	15½	34½	34½	—
	Cuts-off, per cent.	54	27	27	—
Three " 3 "	Cylinders ...	15½	26½	49	—
	Cuts-off, per cent.	54	54	54	—
Three " 4 "	Cylinders ...	15½	25½	34½	34½
	Cuts-off, per cent.	54	51	33	33
Four " 4 "	Cylinders ...	15½	22	32	49
	Cuts-off, per cent.	54	55	55	57

From which it will be seen that the greatest uniformity of cut-off is attained by the three stage three cylinder, and the four stage four cylinder, and that the cuts-off in the divided low-pressure cylinders are impossibly early.

The two stage two or four cylinder arrangement may be arranged to have equal initial loads, and equal cuts-off by increasing the high-pressure cylinder as shown below.

Two stage, 2 cylinders or, two stage, 4 cylinders	Cylinders	20½	49
	Cuts-off, per cent.	30	30

Combined initial load = 138,700.

With the two stage three cylinder and the three stage four cylinder it is impossible to get equal initial loads and equal cuts-off unless the terminal pressure in some of the cylinders is below the back pressure.

The latter arrangement of two stage two or four cylinder would be suitable if equal loads and equal cuts-off were desired, and if the total expansions were, say, 10½ instead of 18½, thus making the cuts-off in each cylinder 54 per cent.

Of course this arrangement entails an addition of 60 per cent. to the total initial load of the unequal cut-off arrangement.

It will be interesting at this point to give the actual initial loads of some three stage four cylinder engines. These below are for H.M.S. "Powerful," the particulars being taken from the published indicator cards taken on her trial trip.

H.M.S. "POWERFUL."

High pressure	=	213,000 lbs.
Intermediate pressure	=	219,300 lbs.
Low pressure	=	104,300 lbs.

It will be noticed that the initial load on each low-pressure cylinder is less than one-half the load on the high-pressure and the intermediate-pressure cylinder.

If the initial loads had been equal the load on each cylinder would have been 177,000 lbs. The load on the intermediate pressure is, however, actually 219,300 lbs., and as the rods, etc., are of the same scantlings throughout, the weight of the moving parts and the surface of the principal bearings are approximately 25 per cent. greater than would have been necessary with equal initial loads.

The writer is not aware of the reason for this. Probably the equal initial loads would have entailed a too early cut-off in the low-pressure cylinders, and consequent insufficiency of steam opening; or perhaps the size fixed upon for the intermediate cylinder would, with equal initial loads, have brought the terminal pressure of that cylinder below the back pressure; or it may have been deemed expedient to keep the pressure in the low-pressure steam-chest as low as possible to minimise the load on the slide valves.

DROP.

We can now consider the question of "drop" between the cylinders. To attempt to determine the theoretical loss due to drop would involve a very complicated calculation.

In the first place, when steam expands without doing external work,

Type.	Initial Loads and Cut-off.	Cylinders.	Drop.	Loss Due to Drop.
			Lbs.	Per Cent.
Two stage ... 2 or 4 cylinders	Equal loads ... Unequal cuts-off	15½ × 49	81	15
Two stage ... 2 or 4 cylinders	Equal loads .. Equal cuts-off ...	20½ × 49	25	2
Two stage .. 3 cylinders ..	Equal loads Unequal cuts-off	15½ × 34½ × 34½	75	10
Three stage .. 3 cylinders ..	Equal loads ... Equal cuts-off ...	15½ × 26½ × 49	42, 12	4½
Three stage ... 4 cylinders ...	Equal loads ... Unequal cuts-off	15½ × 25½ × 34½ × 34½	21, 1	1
Four stage ... 4 cylinders ...	Equal loads ... Equal cuts-off ...	15½ × 22 × 32 × 49	1, 1, 2	½

From which it will be seen that the best result is attained by the four stage four cylinder type and the worst by the two stage two or four cylinder type, with equal initial loads and unequal cuts-off.

Turning Moment.

In order to compare the turning moments of the different types of engine, both three and four crank, Figs. 1-6 (Plates XLV., XLVI., and XLVII.) have been prepared.

The different types of engine have all the same area of low-pressure cylinder or cylinders, the same stroke, number of expansions, and revolutions.

Also approximately the same mean pressure referred to the low-pressure cylinder. Hence the mean turning moment will be approximately the same for each type. The pressures have been taken from diagrams constructed to be as nearly like the actual diagrams as possible.

The inertia of the moving parts has been calculated on the assumption that the angular velocity of the crank shaft is constant.

The weight of the moving parts has been proportioned to the initial load, and the pistons have been taken as of ordinary cast iron design.

From these diagrams we see that the engines which give the most equable turning moment are the four cylinder two stage and the four cylinder four stage, with a variation of 14 per cent. above the mean turning moment and 34 per cent. below for the two stage, and 23 per cent. above and 27 per cent. below for the four stage.

Fig. 6 (Plate XLVII.) shows the disastrous effect on the turning moment with unequal initial loads. In the diagram shown the initial loads in each of the two low-pressure cylinders are one-half the load on the high-pressure and intermediate-pressure. The result is that the maximum turning moment is 39 per cent. greater than the mean, and the minimum 60 per cent. less than the mean, giving a total variation of 99 per cent.

Taking into account all the above facts as to initial load, cuts-off, drop, and turning moment, it would appear that for ordinary mercantile work the three cylinder three stage type is the most suitable, if three cranks are to be used, as it has less total initial load, more equal cuts-off, less loss from drop, and a more equable turning moment than the two stage three cylinder type.

If four cranks are desired the most suitable arrangement for ordinary mercantile work is the four stage four cylinder arrangement, as it has less initial load, more equal cuts-off, less loss from drop, and a more equable turning moment than the three stage four cylinder type.

For navy engines the two stage four cylinder type has many advantages to recommend it. It has less initial load than any of the other arrangements. The cuts-off are not equal, but with the fewer total expansions required by navy engines the cut-off in the low-pressure would be sufficiently late to give enough valve opening. The loss from drop is more than in the other types, but that is not of such importance in the case of navy engines.

The turning moment is more equable than any of the other types, and as the maximum moment is only 14 per cent. more than the mean, whereas in the three stage four cylinder type with unequal initial loads pressure forward, intermediate pressure in centre, and low pressure aft; valve chests all looking forward, two short ends of crank shaft between high pressure and intermediate pressure; two long ends or a short and a long between intermediate pressure and low pressure; intermediate pressure eccentrics on couplings. (2) High pressure in centre, intermediate pressure forward, and low pressure aft; high pressure piston valve and intermediate slide valve in one chest between the cylinders, low pressure slide valve forward of cylinder; short and long length of crank shaft between high pressure and intermediate pressure, also between intermediate pressure and low pressure; high pressure eccentrics on couplings; and (3) the Admiralty design high pressure forward, intermediate pressure in centre, and low pressure aft; high pressure valve forward, intermediate pressure valve forward, low pressure valve aft of cylinder; short and long length of crank shaft between high pressure and intermediate pressure, two short lengths between low pressure and intermediate pressure; no eccentrics on couplings.

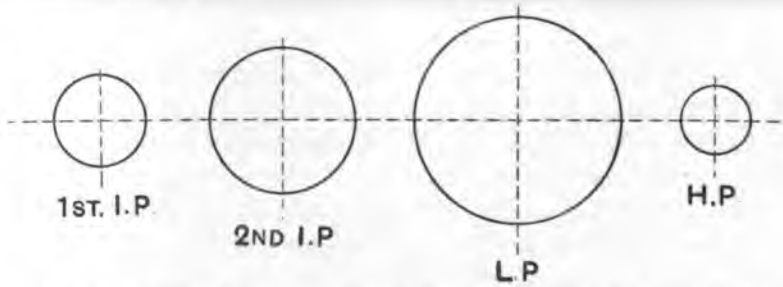
In the four-crank engine the great object will be to save fore and aft space, and some endeavour should be made to reduce as far as possible the number of bearings and working parts. For instance, the crank shaft may be in two pieces only, interchangeable. By doing this six main bearings only are required, provided the two forward cranks and the two after cranks are arranged opposite one another, to take the greater part of the stress off the single bearing between the two forward cylinders and the two after cylinders. Then, if the length of the engines is not to exceed the length of the three-crank engines, two of the valves must be off the centre line of the engine, and if the first and second cylinders are fitted with piston valves, there is no reason why they should not be arranged in that manner. If the two after cylinders and the two forward cylinders have their cranks opposite one another, and if the cuts-off in each cylinder are equal, or nearly equal, then only two sets of valve gear are required, and they may be put together in the centre of the engine, thus reducing the length of the reversing shaft to a minimum.

The slide valves of the two centre engines would look towards one another, and the piston valves at the back of the engines would be worked by rocking shafts, worked by levers and links from the slide valve rods.

There is a prejudice against having valves off the centre line of the engines, no doubt justified when a heavy slide valve is worked by an overhung pin; such an arrangement is bound to give trouble owing to the want of stiffness of the overhung pin; but there can be no objection mechanically to a piston valve worked in that manner, provided there are no overhung pins.

It should be mentioned here that the above arrangement, with the two opposite cranks separated only by the length of the main bearing, is the most suitable one for balancing the weight of the moving parts, as it makes the "arm" of the "rocking" couple, *i.e.*, the distance between the centres of the two opposite cranks as short as possible.

For the four stage type the shortest arrangement of cylinders would be to have the high pressure and the low pressure forward and the two intermediate aft, thus :—



This will make the cranks of the high pressure and first intermediate at right angles the first intermediate and second intermediate opposite; and of the second intermediate and low pressure at right angles. If it were desired to have the cranks of successive cylinders at right angles the arrangement below could be adopted :—

cylinder rising much above, the mean back pressure, the Plates XLIX. and L. have been prepared to show the variation in the exhaust line of the high pressure, first intermediate, and second intermediate, and also the variation in the admission pressure of the first intermediate, second intermediate, and low-pressure cylinders for cranks at right angles and cranks opposite. They also show the effect of different capacities of receiver space, the full lines representing the effect with receiver capacity equal to the cylinder, and the dotted lines the effect with receivers equal to twice the cylinder capacity.

The method of setting out is that described by Prof. Unwin in *Elements of Machine Design*, except that allowance has been made for the effect of the angularity of the connecting rods. It will be seen that, on the whole, the least increase of initial load is secured by the cranks at right angles at the lower pressures. Hence the cranks of the second intermediate pressure and the low pressure should always be arranged at right angles; and if it is a convenience to have any of the cranks opposite, they should be the high pressure and the first intermediate pressure, and the first intermediate pressure and the second intermediate pressure.

In conclusion, the writer would again emphasise the main point which he has attempted to bring out in the paper, viz., the importance of keeping down the cost of the new machinery. This means that a change to a cheaper type of boiler would be desirable, and that the design of the engines should be such as will give the minimum number of bearings and working parts.

APPENDIX.

Calculation (A).

Boiler pressure 80 lbs. = 95 lbs. absolute.
Total expansions = $6\frac{3}{4}$.
Back pressure = 4 lbs.
Drop to cylinder = 10 lbs. = 85 }
Drop to cut-off = 12 lbs. = 73 } 79 lbs. mean initial.

$$\left\{ 79\left(\frac{10}{6{\cdot}75} - \frac{9}{(6{\cdot}75)^{\frac{10}{9}}}\right) - 4 \right\} \times {\cdot}77 = 21{\cdot}5 \text{ lbs. mean pressure.}$$

CALCULATION (B).

Boiler pressure 150 lbs. = 165 lbs. absolute.
Total expansions = $11\frac{3}{4}$.
Back pressure = 4 lbs.
Drop to cylinder = 12 lbs. = 153 } 144 lbs. mean initial.
Drop to cut-off = 18 lbs. = 135 }

$$\left\{ 140\left(\frac{10}{11\cdot75} - \frac{9}{(11\cdot75)^{\frac{10}{9}}}\right) - 4 \right\} \times \cdot78 = 26\cdot5 \text{ lbs.}$$

CALCULATION (C).

Boiler pressure 250 lbs. = 265 lbs. absolute.
Total expansions = $18\frac{1}{2}$.
Back pressure = 4 lbs.
Drop to cylinder = 15 lbs. = 250 } 240 lbs. mean initial pressure.
Drop to cut-off = 20 lbs. = 230 }

$$\left\{ 240\left(\frac{10}{18\cdot5} - \frac{9}{(18\cdot5)^{\frac{10}{9}}}\right) - 4 \right\} \times \cdot78 = 31\tfrac{1}{2} \text{ lbs.}$$

DISCUSSION.

The SECRETARY read the following letter :—

GLENALMOND ROAD, EGREMONT,

DEAR MR. DUCKITT, *13th April*, 1897.

I have skimmed through Mr. Cummins's paper, just received, and look forward with pleasure to a more careful perusal when time permits.

The reference to the engines of H.M.S. "Powerful" arrested my attention and rather interests me. Some two months ago *Engineering*, in recording the "Terrible's" trials, made reference to the "characteristic pluck" of the builders, who attempted to get equal powers in the cylinders by adjusting the cut-offs; and I tried to raise a discussion by having a letter inserted in that paper suggesting that the sizes of the cylinders were at fault. My letter elicited no reply; and I shall be glad if some light is shed upon that phase of the subject during the discussion on Mr. Cummins's valuable paper.

I have not the exact figures at hand; but I remember suggesting that the intermediate and each low-pressure cylinder should be of equal bore, so as to get powers of $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, and $\frac{1}{4}$ in H.P., I.P., F.L.P., and A.L.P. respectively, instead of $\frac{1}{3}$, $\frac{1}{3}$, $\frac{1}{6}$, and $\frac{1}{6}$, as approximately indicated during the "Powerful's" trials.

It seems absurd to have such a curious distribution of power, when all four engines have equal piston and connecting rods, etc., to say nothing of the bad effect produced by the unequal turning moments.

This inequality of initial loads has been recognised in designing the four-crank triples for the new Irish mail boats, and the scantling of each L.P. engine reduced to half the strength of the H.P. and Int. engine.

But I cannot see why, in any engine, the cylinders should not be proportioned to give equal powers at full speed. It is too late to "fiddle" with the cut-offs when the engines are in the ship.

Any information Mr. Cummins can give us on this point will, I am sure, be generally welcomed.

Yours faithfully,

J. H. Gibson.

The President, in adjourning the discussion to the Closing Meeting, said the paper contained plenty of points for consideration, and he only wished there had been a larger attendance to hear it read.

The meeting was adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896-97.

PROCEEDINGS.

EIGHTH GENERAL SPECIAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON FRIDAY EVENING, APRIL 30TH, 1897.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on April 14th, which were approved by the members present, and signed by the President.

THE LATE HUGH MACOLL, VICE-PRESIDENT.

The PRESIDENT said before proceeding to the reading of the paper, he must ask their attention for a few minutes whilst he spoke of the loss they had sustained by the death of Mr. Macoll.

Mr. Hugh Macoll was one of those who took part in the founding of the Institution in 1884, and was the first to be enrolled as a life member of the Institution. He was elected an ordinary member of the Council in 1884, and a Vice-President in 1888, and had served on the Council up to the time of his death (April 25th). He acted on most of the sub-committees appointed by the Council for special objects, chiefly the Shipbuilding Statistical Committee (see Vol. IV. of *Transactions*, page 334), which published its report in 1888, giving particulars of shipbuilding statistics for the world for twenty-five years previous to that date. This involved an immense amount of research, and the task of collecting and compiling was chiefly undertaken by Mr. Macoll. He took a keen interest in the Graduate section of the Institution, and when that section was permitted to hold meetings of its own, independent of the parent Institution, he devoted considerable time to its development, fostering it, and watching its progress. When it was found necessary to renew the measured mile posts on the coast, Mr. Macoll, in conjunction with Mr. Robert Thompson (Past-President), used every endeavour to bring the matter to a successful issue. In the design and execution of the work in connection with the making and erecting of these posts his forethought and practical abilities were well displayed; and not only the Institution, but the shipbuilders and engineers of the district are much indebted to him for his untiring zeal and supervision in carrying out the work. In his death the Institution has lost a most devoted and energetic member.

He thought they should record their sense of the loss the Institution had sustained by the death of such a worthy member, and he proposed that this expression should be entered on the minutes.

This was sympathetically agreed to, and the President then passed to the next business.

Mr. D. B. Morison read a paper on "Gravitation Stamp Mills for Quartz Crushing."

GRAVITATION STAMP MILLS FOR QUARTZ CRUSHING.

By D. B. MORISON, Vice-President.

[Read before the Institution in Newcastle-upon-Tyne, on April 30th, 1897.]

The magnitude of the gold-mining industry of to-day, and the enormous possibilities in the near future, can only be fully realised by those who carefully analyse the returns from the principal fields. Take for example the Rand, which, in 1896, produced gold valued at £9,000,000, and again, the gold-fields of Australasia, with an output of £8,700,000; then consider the vastness of the mineral resources of the United States, Russia, India, South America, Mexico, British Columbia, etc., or a total world's output of £45,000,000, and reflect on what it means even to the manufacturer of mining machinery.

The magnificent development of modern gold-mining is due in no small degree to the ceaseless energy of mining engineers, who have evolved an immense industry from what was formerly a mere speculation, and nothing has contributed to this change to a greater extent than improvements in machinery for milling the ore and in methods of extracting the metal. Hundreds of mines, which a few years ago would have been commercially unworkable, are at present profitable investments, for the reason that the introduction of each new appliance or method which reduces the cost of production marks an era, inasmuch as it is immediately followed by the opening up of mines with still lower grade ore, and the successful working of others whose position or depth formerly rendered this impossible.

A single paper will not admit of the entire machinery of a modern mine being dealt with, so the writer proposes to analyse the mechanics of that almost universal machine, the gravitation stamp battery, and to describe some recent developments.

The principal constituent of gold-bearing reefs is quartz, and in order to extract the gold this quartz has to be stamped into powder. Quartz, when mined, is generally in large pieces, and these are reduced to

$1\frac{1}{2}$ inch cubes by a rock breaker of one of the many well-known types before passing into the stamp mill. One of the earliest records of a stamp mill is that in 1529 one was used in the Hartz Mines in Germany, and the illustration (Plate LI.) is taken from Agricola's work published in 1556. It is naturally very primitive in design, and consists of a wooden barrel with projecting pins which raise and release wooden stems, the stamp heads being of quartzite or of iron. Cornish stamps for tin mining are of much the same general design, modernised as regards the extended use of metal for bearings. Another primitive form of stamp, used in the Malay Peninsula, is shown in Plate LI. The great step in the improvement of stamp mills is due, however, to the ingenuity of American engineers, and took place in 1856, soon after gold-mining commenced in California, the wooden square stems being replaced by round iron, and a rotary movement given to the stamp head by the action of the cam. Since that date the various details have been perfected by engineers of all countries, with the result that of the entire quartz crushing machines in the world it is estimated that 90 per cent. are gravitation stamp batteries. In its essential feature the gravity mill is unaltered, viz., that a spindle with a heavy weight attached is lifted by the action of the cam and allowed to fall on the ore under the action of gravity. The general arrangement of a modern Californian stamp mill is shown on Plate LIII., and its principal details are the frame, stem, cam, head, shoe, die, and mortar. Usually the frame is of wood of very massive design to withstand the intense vibration and is arranged to contain the stamps in sets of five.

The stems (Fig. 1, Plate LIV.) are of wrought steel, about 3 inches in diameter and 14 feet long, tapered at each end for fitting into the head. Each stem is guided top and bottom by wooden guides, and about midway between these guides is the tappet. The modern tappet (Fig. 2, Plate LIV.) consists of a steel or iron casting, bored to fit the stem to which it is secured by a gib tightened by two or three tapered keys; the ends of the tappet are carefully machined, the lower end forming the driving surface. The cam (Fig. 3, Plate LIV.) is usually of the two-armed type, and of cast steel, the surface being carefully machined, and the curvature accurately proportioned. The cam shaft is of iron, about 5 inches in diameter, and supported at the ends by massive bearings. The head (Fig. 4, Plate V.) is of cast iron, bored at one end to receive the stem, and at the other to receive the shoe. Drift ways are cast at the base of each recess in order that the head may be released from the stem or shoe when necessary, the heads being usually about 9 inches in diameter by 16 inches to 20 inches long. The shoe (Fig. 5, Plate LV.) is of forged steel of circular section, about 9 inches in diameter by 8 inches long, terminating in a shank which fits into the head. Its life depends on the quality of the material of which it is made, and on the nature of the material to be crushed. Good cast iron shoes will lose about ·4 lb. to 1·5 lbs. per ton of quartz crushed, and forged steel from ·3 lb. to ·7 lb. The die (Fig. 6, Plate LV.) forms the anvil on the face of which the ore is crushed, and is of cast iron or forged steel, the upper part being cylindrical corresponding in diameter to the stamp shoe; its lower part is octagonal, so that when placed in the mortar box each die is kept in its correct position by the others. The mortar box (Plate LVI.) or the vessel in which crushing takes place is of cast iron, the bottom forming a trough for the reception of the dies. Quartz is fed through a shoot in the back, the inclination being such that the ore is directed to the middle of the dies. In the front of the mortar is the screen, having a frame of wood covered with perforated metal plates or wire gauze, the meshes of which will just pass a fine sewing needle. For wet crushing water is supplied to the mortar box in proportion to the fineness to which the ore is crushed, and varies from 200 to 400 cubic feet per ton, the material passing through the screens in the form of pulp. The extraction of gold from the pulp does not come within the limits of this paper,* except as regards that portion which is extracted in the mortar box. Mercury is in universal use for the extraction of gold, as it is not only fluid at ordinary temperatures, but has a marked affinity for gold, the alloy of gold with mercury being known as its amalgam. Amalgamation inside the mortar box results from charging the pulp with a small quantity of mercury every few hours. The churning action of the stamps soon causes this mercury to be intimately mixed with the pulp, and by coming in contact with particles of gold small accumulations of amalgam are formed, some of which settle down in the bottom of the mortar box, or are caught by adhering to copper plates placed at the back and front of the box, whilst others are forced through the screen and are caught by the copper plate over which the pulp flows when leaving the screens, the remainder being extracted by some chemical, as for example the cyanide process. A general clean up usually takes place once a week, and after the stamp heads have been hung up or suspended the entire mortar box is carefully cleaned out, and all the amalgam collected. Experience has proved that five is the most suitable number of stamps to

* *Vide Gold Milling*, by Henry Louis.

work in one battery. The cams are set at equal angles, the order of falling being 1, 4, 2, 5, 3, or 1, 3, 5, 2, 4, these having been found the most effective for maintaining a uniform wash of pulp, and minimising the accumulation of particles of crushed quartz at each end of the mortar box. In modern mills the total falling weight of each stamp varies from 750 lbs. to 1150 lbs., and the height of drop from 6 inches to 8 inches, depending on the hardness of the quartz to be crushed.

The time taken by the head in dropping depends upon theoretical considerations governing a falling body, together with retardation due to friction. The time occupied in seconds by a body of any weight falling from rest *in vacuo* is equal to $\sqrt{\frac{2H}{G}}$ where H = height in feet, and G = acceleration in feet per second per second due to gravity, and may be taken as 32·2. Thus, a weight would fall through 6 inches in ·176 second (Plate LVII.) and supposing it was raised in an equal time the number of drops per minute would be $\frac{60}{\cdot 176 \times 2} = 161$. A body raised a certain height and allowed to fall from rest acquires a velocity which depends upon the distance through which it falls. Thus a weight falling from rest through a distance of 6 inches would acquire a terminal velocity of 5·67 feet per second (Plate LVIII.) this result being found by the formula $V = \sqrt{2GH}$ where V = velocity in feet per second, H = height in feet, and G = 32·2 as before. Work is also stored up by a body in motion, and a measure of the work is the height through which the body must be raised in order that by falling it may acquire the velocity at which it is actually moving. The amount of work thus stored up $= \frac{W \times V^2}{2G}$, where V = velocity in velocity of the stamp head acquired from the cam is less than that which would be required for it to complete its normal stroke under the retarding influence of gravity and friction, it follows that pressure is exerted on the tappet by the cam, and each is in contact with the other, but if the velocity imparted to the stamp head by the cam is at any portion of its upward stroke greater than required for it to complete its normal stroke under the same conditions, then the tappet leaves the cam and completes the stroke unaided. In practice it is usual to round off the toe of the cam in order to allow for this movement even when running at normal revolutions, but this upward velocity has an important bearing on the available number of drops per minute of the stamp head in that it governs the revolutions per minute of the cam. Another factor influencing the number of drops is the time required for crushing, or the interval between the shoe striking the ore and the cam striking the tappet. It will be seen therefore that there are definite limits to the number of drops per minute in a cam stamp mill, and as the subject is of great importance to mining engineers, the writer hopes the following experimental results will be found useful.

The experiments were made on a stamp head of the following dimensions:—

Stem, $3\frac{1}{4}$ inches diameter; length, 13 feet.

Depth of guides: top, 14 inches; bottom, 14 inches.

Distance between guides, 6 feet 2 inches.

Combined weights of stem, tappet, head, and shoe, 900 lbs.

A Sandycroft standard cam was used, and the machine was worked for a week before any records were taken, the guides being very carefully lubricated, so that the terminal velocities of drop certainly exceed those which are obtained in everyday practice.

Diagrams were taken on a drum 7 inches in diameter, driven at a uniform velocity by a pulley on the cam shaft. A recording pencil was attached to a washer on the stem, this washer being loose on the stem, and held in position by a collar on either side, so that the rotation of the stem was not interfered with. Careful records of the number of revolutions per minute were made by three independent operators, each experiment was repeated at least three times, and the utmost care was exercised throughout to obtain reliable and correct data. The first series of experiments were made under the conditions of dry crushing, or without water in the mortar box; in the second series the heads were immersed in water, as in wet crushing, just sufficient material being kept on the dies in each case to prevent metallic contact. Half the experiments were made with the tappet set to a $6\frac{1}{2}$ inches drop, and the remainder at a drop of 8 inches. Diagrams (Plates LIX., LX., and LXI.) were taken under the conditions of wet crushing at 82, 88, and 97 drops per minute, with the tappet set at $6\frac{1}{2}$ inches; the cycle of movement being—(1) raising the weight, (2) dropping the weight, (3) the time during which crushing takes place. When the cam comes in contact with the tappet, the weight is not raised gradually, but is supposed to acquire instantly a velocity corresponding to that of the cam, or, in other words, a blow is struck on the tappet by the cam; and it is this blow which is the cause of much of the intense noise and vibration which are inherent defects in a cam stamp mill. This vibration may be, of course, minimised in intensity by constructing the framework with heavy scantlings, and providing deep foundations; but the tendency to vibrate, due to the action of the cam, still remains, and the mechanical efficiency cannot be increased by simply adding weight of material, but only by removing the cause. In a properly constructed cam, designed to give a drop of 8 inches, for example, the vertical component of the velocity of the cam is, for 80, 90, and 100 drops per minute, about 1·608, 1·8, and 2·01 feet per second respectively; and reference to Plate LVIII. will show that, having acquired a velocity of 2 feet per second, a weight will continue its upward movement $\frac{3}{4}$ inch unaided—due to its momentum; less, of course, the retardation through friction. It is principally on this account that a cam stamp has such a low limit of available speed; as it is evident, that if the uniform upward velocity is such that the weight travels beyond its normal stroke, then, before it has time to reach the die, the second cam meets it, and by receiving the full force of the blow, an accident is very liable to result. Diagram Plate LXIV. was taken at this critical period, and evidence prove this, the head and shoe were removed, and the resulting diagrams gave a loss of 24 per cent. The dry crushing experiments showed a loss of 5 per cent. less than wet crushing, this being the mean of twenty-four experiments. It will be observed that no fractions of a drop are taken, so that the terminal velocities are correct to within a maximum of one drop per minute, or, say, to within 2 per cent.; but the uniformity of the results extending over forty-eight experiments was very marked, so that the means may safely be accepted as representing accuracy.

The practical deductions which can be made from these experiments are, that a cam stamp having a 7 inches drop cannot be driven at more than 94 to 98 drops per minute in ordinary everyday work, and that the falling weight loses in wet crushing at least 17 per cent. of its possible efficiency, due to retardation through friction, and under the average conditions of work this will probably be increased to from 20 per cent. to 25 per cent. A glance at the frame of a standard mill shows that the scantlings are exceedingly heavy, the battery post being 21 inches by 12 inches, and the struts 12 inches by 10 inches, whilst the cam shaft is no less than 5 inches in diameter. Those who have heard a cam stamp battery at work, however, and noted the deafening noise and extreme vibration, at once realise the waste of power which must result. It may be argued that all this excessive weight and waste of power is of no consequence when mining for such a valuable metal as gold; but it is impossible to entertain a greater fallacy, as mining has developed from a speculation into an industry, and the greater the work which can be obtained from a given weight of machine in a given time, and from a given expenditure of power, the greater will be the commercial success. Weight of machinery means heavy cost of transport; low efficiency results in waste of fuel, and a useless expenditure of labour, and these three factors combined represent very often the difference between success and failure. Who would, in these enlightened days, think of driving a steamship with a low-pressure engine with its extravagant consumption of coal? Such an experiment would mean commercial ruin; or, who would compare the old wooden bicycle with the modern pneumatic-tyred machine? yet the difference in the efficiency of the latter is due entirely to decreased vibration and reduced friction. It is natural, therefore, that numerous attempts should have been made to improve the gravitation stamp mill, but these have failed practically in all cases because the designers attempted too much. A quartz crusher must above everything be strong and simple, as it is often subjected to gross illusage at the hands of ignorant or careless attendants. Splendid modern mining plants, such as those on the Rand, should not be taken as a guide in this respect, but rather those cases where skilled attention is more difficult to obtain, and where a breakdown would mean considerable loss and delay. In attempting to improve the cam battery it should also be borne in mind that it represents the combined efforts of mining engineers during the last fifty years, and a vast amount of care and ingenuity have been expended on its available perfection, so that when the writer commenced on this problem he adopted the principle of "leaving well alone," by retaining every detail of the modern gravity battery in its present form with the exception of the cam and tappet, in fact the machine illustrated in Plates LXV. and LXVI. is made from the standard design of Messrs. The Sandycroft Foundry Co., the well-known mining engineers of Chester, the mortar box, heads, shoe, and dies being of their manufacture.

The improvements desired were—

I.—Increased mechanical efficiency.
  Decreased vibration.
  Less friction.
  Less fuel per ton of quartz crushed.

II.—Increased drops per minute.
  Decreased weight of mill per ton crushed.
  Less floor area.
  Less cost of transport.

III.—Greater output per stamp head.
  Decreased labour per ton of output.

IV.—Ability to convert existing machines.
  Increased output from existing mines.

cylinder also makes the cylinder and jacket common to one another. The cylinder below the lower port is filled with liquid, the jacket also contains liquid, and above the liquid is air space, both in the cylinder and in the jacket. When the bottom of the piston closes the lower port and the cylinder moves upward, the piston and stamp head are supported by a body of liquid. If none of this escapes, and the down strokes of the cylinder do not exceed the number which the stamp head could make under the action of gravity, minus the retardation through friction, and if the length of stroke of stamp head is the same as that of the cylinder, the position of the piston within the cylinder remains constant, and the liquid is practically undisturbed. If, however, the stroke of the stamp head is less than that of the cylinder, and the speed of rotation is as before within practical gravity limits, it follows, when the shoe strikes the die, and the cylinder has completed its stroke, that the position of the bottom of the piston is above the cut-off point by an amount equal to the difference of stroke between the stamp head and the cylinder, this space being filled with liquid, which has been drawn in from the jacket. On the upstroke of the cylinder this liquid is forced out into the receiver until the cut-off position is reached, when the piston is again raised on a liquid medium as before. It is evident that if the point of pick-up occurs before mid stroke, that the stamp head will acquire the same upward velocity as the cylinder, the latter comes to rest, however, by the action of the crank, whilst the former is governed by the retarding influences of gravity and friction, so that at ordinary working speeds the piston will continue its upward motion after the completion of the upstroke of the cylinder by an amount dependent on the velocity acquired at about mid stroke. At certain velocities of rotation, when the stamp head commences to fall, the cylinder will have completed a portion of its down stroke, and if the velocity of fall of the cylinder is not less than that due to gravity, minus friction, the velocity of fall of the stamp head will be increased by the assisting effect of the friction between the surfaces of the cylinder and piston, and also between the rod and the packing, with the result that a very much greater number of drops can be obtained than is possible with the cam arrangement.

The liquid used is water, with a sufficient addition of soap for purposes of lubrication and to prevent corrosion, and the quantity of liquid is maintained by the continuous flow from a small supply pump from a fixed tank, inflow and outflow being by means of small tubes; one small pump being sufficient for any number of stamps. The upper part of the cylinder above the top port is grooved longitudinally, so that if a stamp head is hung up the air passes from one side of the piston to the other without resistance.

In order to provide for the wearing of the shoe and the consequent lowering of the piston within the cylinder, several cut-off holes are provided at about 1½ inches pitch, so that on the shoe and die wearing to that extent all that is necessary is to unscrew the next lower plug, thus establishing a new cut-off port 1½ inches lower than the previous one. It has been found that the piston, floating as it does on a quantity of liquid, renders the stem so susceptible to rotation that the shoe rarely strikes the die without certain rotary movement resulting, and it is probable that this will be found sufficient in practice to ensure the even wearing of the surface of the shoe and die, but, if desired, a very simple sytem of turning gear can be fitted which works very effectively. No trouble is experienced through leakage at the gland, as midway in the stuffing box is a lantern bush connected to the jacket so that the packing below this bush is only subjected to the pressure due to the head of liquid in the jacket, or under 1 lb. per square inch. Special attention has also been given to the danger of any lubricant falling into the mortar, the lower supporting frame being constructed of trough form, with an inclined base, so that all waste lubricant is caught and retained.

The experiments were made on the high-speed stamp exactly in the same manner as with the cam stamp, the same recording apparatus being employed, in fact the conditions were identical in every respect. Reference has been made in the description of the high-speed stamp to the accelerating influence due to the friction of the piston and the packing in the stuffing box. Great care was taken to minimise this accelerating effect in order that the results should not be exaggerated in any way, and, as the experiments were made on a cylinder which has been almost in daily use for the last six months, the accelerating effect of friction may be taken as the least possible. This is an important feature, as the condition of least friction naturally represents the condition of greatest mechanical efficiency as distinguished from crushing efficiency, and it also represents the lowest range of drops per minute. Diagrams (Plates LXVIII. and LXIX.) were taken at 125 and 130 drops per minute respectively with a 900 lbs. head, under the condition of wet crushing. The most noticeable feature to the operators was the great difference in vibration, as even at 125 drops it was not comparable to the cam at 90, and this is illustrated by the clear sharp outline of the actual diagrams in the one case and in the ragged wavy outline in the other. The reason for this is evident, as with the cam a heavy blow is struck on the tappet at each upstroke, whilst with the high speed there is absolutely no shock whatever, the liquid being gradually squeezed out until the resistance of the weight is overcome. There is also an absence of the great noise which is associated with a cam stamp, except of course that due to the blow on the dies, which is the same in each case.

In analysing the diagram in its complete cycle or rise, drop, and period of rest, the chief point in the former is that whereas the cam raises the weight at a uniform velocity throughout its lift, the high speed raises it at a variable velocity due to the working of a crank and a connecting rod, the velocity of which is greatest at about mid stroke, decreasing harmonically to zero at the end. This modified harmonic path more nearly coincides with the gravity curve than does the uniform velocity due to the cam, hence the same height of lift can be made in a less time. Having arrived at its maximum height, the stamp head falls under the action of gravity, retarded by the friction of the guide and its passage through the water, and accelerated by the friction of the stuffing box. In the case under notice one neutralises the other, with the result that the terminal velocity is equal to theoretical gravity, or 17 per cent. greater in energy of blow per drop than was obtained with the cam. On the down stroke of the cylinder the velocity is greatest at about mid stroke, falling to zero at the end, so that if the stroke of the stamp head was equal to that of the cylinder no blow would be struck, but the stroke of the head is less, and herein lies one of the interesting mechanical problems connected with the high-speed stamp. At the commencement of the downward stroke the cylinder at the ordinary speed of working begins its fall before the stamp head, due to the momentum acquired by the latter on the upstroke, consequently the fall of the head is accelerated up to mid stroke, and before it can lose the energy acquired the stroke of the head is completed and the interval of time between that point and the point of pick-up represents the period during which crushing takes place. Thus is the cycle completed, and in every way exactly as required by what experience has shown to be necessary for success from a miner's point of view, and with a mechanism which, for extreme simplicity, cannot fail to recommend itself to an engineer. Diagrams (Plates LXX. and LXXI.) were taken with the die 1½ inches lower than in those in Plates LXVIII. and LXIX., consequently they represent the range allowed for wear, and in order to establish the conditions of the latter diagrams all that is necessary is to open another cut-off plug. It may be a small matter, but the parallel operation in a cam stamp is to release the 140 lbs. tappet with its three keys and refix it in a new position, an operation which requires care, especially with heavy tappets. A diagram (Plate LXXII.) was taken at 142 revolutions with a tighter gland, and although interesting as an example of the possible capacity of the machine, the writer is of opinion that a speed of from 125 to 130 drops per minute will be found the most suitable in ordinary practice.

Viewed only as a crushing machine the range of possibilities is considerable, as the design lends itself admirably to increased weights, say from 1,500 lbs. to 1,800 lbs., at either the same or reduced heights of drop, whereas in a cam stamp a weight of 1,500 lbs. would necessitate a structure of alarming proportions, and have a greater tendency to break down. A stamp mill is governed, in its capacity as a crusher, to a great extent by its capacity to discharge through the screens, but the wash or splash in the mortar box due to the high speed of 125 drops is such that a much deeper screen has been found necessary than the standard size used with cam stamps, and in the opinion of the many mining engineers who have seen the mill at work, the discharge capacity may be taken as proportionate to the drops between the range of 95 and 130 per minute. Whether this can be exceeded can only be determined by experience, but, if so, then the crushing capacity can very easily be increased by adding to the weight. For example, with equal terminal velocities, an increase of 900 to 1,200 lbs. in the weight of the head would result in a proportional increase in energy of blow. In comparing the two machines, the most valuable features are of course the increase of drops from 95 to 125, or an increase of 30 per cent. per stamp head, with a decrease of weight of head from 12 to 17 per cent., and also that the standard gravity mill can be readily converted into the new system. It is estimated that there are 50,000 heads at work throughout the world, so that it is highly probable that in many cases it will be found more profitable to increase the output by 25 per cent., by converting the existing mills rather than by erecting additional costly plant.

The power required by both the cam and high speed stamps per ton of quartz crushed is not readily obtainable except at a mine and with similar ores. In the cam stamp the losses are those due to friction of mechanism, and the vibration resulting from the blow by the cam on the tappet. In the high speed stamp the losses are due to the friction of mechanism and the flow of the liquid through the port, but the vibration is so minimised that it is highly probable that the power per drop is also less at equal speeds. The mill illustrated in Plates XV. and XVI. is, as has been before mentioned, of standard dimensions in every respect, and was built to show the adaptabilty of the new system to existing mills, but the vibration is so very much less than in a cam stamp that the weight of framing, in the case of new mills, can be greatly reduced, which is a most important consideration in view of the fact that transport often costs nearly as much as the machine itself. The general design can also be adapted to many purposes, and, being driven from a revolving shaft, the efficiency would be much higher than in the case of steam or pneumatic hammers, especially when arranged to give a variable and controllable drop. It may also be found of advantage in some cases, as for example in prospecting plants, to work the piston from the crank and allow the cylinder to form part of the falling weight, but many modifications in design are evident, and will doubtless be developed by experience.

It may be said that the cylinders, etc., are a little more costly to manufacture than the cams and shaft, but the basis of comparison should be a commercial one, viz., the crushing capacity per head per day; or again, the question may be asked is not the cam construction more simple than its high speed rival? but the crude mechanics of the cam cannot be compared with the greater efficiency obtainable from a crank connecting rod and cylinder, a mechanism which in engineering may be considered as unrivalled for the production of reciprocatory motion. In the cam stamp the shocks have been conquered by adding masses of metal, and even then fractures of cam shaft and cams are by no means unknown, and involve very considerable loss and delay. In the high-speed stamp, however, the weights are lifted without jar or shock of any kind, whilst the wear of the parts after many months' running is practically *nil*, in fact from a mechanical point of view it would be very difficult to say in what direction trouble could result as every detail works with the greatest ease and smoothness. There is also no doubt that the possibilities with the cam as regards weight of head and number of drops per minute are exhausted, although mining engineers are still demanding an increase of both, the high-speed stamp therefore meets their requirements, and opens up a new range of possibilities for that practically universal machine, the gravitation stamp battery. The high-speed stamp also produces a more active circulation in the mortar box and a less tendency to sliming, which is a matter of substantial economy in itself.

But these are questions for the consideration of milling engineers, and the writer hopes that they may be dealt with during the discussion.

The illustration of the high-speed stamp shows it as driven by an electric motor, and being a very smooth running machine it is particularly adapted for this method of driving.

The question of mechanical efficiency of mining plant as a whole is one deserving close attention, as in cases where fuel is costly it has a direct bearing on commercial success. Power should be centralised and distributed with the least possible loss, and in cases where the machinery extends over a large area the application of electricity has resulted in very great success. Plate LXXIII. shows a multiphase alternating generator and motor designed by C. E. L. Brown, the eminent electric power engineer of Baden, for Messrs. T. Richardson & Sons, Limited, Hartlepool, and being exceedingly simple this system seems very suitable for mining purposes.

In conclusion, the writer desires to thank the many mining engineers who have at great personal inconvenience visited Hartlepool during the testing of the high-speed mill, and by their assistance and suggestions enabled him to carry out these experiments and developments in a manner which he trusts will prove of some service to the mining industry in the future.

The PRESIDENT read a letter addressed to Mr. Morison from Prof. Henry Louis, of the Durham College, Newcastle, regretting that his indisposition would prevent him speaking on "The Chemical Extraction of Gold," as he intended, in connection with the paper to be read, and hoping that he might be allowed to contribute a statement in writing.

DISCUSSION.

approaches the perpendicular so the force increases. Comparing the two diagrams it will be seen that the most striking difference is in the upper part of the diagrams, or in other words the lift. With the cam stamp the velocity rises to its maximum value almost instantaneously, and the resultant reaction of this great force must be taken up by the framework of the stamp; on the other hand the velocity of the Morison high speed stamp rises more gradually, so that the reaction which has to be taken up by the frame is very much less. It is also evident that a certain amount of time is lost when the stamp is raised by a cam, for in order to obtain the maximum number of drops per minute in a gravitation stamp the initial impressed velocity should be sufficient to raise the stamp to the end of its lift. This condition is more nearly approached by the high speed stamp than the cam stamp, and it is this, together with the shorter interval of time between the fall and the lift of the stamp head which to a great extent makes it possible for the high speed stamp to be worked with a greater number of drops per minute. The next point of interest is in the fall; the cam stamp head falls with uniform acceleration, whilst the acceleration of the high speed stamp varies, being greater at the beginning than at the end of the fall; it will therefore be seen that when crushing large pieces of quartz, say 2 inch cubes, full advantage may be taken of the increased acceleration, and a comparison of the blows struck in this manner will be much more favourable to the high speed stamp than when both machines are considered as working with clean dies. It is, of course, well known that there are other stamps, such as pneumatic stamps, from which an increased number of drops per minute may be obtained; but it has been found in practice that not only is the mechanical efficiency low, but that the diameter of the cylinder necessary to support the stamp head on a volume of air is so great as to entirely upset the requirements of milling engineers as regards the size and design of the mortar box.

Prof. R. L. WEIGHTON, Durham College of Science, Newcastle, said he thought the first thing one had to do was to congratulate their friend, Mr. Morison, for the very complete analysis he had made, by experiment, of the gravitation stamp both in its original form and in its improved form; and secondly, to congratulate him especially upon having produced a machine which, to an engineer, at least (he did not know how a mining expert looked at it), was a vast improvement upon its predecessor. Mr. Morison had entered so fully into the details of the action of both of these machines that there was very little left for one to speak about; but this machine of Mr. Morison's, it appeared to him, could be worked in two ways. He (Prof. Weighton) might say that he had had the advantage of seeing it working under several conditions, and he had also seen a cam stamp battery at work. Mr. Morison's machine might be worked, first, with a view to maximum output; and second, with a view to maximum economy—by maximum economy he meant the greatest amount of work realised from a given power employed in driving. The two cases were entirely different. First, with regard to the maximum output, he should take the liberty of illustrating by means of Mr. Morison's model. He got the maximum output from the maximum number of blows in a given time. But there was a limit to the number of blows: that limit was gravity acting on the stamp head, rod, and piston. Now, they could assist gravity by working with the stuffing box gland tight. If they tightened the gland it had no effect upon the upstroke; but on the downstroke the friction of the rod in the stuffing box assisted gravity by pushing the rod down, and thus a speed of descent, in excess of that due to gravity acting by itself, was obtained. So, if they wished to get the maximum output, they would work with a tight gland, securing thereby an increased number of blows per minute, because the falling piece was prevented from lagging behind the driving piece—the cylinder. By that means they could run satisfactorily up to 160 blows per minute, and possibly higher. That was the first way of working the machine without reference to economy of driving power; secondly, they could work the stamp with a view to its maximum economy irrespective of its output, (but which latter would still be much higher than the cam stamp), by working with the gland as slack as possible, only sufficiently tight to prevent the liquid escaping. Under these circumstances he believed the partly utilised in revolving the head. This was so, but it was a very expensive way of imparting rotation by friction so very near the centre of the stem. There was next a great deal of loss in the cam stamp due to the blow to which Mr. Morison had referred in his paper. From the nature of the mechanism there must always be a blow when the cam struck the tappet, and a blow always meant loss of power, besides the tear and wear and injury done to the structure generally. These seemed to him to be the principal losses of the cam stamp, which had no equivalent in work done. Now, about the new stamp, what were the losses? First, there was of course friction of the guides, the same as in the other machine. There was, however, no blow, and that was a valuable feature in this machine. The starting into motion of the stem and head was gradual, due to the liquid connection. This action was well shown by the nature of the lifting curve on the diagrams. Compare with this the corresponding curve for the cam lifting action. In the latter case the speed had to be generated all at once, and this was shown by the straight sloping line rising at once from the base without any curve connecting the two, whereas in the Morison stamp the diagrams showed a gradual rise in speed from zero to a maximum, thus avoiding shock. The greatest source of loss in Mr. Morison's machine would probably be found to take its rise in the stuffing box, which he had already referred to, and that could be minimised by working with a slack gland. The churning of the water to and fro through the orifice was another source of loss, which loss would be measured by the amount of heat generated in the fluid. He had tried to calculate this, but he had given it up in despair and had come to the conclusion it was very little indeed. It was, therefore, very obvious that the new machine had a considerably higher efficiency in crushing than the old one, and that irrespective altogether of the speed with which it crushed. Taking a general view of the matter, and passing over a great many interesting kinematical questions involved, it seemed to him the mechanical advantages of this stamp were twofold: (1) Increased output. This was very obvious, because it was susceptible of being driven at a much higher speed than the cam. In connection with this question of increased output it had to be noticed that the output (that was the amount crushed) would increase faster than the number of blows in a given time. If they doubled the blows they doubled the quantity crushed, other things being equal. But other things were not equal in this case. Each blow in the hydraulic arrangement was of greater value than in the cam arrangement, because there was a greater velocity of descent, and the relative motions of cylinder and head could easily be so arranged that the blow was struck when the head was at or near its maximum velocity. The crushing effect of each blow would be measured by the square of velocity of impact, for it was of the nature of accumulated work. He (Prof. Weighton) spoke in the absence of any direct experimental proof, but it seemed to him that the amount crushed by Mr. Morison's stamp would be very much greater than would be expected from the number of blows. (2) It had an advantage from the point of view of durability. Its sweetness in working, he knew, from actual observation, and this was quite in accordance with what would be expected from the nature of the mechanism. He thought there was no doubt at all that this stamp was vastly superior in its action to the cam stamp from a purely mechanical point of view. He should like to hear what mining engineers had to say about it.

Mr. W. Lawrence Wildy (Mem. Inst. Mech. E., London), who thought the practical discussion of the mechanical part of the new machine had forestalled part of his remarks, said he was sure they had all listened with great pleasure to the paper which Mr. Morison had submitted, and appreciated the exceeding care and ability with which it had been prepared, delivered, and illustrated. He had laid before them the skeleton of a subject which was of the greatest importance to the mining world, and the very thorough way in which Mr. Morison had attacked and expounded the practical mechanics of the stamp battery was worthy of the highest commendation and the warmest thanks of the mechanical engineering section of the mining community. The graphic diagrams which had been shown on the screen and in the hall conveyed to the practical mind an amount of information which had hitherto been

[redacted]

a perfection of construction which it would be difficult to surpass. But what did this mean to them as milling engineers? What did it mean to the mining companies or mine owners? It meant a very great deal, and especially to the mine owners, and still more to those running mines of low grade ore. The low grade ores of 4 or 5 dwts. per ton were the bugbear of mine owners, and from his experience in the Rand he knew the only way to get over it was to have a greater output from the mills. If they could only put out 20 per cent. more they should reduce their milling cost per ton 20 per cent., and make a dividend on some of the small yield mines which were only now clearing expenses. The present shareholders wanted dividends now, not fifty years hence, and the drawback was the restricted output.

The cost per ton of milling depended principally on four factors:—(1) Output per head; (2) power required; (3) cost of fuel; and (4) skilled labour required. He would consider the numbers 2, 3, and 4 first, and come back to No. 1 later.

The power required to run a 950 lbs. stamp battery at its maximum practical speed of about 95 drops per minute was found by practice to be about 3 indicated horse-power per head, and of this only about 1·7 horse-power was represented by weight lifted. In the Morison battery the power required to run the machine at 135 drops per minute was, for weight lifted, 2·42 horse-power per head, and allowing 25 per cent.—a very liberal allowance, considering the excellent design and perfect balance of the parts—for friction, they get 3·02 horse-power, or practically the same power for the enormously increased number of drops. Absorbing the same power it was natural to conclude that the fuel consumed for the larger number of drops, and greatly increased output, would be the same as for the lesser number of drops, and therefore no extra cost was involved under this item by the increased speed. In making this estimation he had purposely refrained from taking into consideration the heavy loss resulting to the cam battery by the repeated attempts made by the cam to set in immediate full-speed motion the whole of the constituents of a head of stamps as compared with the cushioned pick-up of the Morison lift.

The question of skilled labour was more difficult to decide, but he did not apprehend that it would be necessary to increase the battery house staff, though the plates would require to be scraped more often. More unskilled labour would probably be required to look after the feeders, and to keep up the supply of ore to the bins, but the cost per ton would be no greater, but probably rather less for the increased output.

They had now to consider what would be the effect of increased output. From the calculations and experiments made by Mr. Morison, he found that there was a loss of at least 17 per cent. in the crushing effect of the cam stamp, in other words only 83 per cent. of the theoretical was effective. This 83 per cent. was represented to-day by 4 tons crushed per head per day of twenty-four hours. Some batteries are crushing over 4 tons, and some under, and 4 tons is taken as a mean. In the Morison high-speed gravitation stamp they saw by the diagrams that the time required for the cam head to fall, through the height of drop allowed for, was considerably less than the time required for the same weight to fall through the same distance by gravity alone; but supposing it were only the same time, and that no acceleration of gravity, and consequently no increase in the terminal velocity of the falling weight took place, the crushing effect would be represented by 100 per cent. of the theoretical. Now, if 83 per cent. gave them 4 tons crushed, 100 per cent. would give them 4·8 tons per head per day, and this with 95 drops per minute. By increasing the drops from 95 to 135 they should get 6·8 tons per head per twenty-four hours, or a total gain of 70 per cent. on the output capacity of the present average mill.

To take concrete figures, he proposed to deal with a supposititious 60 head stamp mill. With the existing arrangement, such a mill running 350 days per annum would crush, at 4 tons per head per 24 hours, 84,000 tons of rock, at a cost of about £17,000, and, supposing the ore to yield 8 dwts. only per ton, the total annual gold output would be 33,600 ozs., say £127,000 in value. Mr. Morison's high-speed mill, in the same period, would crush 142,800 tons of ore, and at the same yield of gold per ton of quartz, would give 57,120 ozs., say £217,000 in value, or £90,000 per annum excess for the same number of stamps, the same power, the same attendance and cost of milling. This was an advantage which no milling engineer could afford to ignore, and in giving his attention to this matter, and designing a machine so effective, so simple, and so economical, Mr. Morison deserved the thanks not only of the milling engineer, but of the thinking world at large, and most particularly of the shareholder in low grade mines, which at present could not make returns on the capital invested.

A most important feature in the design of the Morison battery was its ready adaptability to existing battery frames for "conversions." To convert a present low-speed battery to a Morison high-speed, it was only necessary to remove the cam shaft and stems, fix the entablature, carrying the shaft bearings, on the top of the king posts, put in new guides and stems, and couple up to the heads. All the parts could be prepared in advance, and a unit of five heads stopped for two or three days to put in the new parts, and the conversion of that unit was complete. By this means a battery of 100 head could be converted from low to high speed, and from low output to practically maximum theoretical yield by dismantling only 5 heads at a time, and the possible stoppage of the companion five heads for an hour or two to screw up through bolts, etc. In running, the new battery produced much less vibration, and owing to the perfect balance of the rotating parts and to the cushioned hydraulic lift, the jar and noise were very materially reduced, and the life of a battery very greatly extended. Massively constructed, and very costly, built up timber pulleys for the driving shaft, and heavy belt-torturing tightening gears would no longer be necessary, as their *raison d'être* no longer existed.

Within a range of 2 inches the machine automatically adjusted itself for wear of shoe and die, and by gradually increased drop as the head wore away the effective crushing power was automatically maintained. Should the nature of the ore require it, the weight of the drop could be increased or reduced as might be desired.

The diagrams which they had seen that night pointed to a result which all milling men desired to attain, namely, the crushing of the ore without making slimes. The blow, as they would see by the sharp point formed at the junction of the falling curve and the curve of rebound, indicated a quick "knapping" sort of blow, which had proved so successful in the knapping action of Baxter's stone breaker, and there was no return of the head to pulverise the ore. They did not want to pulverise the ore, they only wanted to granulate, and the rebound of the cam action stamp tended to pulverise the already partly granulated ore, and so to produce slimes. The cyanide man would welcome this stamp, because his solutions would readily permeate his vat of tailings, and on drawing off his liquors they would percolate more readily through the mass. More complete absorption and easier leaching would result, and a larger recovery of gold would ensue.

Mr. Morison thought they would require more screening area. He (Mr. Wildy) did not think so. The screens they used had from 700 to 900 holes per square inch, and the maximum amount of ore that could be washed through these had never yet been found. Screens had never yet been found too small for the number of drops, and he thought they should prove in practice that every splash washed out the ore crushed by the drop producing the splash. If a stamp dropped 95 per minute, it made 95 splashes, and every splash would carry its own ore through the screen, and he thought up to 200 they could wash it all through a 9 inch screen the same as they could with 95 drops. He would be pleased to answer any question or give any further explanation in his power.

Mr. J. R. FOTHERGILL, Vice-President, said he rose more especially to join with the other speakers in expressing thanks and appreciation to Mr. Morison for the very able and lucid paper to which they had had the pleasure of listening. The whole subject had been so thoroughly gone into and made perfectly clear, not only in the paper itself, but by the two gentlemen who had just spoken, that much of what he intended to have said was now unnecessary. He had had the advantage of seeing the apparatus during manufacture, and afterwards at work, and he could fully confirm all that had been said as to the capability of working it successfully at a much higher speed than the cam stamp. There were one or two points he would venture to touch upon. Although a great number of patents had been taken out for crushing or pulverising quartz, the reason the old-fashioned cam stamp held its own was that experience had shown it was absolutely necessary to economic results to have a gravity deadweight blow. This was an important point to remember and the keynote of Mr. Morison's success, for his stamp retained in its best form the blow of gravity. Perhaps it might be a little difficult at first to clearly understand the action of the cylinder and piston. The fact of a piston in a cylinder connected to a crank rather led one to assume the piston worked in the cylinder after the ordinary manner, but this was not so. The cylinder might be considered a travelling guide to the piston, which was water borne. If the speed of the cylinder and the piston were the same there would be no friction, but if the cylinder—namely, the guide—travelled quicker than the falling weight—namely, the piston—the friction produced was accelerating friction, and would therefore increase the velocity of the falling weight above that due to gravity, were it not absorbed in neutralising the friction of the lower guides. The ultimate result being that the energy of the blow practically corresponded to that due to theoretical gravity, or 20 per cent. greater than the cam stamp, and therefore the same drop could be completed in less time. With the cam stamp the fall was entirely due to gravity with the retarding influence due to friction of guides, which was increased by the angularity of the rod caused by the lateral thrust of the cam on the tappet, producing a loss in energy of blow equal to 20 per cent.

The great value in the Morison stamp existed in the advantage of being able to obtain a high velocity early in the upward stroke, decreasing, by reason of the crank and connecting rod approximately, to the retardation due to gravity, whereas in the cam stamp an instant velocity was acquired, and that velocity retained over a large portion of the stroke; therefore, if at the end of that portion of the stroke the velocity was in excess of what was required for it by gravity at that point, to complete its normal stroke under the retarding influence of gravity, the length of the stroke would be increased beyond the normal, and the cam would meet the tappet before the head had struck the die.

The great advantage of the Morison stamp as compared with the cam stamp was very graphically depicted in the diagrams, and he particularly desired to draw attention to the velocity diagrams taken out by Mr. Watt, who had so clearly described them. These diagrams showed at once where the Morison stamp gained in time and efficiency in energy of blow. In conclusion, he wished Mr. Morison every success, and believed the stamp would prove a veritable gold mine.

Mr. Jas. Patterson thought if Mr. Morison had succeeded in doing away with the noise, racket, and excessive strains of the present stamp mills he would have done an important thing, or, if he had obtained an increased number of drops without doing away with the noise and racket, he would have done a good thing; but to get 30 per cent. or more increase and do away with the noise and racket was a feat one might very well be proud of. The history of the cam stamp might be broadly described as a gradual decrease in the height of drop used, with a corresponding increase in the weight of stamp, the object being to get more drops per minute. They had now arrived at what might be called the final point in this development, as mining engineers had made the stamp as heavy as they could and the drop as short as would give the blow required to crush the quartz. Mr. Morison started away with the weight of stamp and height of drop, where the cam stamp left off, and got an increase of at least 30 per cent. in the number of drops per minute, and he was by no means at the limit of weight. He could increase the weight and decrease the height, and so get more blows per minute. He thought they would see how this was attained by comparing two of the diagrams, Plates LXI. and LXX. The former was the cam and the latter the high speed stamp diagram, and he chose these because the drop was exactly the same in each (slightly over 7 inches), and so compared exactly. With the high speed there were 128 drops per minute, and 97 with the cam, and that appeared to be the maximum attainable with the cam. The high speed stamp saved time in all parts of the cycle of operations; it saved time between the blow on the die and the commencement of the lift—it saved in the lifting, and saved in the time of dropping. Now, why could not the cam stamp be hastened? Well, they could not hasten the drop, that depended upon gravity, less the friction which was practically at a minimum. There was little or no time to be saved between the blow on the die and the commencement of the lift in the cam stamp, which was about the minimum, because they would notice the straight part in the Diagram Plate LXI. was only a twentieth of a second, and that he should think about the minimum amount of margin to be left in any mechanism of the magnitude of cam stamps. If they tried to shorten that they came dangerously near the point where the cam caught the tappet when the stamp was falling after its rebound, and as the whole mechanism was made to stand the blow of the cam in ordinary circumstances, and not the extra blow due to the rebound, this was of course impracticable. There only remained the time of lifting to consider, and here again it was impossible to gain much, if anything, because if the speed of revolution be increased so as to lift quicker, it was evident that the cam, after it left the tappet, would be a shorter time coming round again to the striking position, *i.e.*, would allow a shorter time for the falling of the stamp and completion of the blow on the die, which, as already shown, could not be done. If the cam stamp could be made with heavier weights and shorter drops, it would give more drops per minute; but this was hardly possible because the heavier the weight the greater the blow required to start it, and the more drops per minute the greater the speed of revolution, and, consequently, the velocity of blow on the tappet, and the whole structure would have to be stronger every way—a heavier stem for the

[redacted]

Diagram Plate LXX., could be reduced to nearly half that without any danger to the apparatus. He thought the great point, in comparing the one with the other, was that the cam stamp had arrived at finality, whereas the Morison machine, with already 30 per cent. to the good, was only at the starting point in its development, and could be proportioned to give a very much greater increase.

Mr. GEORGE McFARLANE (Glasgow) said that he heartily congratulated Mr. Morison on the ability of the inception and the extreme care and ingenuity he had displayed in working out the development of what he (Mr. McFarlane) believed to be the machine which would eventually displace the cam stamp mill. The simplicity of the machine was most apparent, whilst its strength, compactness, and mechanical efficiency all went to make it as a whole eminently suitable to meet the requirements of quartz crushing. The battery experimented on by Mr. Morison appeared to be of the ordinary scantlings as regards framing, and was doubtless intended to show the possibility of converting existing machines, but in the case of new mills there was no reason for such a heavy frame, which if made of iron, would be lighter and more in accordance with modern engineering practice. A point which should be kept in view was that Mr. Morison's was essentially a gravity stamp, as it would be a very easy matter to obtain a high number of blows per minute with either steam, pneumatic, or spring stamps, but all these had been tried in endless variety, and yet the result was that when combined they only represented a mere fraction of the total number in use. It is the gravity stamp which has been proved by milling engineers, after years of experience, to meet practical requirements better than any other, and by retaining all the details of the cam stamp, which had proved successful in practice and rejecting those which were known to be bad, Mr. Morison had produced a machine which at one bound placed itself 25 per cent. ahead of its most formidable competitor in crushing capacity.

Mr. G. W. SIVEWRIGHT said he had been very much interested in the paper read by Mr. Morison, and especially so as he saw that the hammer could be modified in design so as to be used for many industrial purposes. He (Mr. Sivewright) had had considerable experience in driving machinery with electric power, and in the shipyard of his firm the only machines which did not lend themselves to that method of driving were hammers, and as a consequence they had to adopt either steam or pneumatic, both of which were very wasteful in power. If Mr. Morison designed a power hammer on the "liquid pick-up" principle it would undoubtedly be of great advantage for many purposes other than quartz crushing, as, in these days of competition, any machine which saves power, and therefore saves money, would be at once adopted.

Mr. W. L. WILDY described a large number of pictures of South African and other mines thrown on the screen from photographs, and also specimens of gold ore and quartz which he had brought for exhibition.

The PRESIDENT, having closed the discussion and intimated that Mr. Morison would reply in writing to any points raised in the discussion, said he did not think there was much to answer, all that had been said having been so complimentary. He now moved a hearty vote of thanks to Mr. Morison for his able and interesting paper. Although they looked upon themselves as principally an institution for shipbuilding and marine engineering, they were not so confined in their outlook as regarded objects, more especially when one of their own number had something of importance to communicate. This certainly applied to the contents of Mr. Morison's paper, and he asked them to carry the vote by acclamation.

The vote was cordially given.

The PRESIDENT said as a supplement to the vote of thanks to Mr. Morison, and which they had carried so enthusiastically, he thought it was due to Mr. Wildy to accord him also a vote of thanks for his very interesting contribution with regard to gold-mining. His knowledge as a practical miner and the slides shown on the screen had added much to the interest in Mr. Morison's invention. It would, he hoped, be of value beyond the gold-mining industry, and that it would bring about such a demand for stamps as to be a source of occupation and profit to the producing firm at Hartlepool. He asked them to give a hearty vote of thanks to Mr. Wildy.

The vote was carried by acclamation and the meeting terminated.

Communications.

The following communication has been received from Prof. Henry Louis, M.A. (Durham College of Science):—

Dear Mr. Duckitt,

In considering Mr. Morison's paper, it is necessary to treat separately the two parts into which it seems to naturally divide itself—the first part referring to his experiments on the ordinary cam stamp; the second to his description of his new high-speed stamp.

Whatever opinion engineers may hold as to his new invention, I think there can be no doubt about the great importance to mining engineers of Mr. Morison's experiments on the cam stamp. Although these have not determined any really new principle, they have rendered us the great service of making clear and definite points concerning the action of the cam which were hitherto more or less doubtful, and have proved mathematically a great deal respecting the motion of the cam stamp, which had before been little better than guesswork. The Diagrams, Plates LIX. to LXIV., show with the utmost clearness what takes place when the cam stamp is in operation. The cam is first of all seen to lift the stamp with practically uniform velocity, as indicated by the straightness of the line of lift, until within $\frac{1}{4}$ inch or so of the top of the lift, when the rounding off the cam toe comes into play; the stamp continues to move upwards for a short distance, which is seen to increase as the speed increases, as would naturally be expected; it then commences to fall, its rate of falling being due to the acceleration of gravity retarded by the friction of the stamp stem in the guides, and of the stamp head in the pulp of the battery box, the retardation amounting apparently to between 7 and 10 per cent., and tending, as would naturally be expected, to convert the uniformly accelerated motion *in vacuo* into simple uniform motion. This result might have been predicted from the fact that the retarding influence of friction increases as the square of the velocity of motion, and corresponds with what we know of the falling of bodies in liquids. Mr. Morison has, however, proved for the first time the actual amount of retardation that the falling stamp undergoes. It was long known that an interval of rest between the time when the stamp had dropped and the commencement of the next lift was necessary, but the exact length of this interval was not known before now. From the diagrams here given, this interval is seen to decrease as the speed of the mill and the length of drop increase, varying between 0·23 and 0·10 second. So much information as to the behaviour and efficiency of action of the stamp mill is obtainable from these diagrams, that it is to be desired that Mr. Morison should publish full particulars of the construction of the recording apparatus used by him. No doubt many mining engineers would be glad to avail themselves of it, so as to obtain permanent records of the way in which their mills are working, in precisely the same way that indicator diagrams are taken from time to time from steam engines in regular work.

From the data supplied by Mr. Morison it is easy to see that there are limits to the speed of the cam stamp. I have shown in the book that Mr. Morison does me the honour to quote,* that the speed of lifting the stamp depends, other things being equal, upon the cam radius, which is fixed by the construction of the mill; the speed of falling is limited by the action of the gravity, and, as before said, an interval of rest is necessary; Mr. Morison has proved the length of the latter, and his figure practically coincides with mine, which I had obtained empirically rather than scientifically. The speed of the cam stamp being thus limited, Mr. Morison gets higher velocities by means of a crank, which is able to overcome the action of retardation in the drop. This is a very interesting matter, because it is a step in advance in the direction in which all improvements in stamp mills have tended for a considerable time past. My experience in stamp mills dates back over twenty years, and the mills I had then to do with were old-fashioned even for that time. In those days, a heavy mill was one with 500 or 600 lb. stamps, the average speed was 60 to 70 drops per minute, the length of drop about 12 inches, and the crushing capacity 1½ to 2 tons per head per 24 hours. As the fall of the stamp not only crushes the stone but tends to expel the crushed stuff from the mortar, and as the second effect is quite as important as the first, it was soon seen that the capacity of the stamp mill could only be increased by increasing the number of drops. This, however, could only be done by shortening the length of drop; this, again, would have diminished the crushing power, unless the momentum of the stamp were maintained by making the latter heavier. Thus gradually was the modern stamp mill evolved, with heads of 900 to 1,000 lbs. in weight, giving 90 to 100 4 inch to 6 inch drops per minute, and crushing up to 5 tons of quartz in 24 hours. I have followed closely every improvement in the mechanism of stamp mills during the past twenty years, and none have shown themselves to have any permanent value except those that tended to develop increased speed. I should perhaps except ore feeders from this statement; these have proved to be inventions of the greatest

* *Handbook of Gold Milling.* Macmillan & Co.

value, though fiercely opposed at first, but their discussion is beside the present question. It seems to me that there is little hope of pushing the improvement in the speed of cam stamps further, because a shorter drop than 5 or 6 inches will not drive the crushed stone out of the mortar, and increasing the weight of the stamps is, as I have tried to show, useless unless the speed of the mill be increased proportionately at the same time. This sufficiently accounts for the fact that stamps weighing over 1,000 lbs. have been found unsatisfactory, though tried in several places. To get increased speed the cam will therefore have to be discarded, and Mr. Morison has evidently solved the problem of increasing the speed of the stamp mill by means of the crank and hydraulic cylinder; it must not, however, be forgotten that very similar machines driven by a crank have been invented before, some like the Elephant stamp using a steel spring, some like the Husband stamp using a pneumatic spring, but that all of these have proved themselves unsuitable to the requirements of gold milling. It would be a difficult matter to point out all the causes that brought about this failure, but it is probable that one of them, at any rate, is due to their attempting a different kind of crushing, and using a special shape of mortar box. The long narrow mortar has been shown by experience to be the best suited to gold milling, and it is a point in Mr. Morison's favour that he has not attempted to alter this part of the machine. That an increased speed of crushing gives many advantages, besides increased output, such as diminution in the proportion of slimes and a more granular product, is undoubted, and if these can be attained without impairing the machine as an amalgamator, a very real improvement will have been achieved. Mr. Morison's diagrams show that the stroke of his high-speed mill is so like that of the cam stamp, that very similar results may fairly be expected from it, and I shall look forward with keen interest to the results obtained by it in actual practice.

Yours faithfully,

HENRY LOUIS.

Mr. SELBY BIGGE wrote that with reference to the last paragraph in Mr. Morison's valuable paper the high-speed stamp was driven, as shown in the illustration, by an ordinary shunt-wound motor, and owing to the exceedingly regular and steady running of the stamp the motor was found admirably suited for the work. In actual practice, however, out on the gold-fields, where the stamp batteries of the various mines are often at considerable distances from one another, it will probably be found advantageous to erect central stations, capable of providing the power for a number of motors for driving various stamp batteries in the district. Where this can be done the electric motor is decidedly the most suitable form of driving power to employ; but instead of making use of continuous current machinery it will clearly be a case for the application of polyphase machinery, which will require considerably less attention and up-keep than machinery of the continuous current type. The main points in which multiphase machinery differs from continuous current machinery are probably well known to most engineers, the multiphase motors being entirely devoid of brushes or commutators, which have been found to be the chief source of trouble with the continuous current motor. This system is particularly suitable for mining work as the pressure can be transformed up or down at will, and the power conveyed for enormous distances with the least possible capital outlay in copper mains. The weight of the motors required to drive these stamps when compared with engines and boilers will, of course, be very small indeed, and this in itself constitutes an important factor in the question of transport about the country. Owing to the steady running of Mr. Morison's high-speed stamps it will not be necessary to drive on to any countershaft. The motor can be placed in any convenient position and drive direct on to a pulley fixed on the main shaft of the mill. This will also constitute an economy in the erection of the mill. Of course, where water power exists within any reasonable distance of the mines, it would be advisable to obtain the power direct from this source in preference to laying down a central generating station. At the same time as driving the stamp battery, current can be taken off for lighting purposes, should this be found desirable.

Mr. T. RICHARDSON, M.P., Past-President, wrote that he regretted having had to leave the meeting without having expressed the great interest he felt in Mr. Morison's stamp mill, the developments of which he had followed with much attention. The battery had been working at Hartlepool since the autumn of last year under the most severe conditions, so that it may safely be considered to be beyond the experimental stage, and he believed it would prove as valuable to the mining industry as was the cyanide process, as not only would it cheapen the cost of production, but would enable many mines which were working on low grade ores, and barely paying expenses, to become successful commercial undertakings. Another important feature was its adaptability to existing batteries, as this alone represented an enormous field in all parts of the world.

MR. D. B. MORISON'S REPLY.

(COMMUNICATED.)

Mr. D. B. MORISON, in reply, tendered his thanks to the various gentlemen who had taken part in the discussion, and so added materially to the value of his paper. The diagrams prepared by Mr. Watt showed at a glance the reason why it was possible to obtain from 30 to 40 per cent. more drops per minute from the high-speed stamp than with the cam design, and yet to maintain a practically identical blow in each case.

Mr. Watt mentioned that the acceleration at the commencement of the stroke was much greater than that due to gravity, and that this acceleration decreased towards the end; care should be taken, however, to differentiate between acceleration and velocity, as the crushing effect depended on velocity and weight, and the diagrams showed that the velocity at the end of the stroke was greater in the high-speed mill than in the cam mill, and that this difference increased as the amount of drop decreased. Prof. Weighton had referred to the possibility of working the high-speed mill with a tight gland, which might be of advantage in some cases, but in ordinary practice the condition of least friction or greatest mechanical efficiency was preferable. Another evident method of obtaining a higher number of drops would be by using a spring above the piston, but such an arrangement would not be satisfactory in practice. He was greatly indebted to Mr. Wildy for his interesting remarks, because they were based on actual milling experience and an intimate knowledge of the various designs of quartz crushing machines at present in use. A great many milling engineers had visited Hartlepool during the tests of the high-speed stamp, and he was particularly struck with the extreme care they took to master its details, how relieved they were to find that the mortar box was unaltered, and that the nature of the blow was identical with that of the cam stamp. This was very natural, however, as the modern mortar box was the result of years of experience of milling engineers all the world over, whilst the nature of the blow due to gravity had so identified itself with success in quartz crushing that any deviation was looked at with suspicion and distrust. Mr. Fothergill very aptly described the cylinder as a travelling guide for the stem; as viewed in this way it was easy to understand that the retarding friction would be *nil* if both travelled at equal speeds, whilst if the guide travelled the faster, then the friction would be accelerating friction, and would compensate for or neutralise the retarding effect of the friction of the lower stationary guide.

Mr. Patterson had referred to the flexibility of the high-speed stamp as regards weight of stamp head, height of drop, and number of drops per minute. The various diagrams had laid bare the possibilities of the machine, and it was now for the milling engineer to determine the weight, drop, and speed which would be the most suitable for any particular conditions.

Mr. McFarlane was correct in assuming that the high-speed mill had been built on the ordinary scantlings, as the intention was not to disturb the standard frame of the cam stamp in any way, but in the case of new mills the weight of framing could be very much decreased on account of the greatly reduced vibration.

There were, as Mr. Sivewright had suggested, a great many purposes to which the liquid pick-up hammer could be applied, and especially in cases where economy of power was of importance.

Prof. Louis and other speakers had referred to the pneumatic stamps which were introduced by Mr. Husband in 1870. The arrangement consisted of an overhead crank connected by a rod to a cylinder, within which was a piston whose rod formed the stamp stem. When the crank was at the bottom of its stroke and the stamp head rested on the anvil the piston was midway in the cylinder; and in the sides of the cylinder immediately above and below the piston were ports through which air was drawn in and expelled by the movement of the piston relatively to that of the cylinder. When the cylinder moved upward the air below the piston was compressed until the weight was raised. The weight in its upward stroke acquired momentum, and when the cylinder arrived at the top centre the momentum was intensified by reason of the expansion of the air below it. On the downstroke of the cylinder, however, the air above the piston was hammers, however, was very low, on account of the great loss of energy resulting from the heating of the air; but in the case of pneumatic stamps the size of cylinder required a special mortar box, so that the disadvantages were both evident and numerous, and, as a consequence, the system had not been successful in practice. The same might be said of stamps in which the weights were raised through the medium of metallic springs, as, although handy for prospecting purposes, they could not be expected to be successful for heavy and continuous work. Endless variations of both pneumatic and spring stamps might be found in the records of the English, United States, and German patent offices, but none appeared to get beyond the experimental stages—for the reason, probably, that they were based on principles which were not only unsound in theory, but were also not consistent with successful engineering practice.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THIRTEENTH SESSION, 1896-97.

PROCEEDINGS.

CLOSING BUSINESS MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, 12TH MAY, 1897.

J. R. FOTHERGILL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

The VICE-PRESIDENT said Col. Swan (President) had communicated to the Secretary that he was detained in London, and, unfortunately, was not able to be present that evening.

The SECRETARY read the minutes of the previous General Meeting held in Newcastle-upon-Tyne, on 30th April, 1897, which were approved by the members present, and signed by the Vice-President.

The SECRETARY tendered Mr. J. H. Gibson's reply to the discussion on his paper "On the Machine-cutting of Accurate Bevel and Worm Gears."

The discussion on Mr. W. R. Cummins's paper on "High Pressures for Marine Engines" was concluded.

Closing business.

MR. J. H. GIBSON'S REPLY TO THE DISCUSSION ON HIS PAPER "ON THE MACHINE-CUTTING OF ACCURATE BEVEL AND WORM GEARS."

11, Glenalmond Road,
Egremont, Cheshire,
27th April, 1897.

Dear Mr. Duckitt,

I duly received reports of discussion, and now beg to reply in the form of a letter, which you will kindly communicate to the members when the subject is again before the Institution.

My thanks are due to the President and Mr. Fothergill for their words of welcome, as well as to the members generally, for their kind reception of me, a comparative stranger.

In reply to Mr. Henderson, I doubt very much whether double helical teeth would ever have been thought of if accurate parallel teeth could have been obtained. The helical tooth is merely a development of the stepped pinion and rack still to be seen on planing machines, where a smooth and uniform motion is required. The only way to cut double helical teeth would be to split the wheel into two discs, which could be bolted together after machining; but given the choice between perfectly parallel teeth and perfectly helical teeth, I should prefer the former as being simpler and more straightforward.

Messrs. Hulse *made* a wheel-cutting machine to my designs; they did not *produce* one in the sense the question would infer. They do not use it themselves, because, in the first place, they have no permission to do so, and in the second place, they probably prefer to give out that class of work until the demand for machine-cut wheels warrants the laying down of plant that can be kept constantly employed.

Mr. Seaman asked whether these machines were likely to be in the market soon. My answer is, "Not just yet," and for the reason just stated: the present demand does not justify it. But in reply to his next query I may perhaps state that wheels cut by them are readily obtainable, and that Messrs. Henry Wallwork & Co., Redbank Ironworks, Manchester, who are the present licensees, have laid down plant for cutting all ordinary sizes of bevel and worm wheels. Larger and smaller machines will be added as the exigencies of the work require. Enquiries have come to hand by the same post for wheels varying from 2 inches to 12 feet in diameter, so that various modifications in detail have to be made in building machines to meet these extreme cases. When the machines are eventually put on the market, I hope they will be as perfect in practical detail as in principle.

Mr. Wilson very tersely summed up the advantages accruing from the use of machine-cut gearing in the reversing gears of large cruisers.

Another inestimable advantage is the freedom from noise and clatter in any machine to which it is applied. Noise affects human nerves, and clatter produces crystallization and fatigue of material, which slowly but surely weakens the whole machine, framing included.

Mr. Atherton has apparently traversed the whole subject, and his valuable criticism calls for a carefully detailed reply. I am quite willing to have the present-day cut gears brought under the same condemnation as is meted out to machine-moulded gears in the extract quoted, and a large part of my paper was devoted to that end. I admit that for rough, heavy work, where the wheels must of necessity be exposed to grit, cast wheels of shrouded or double helical patterns are the best; machine-cut gears under such circumstances would be an unnecessary refinement.

My reference to mortice wheels was primarily to illustrate the fact that the teeth of wheels in gear tend to assume the correct theoretical shape, and that therefore it is not necessary to spend much time in getting up mortice teeth to the exact shape—a few turns into the iron wheel does that.

I am afraid there are still many shops where the "rule of thumb" applies to toothed wheels, especially those shops that make only an [redacted]

Mr. Atherton said that the attempt to cut bevel wheels with a point-tool was by no means new. I would go further—I cannot imagine anyone with an open mind on the subject attempting the job in any other way, and I was very much surprised when I first took the matter up to find the rotary cutter in use at all. But the fact remains, that the majority of bevel wheels in existence, whether cut one way or the other, are notoriously bad; so there must be something wrong with the machines that cut them. For instance, a great fuss was made a short time ago about a chainless bicycle, which was driven through two pairs of bevel wheels. It was stated that these wheels were absolutely perfect, a "result hitherto unattainable," being cut on a machine specially designed for the purpose. The actual fact is that every tooth is filed up to shape after the machine has done its work.

The use of angle wheels, as Mr. Atherton aptly termed them, is sometimes permissible, as in the back gear of a long lathe where a pinion for hand traverse has to gear into the same wheel as the worm; but for such heavy machines as he described they should be abolished. Worm wheels for training quick-firing guns are of a special type, the worm shaft usually making a considerable angle with the plane of the wheel. I can quite understand that in hobbing such wheels, the wheel would have to be driven independently; but I think I am right in saying that, in the majority of cases, the hob has to rotate as well as cut the wheel.

I knew an extreme case in which a man attempted to "hob" some 30 toothed worm wheels direct, without gapping. The first wheel came out with 32 teeth (!) of decidedly curious shape.

My reference to patterns of teeth applies equally to machine-moulded and pattern wheels. Spur wheel teeth can be planed in a long strip, cut off in lengths and dovetailed round the rim of a pattern, or into a moulding block; but in either case bevel and worm wheel teeth have to be carefully shaped separately.

I must confess that I fail to see where the advantage of the "Hindley" gear comes in. It appears to me to be wrong in principle, since the part of the worm marked (*a*) has a greater circumferential speed than the part marked (*b*), and yet both parts gear into a wheel (*c*) which is moving at a uniform speed. I have never heard that this combination actually gives better results than the ordinary gear. On the other hand, I have known worms to be made slightly barrel-shaped, with very satisfactory results as regards increased efficiency and freedom from pulsation in the wheel.

In reply to Mr. Paulin's query: the cutters have to be very carefully set and tried round in the tool-holder; but it is a process closely akin to chucking a job in the lathe, and a good workman experiences no great difficulty. Of course, when the double-threaded wheel has an odd number of teeth, or the triple-threaded wheel a number not divisible by three, the teeth must come out equal all round, even if the tools are not set dead true.

I am obliged to all these gentlemen for raising moot points and giving me an opportunity of clearing them up, which I trust I have done to their entire satisfaction.

Yours faithfully,

J. H. Gibson.

ADJOURNED DISCUSSION ON MR. W. R. CUMMINS'S PAPER ON "HIGH PRESSURES FOR MARINE ENGINES."

Mr. A. L. Mellanby, continuing the discussion on Mr. W. R. Cummins's paper on "High Pressures for Marine Engines," said he thought it deserved the careful consideration of all the members, and they ought to feel grateful to the author for the time and trouble he had taken in preparing it. There were one or two points raised which he should like, with permission, to discuss. In the first place, he failed to follow the reasoning by which Mr. Cummins fixed his mean pressure. Why? Because a triple expansion engine working at 150 lbs. showed a gain of 25 per cent. over a compound working at 80 lbs., he was unable to see why the mean pressure of the triple should be made 25 per cent. higher than that of the compound. He believed that the mean pressure given was the one generally adopted, but he thought it was more a coincidence than that it followed from such reasoning. In the same way he could not understand how the mean pressures for the higher initial pressures were fixed. It seemed to him that the only scientific method of treating the subject would be as follows:—First, fix upon the vacuum at which they wanted their engine to work. Then determine what terminal pressure they desired for their low pressure steam before exhaust. This, of course, was fixed by the amount of drop they wanted, which drop should be at least equal to the pressure required to overcome the friction of the low pressure engine. They had now got the initial pressure of their steam and the final pressure, and could easily determine what number of expansions were required. Thus, for a vacuum of about 27 inches, and an initial pressure of 200 lbs. absolute, they ought to obtain a terminal pressure of about 6 lbs. absolute, with about 22 expansions; by the use of the temperature-entropy diagram this could be determined immediately. But if they worked out the amount of work—deducting what would be lost by back pressure—they could theoretically obtain from a cubic foot of steam expanding adiabatically 17 times and 22 times, they would find there was very little gain with the larger number of expansions. But even this method, although theoretically correct, could not be strictly applied to the case of the steam engine, because it assumed a state of things which was not present in any type of engine yet made. What he meant to say was, that it ignored entirely initial condensation. He doubted very much whether there were any; at all events there would be very few engines where, of each cubic foot of steam that entered the cylinder, more than 80 per cent. of it was dry, at least 20 per cent. of it being initially condensed. It was this factor which so largely made it impossible to theorise upon what an engine was going to do. He might say that he spoke feelingly upon this point. For the last two years he had been constantly engaged in making engine trials, and unless they had made a series of experiments and had got to know something of the law governing the results of the changes they were making, he had always found that the theoretical results were a long way different from the actual results. In the next place, they had to consider that what they wanted was consumption per effective horse-power, and not per indicated horse-power; and there was no doubt that the friction horse-power of an engine increased as the pressure rose, so that they might obtain a considerable increase of efficiency per indicated horse-power from the use of high pressure steam, whereas the increase of efficiency per effective horse-power might be very small. Here he might remark that the engine builders of this district ought to congratulate themselves at having in their midst the best experimental engine in the world, by means of which many of the points raised by Mr. Cummins might be settled in a practical and effective manner. To show how far the actual results differed from those at which Mr. Cummins had arrived, he gave them the following results obtained from the engine at the Durham College of Science. With steam at 150 lbs. boiler pressure the consumption was 15·76 lbs. per effective horse-power; at 210 lbs. boiler pressure, 14·66, a gain of only 7 per cent. Let him still further remark, that the number of expansions in both cases was the same, 17·4, which was about the best for 210, but not at all for 150—probably 11 or 12 would be of expansions being carried out, with, in the first case, two cylinders, namely, two and four, as high-pressure and low-pressure, and in the second case, with three cylinders, namely, two, three, and four, as high-pressure, intermediate-pressure, and low-pressure. Here they had two experiments with the same high-pressure cylinders, the same cuts-off, and the same initial pressure, and they might expect the same consumption of steam; but the results were greatly different. With the compound the water consumed per hour at 90 revolutions was 1,126 lbs., and with the triple only 977 lbs. The indicated horse-power of the compound at 90 revolutions was 58·2, and of the triple 62·9; giving 19·34 lbs. per indicated horse-power for compound and 15·5 lbs. per indicated horse-power for triple. What he particularly wished to call their attention to was the water used in both cases; and remembering that it was the same high-pressure cylinder, with the same cut-off, so that the theoretical amount of steam to be used in both cases was the same, yet with the compound they had over 15 per cent. more water used than with the triple. The temperature range of the high-pressure cylinder was, compound about 106 degrees, triple about 83 degrees. To take a more extreme case, which would show the effect of temperature range, he made three other experiments, first, compound cylinders 1 and 4, and triple 1, 3, 4, and 1, 2, 4. The water used per hour at 90 revolutions was:—

	Lbs.	Ranges of Temperature. Degrees.
Compound, 1 and 4	1,001	... 110
Triple, 1, 3, 4	808	... 60
,, 1, 2, 4	794	... 50

In this case the compound consumption was 27 per cent. more than that of the best triple. Trying triple and quadruple at 200 lbs. pressure, the results were similar. He might say that as experiments these were conducted with the greatest care, and that the water used was measured in a very exact manner. There was a separator just before the steam chest and two calorimeters were used, both of which gave the steam as being practically dry. This showed the extreme importance of the proportioning of the second cylinder. Mechanical efficiency demanded an amount of drop in the high-pressure cylinder sufficient to overcome the friction of that engine. More drop than this meant a larger range of temperature than necessary in the high-pressure cylinder, and consequently a greater consumption of steam. He might mention that he had been working at a most interesting series of experiments at the Durham College of Science on this subject, and hoped soon to have some definite information on the right proportioning of the intermediate cylinders.

The last results might also be, he thought, a substantial argument against the idea that any great gain was to come from increased pressure. Higher pressure meant greater temperature range, and therefore greater initial condensation. He thought that if the pressures were carried much above 200 lbs. then, in order to get the best efficiency in terms of indicated horse-power, the expansion would have to be carried out in five stages. What results this would give in terms of effective horse-power he did not care to say; and then there was the question of cost to be considered. He desired to again thank Mr. Cummins, and thought that by the discussion of his carefully thought-out paper a large amount of good might be obtained by North East Coast engineers.

The VICE-PRESIDENT, in closing the discussion, said they would much regret Mr. Cummins not being present; his reply would have to be communicated to the Secretary. He was sure he would have their hearty approval in proposing, first, a vote of thanks to Mr. J. H. Gibson for his very able paper "On the Machine-cutting of Accurate Bevel and Worm Wheels." The Secretary had had a great many communications on this paper, which he had sent to Mr. Gibson. He had heard the paper spoken of outside as very able and interesting. He had also to ask them to accord a hearty vote of thanks to Mr. Cummins for his most interesting paper. He only regretted that they had not had a more exhaustive discussion on a paper which had taken so much time and attention to produce.

The motions were carried by acclamation.

In reply to Mr. Gibson's suggestion of modifying the size of the intermediate cylinder in the four-cylinder three-stage arrangement, a slight improvement might be obtained by making this cylinder smaller than it would be in the case of the three-cylinder three-stage arrangement, but alteration to its size would give equal initial loads and equal cuts-off unless the terminal pressure in the high-pressure or intermediate-pressure was allowed to come below the back-pressure line.

The expedient of making the rods, etc., of the two low-pressure cylinders less than those of the high-pressure and intermediate-pressure was a very unsatisfactory way of getting out of the difficulty, as the turning moment would be adversely affected, perhaps necessitating an increase in diameter of the shafting, and also entailing the carrying of a double set of spare gear for the differing parts.

In reply to Mr. Mellanby, it appeared to the writer that the very fact of stating that the steam economy effected by 150 lbs. steam over 80 lbs. steam was 25 per cent. implied that the increase of mean pressure was 25 per cent. ; that is if Mr. Mellanby and the writer were looking at the economy from the same point of view.

They knew that by increasing the boiler pressure from 80 lbs. to 150 lbs., and using a suitable number of expansions in each case, that with the same low-pressure cylinder, and of course the same piston speed, they could indicate 25 per cent. more power with the same expenditure of coal, which of course meant that the average pressure must be 25 per cent. more in the case of 150 lbs. boiler pressure.

How this increase of mean pressure had come about, whether by higher initial pressure, less cylinder condensation, less drop, or what not, they did not know exactly, and the object of taking the actual expansions in each case was not so much to secure a scientific method of treating the two types of engine, but a more or less practical method of comparing theoretical economy of steam of 80 lbs. and 150 lbs. working in a perfect engine, under the same conditions as regarded initial pressure, number of expansions and back pressure, as in actual examples of compound and triple engines having the agreed on relative economy of 25 per cent.

Mr. Mellanby suggested that a terminal pressure should be chosen irrespective of the actual terminal pressure of the type of engines they want to compare, and also irrespective of any difference there might actually be in the terminal pressure of the two types under comparison, and then calculate the theoretical expansions from the chosen terminal pressure. The writer thinks that for *comparison* the more satisfactory method is to take the actual expansions in each case, and work the formula with the theoretical terminal pressure.

The consumption per effective horse-power had purposely not been touched on in the paper as it did not affect steam economy.

Mr. Mellanby pointed out that the results of experiments obtained from the engine at the Durham College of Science with boiler pressures of 210 lbs. and 150 lbs. pressure differed from those obtained by the writer's calculations, but he totally missed the point of the calculation. In the first place the results of the experiments were in consumption per effective horse-power, which, as Mr. Mellanby said, might be very different from consumption per indicated horse-power, and in the next place the expansions were the same in the experiments, but not so in the writer's calculation, and they did not yet know what was the most economical number of expansions for steam of various pressures. Again, the experiments were presumably carried out without the use of a steam calorimeter.

The object of the calculation was to point out that with steam of 80 lbs. and 150 lbs. and the given number of expansions and back pressure, the theoretical steam economy, starting with the same quantity of heat in each case, would be 22 per cent. in favour of the higher pressure.

The actual economy obtained by the rise of pressure in practice was about 25 per cent.

The theoretical steam economy obtained by increasing the pressure from 150 lbs. to 210 lbs. with the given expansion and back pressure was 11 per cent.

Hence an economy of about 11 per cent. was what they might reasonably expect in practice if the increase of pressure did not introduce any new, nor aggravate any of the old, sources of loss.

Mr. Mellanby's experiments on temperature range were most instruc-

CLOSING BUSINESS.

ALTERATION IN BYE-LAW No. 40.

The VICE-PRESIDENT, on behalf of the Council, moved that Bye-law No. 40 be altered to read as follows:—"The *Transactions* shall not be supplied free to members whose subscriptions are unpaid." The Council, he said, had found this to be absolutely necessary, due to the fact that more than one member, after election to the Institution, paid only one year's subscription; but got, by reason of his membership, copies of the *Transactions* for a couple of years. It was unfair to the Institution and not complimentary to the gentlemen who accepted them, and therefore the Council had felt there was no other course left than to withhold the *Transactions* until members were clear on the books. He asked them, by a show of hands in the usual way, to declare whether or not they agreed with this alteration of the bye-law.

There being none against it, the VICE-PRESIDENT declared it unanimously agreed to.

APPOINTMENT OF AUDITOR.

Mr. E. J. CROSIER proposed that Mr. R. W. Sisson be re-elected Auditor of the Institution. He had had some experience of him and his work, and although he would put them to some trouble over a missing voucher, that was only an evidence of how thoroughly he did his business.

Mr. R. WALLIS seconded the re-election, which was carried *nem. con.*

VACANCIES IN THE COUNCIL.

The VICE-PRESIDENT declared the following gentlemen elected to fill the vacancies in the Council:—

President—COL. H. F. SWAN.

Vice-Presidents—MESSRS. J. R. FOTHERGILL, J. M. RENNOLDSON, and R. L. WEIGHTON.

Hon. Treasurer—MR. G. E. MACARTHY.

Ordinary Members of Council—MESSRS. J. H. HECK, R. H. MUIR, P. PHORSON, C. RENNOLDSON, and M. SANDISON.

THANKS TO THE RETIRING MEMBERS OF COUNCIL.

Mr. H. G. GANNAWAY had much pleasure in proposing a hearty vote of thanks to the retiring members of the Council.

Mr. W. H. ATHERTON seconded the motion, which was adopted by acclamation.

The VICE-PRESIDENT said he was certain the retiring members of the Council would fully appreciate the vote they had so kindly accorded. He had only now to declare that the session was closed, and in doing so, perhaps, he might make a slight comment relative to the papers that had been read. He was sure that the papers, on the whole, would be admitted to have been up to the standard of the Institution; but a peculiar feature associated with them was that they had all been engineering papers—they had not had a shipbuilding paper, and so it had been entirely an engineering session. He did not know whether shipbuilders had been so much engaged that they could not find time to get up papers on shipbuilding; but one might reasonably hope that next session the "shipyard" would be to the front, and that shipbuilders would retrieve their credit and renown in the Institution. He now thanked them for their attendance at the meetings, and hoped that next session they would have more life and vigour infused into their gatherings, so as by ample discussion to give the very best encouragement possible to those who read papers. The Secretary would be very pleased to receive notification of any papers for next session, especially any which shipbuilders might have to submit.

The session then closed.

MEMOIRS.

WILLIAM ARCHBOLD.

William Archbold was born in Newcastle-upon-Tyne on the 26th December, 1868, and died on the 10th November, 1896, of exhaustion following an operation for appendicitus. He was educated at Bath Lane Science and Art Schools, and at the age of twelve won a scholarship for science and mechanics. At the age of fourteen he was placed in the works of Messrs. R. & W. Hawthorn, St. Peter's-on-Tyne, as apprentice engineer under his father, who was then manager, where he remained till January, 1884, when, on his father's removal from the district to take an appointment with Messrs. Fawcett, Preston, & Co., engineers, Liverpool, he was transferred and completed his apprenticeship in the workshops and drawing office of that firm. In the year 1889 he returned to Newcastle-upon-Tyne, and was for a short time employed in the drawing office of Messrs. Ernest Scott & Co., Close Works, Newcastle-upon-Tyne: afterwards he assisted his father in the management of Messrs. The Blyth Dry Dock Co., Limited, Blyth, and remained there until the 14th July, 1891, when he joined the Australian liner, "Port Denison," as fourth engineer. On the voyage he was seized by a severe chill, which brought on rheumatic fever, and on the vessel's return to London he was compelled to give up sea life. After a short rest, he accepted the appointment of chief draughtsman with Messrs. Ernest Scott, Mountain, & Co., Limited, electrical engineers, Newcastle-upon-Tyne, which appointment he held up to the time of his death. He possessed a remarkable knowledge of the science of electricity, and gained for himself considerable distinction in his profession. At the time he was seized with the illness which proved fatal he was engaged with a series of experiments, which had for their aim a great development in the use of electricity in its application to motive power for machinery. By his kindly disposition and his consideration for those who were placed under him, he obtained the goodwill of all with whom he came in contact, and his untimely death at the early age of twenty-seven years was deeply regretted by a large circle of friends. He became a member of the Institution in the beginning of 1894.

EDWIN GRAHAM.

Edwin Graham was born in Manchester in March, 1837. He was educated at Dumbarton, afterwards serving a seven years' apprenticeship as an iron shipbuilder with Messrs. Denny & Sons of that town, after which he was for some time with Mr. Winter, naval architect, London, and in 1862 he was appointed chief draughtsman to Messrs. T. R. Oswald & Co., of Sunderland. In 1864 he took the entire management of the shipyard at Kinghorn, Fifeshire, for the late Mr. John Key; and in 1867 he went back to Sunderland as shipyard manager to Messrs. T. R. Oswald & Co. This position he held until 1871, when, along with others, he started iron shipbuilding at Hylton, near Sunderland, under the style of Messrs. Osbourne, Graham, & Co., and continued to take an active part in the business up to his death, which occurred at his residence at Hylton on the 22nd February, 1897, after a short illness. He leaves a widow and a grown up family. He became a member of the North-East Coast Institution of Engineers and Shipbuilders at its formation in November, 1884, was one of the first members of the Institution of Engineers and Shipbuilders of Scotland, and was a member of the Institution of Naval Architects.

THOMAS F. IRWIN.

Thomas F. Irwin was born in Birmingham on the 10th of May, 1848. He commenced his apprenticeship to the engineering trade at the Britannia Ironworks, South Docks, Sunderland, in January, 1863, and at the end of 1866 he went into the service of Messrs. Thompson & Boyd, engineers, Newcastle-upon-Tyne, where he completed his apprenticeship and remained with them for some time as a journeyman. On leaving them he went to the works of Messrs. Samuel Tyzack & Co., thence to Messrs. William Pile & Co., shipbuilders, Sunderland, the North Eastern Marine Engine Works, Sunderland, and thence to a firm in Stockton. He afterwards went to sea for some time as a sea-going engineer, after which he again joined Messrs. William Pile & Co. as chief draughtsman in their engineering department. When Messrs. The Wallsend Slipway & Engineering Co. opened their works at Wallsend-on-Tyne, the late Mr. Charles S. Swan engaged him as manager over the engineering department, and subsequently he left them and joined the firm of Messrs. Inman & Co., steamship owners of Liverpool, as superintendent engineer. Leaving this firm about the year 1883, he began business in Liverpool as a consulting and inspecting engineer, being latterly one of the partners in the firm of Messrs. Irwin, Atkinson, & Young, with whom he was associated up to the time of his death. Previous to his death, which occurred at Gilsland on June 11th, 1897, he was in very bad health, but his persevering nature and indomitable will would not permit him to take the rest, which, under the circumstances, was necessary. His frank and genial disposition gained for him many friends. He joined the Institution at its formation in November, 1884.

HUGH MACOLL.

HUGH MACOLL was born in Glasgow in the year 1841. He was apprenticed to the firm of Messrs. Barclay, Curle, & Co., of that city, his father being their foreman shipwright. After spending some time in the yard, he entered their drawing office, in which he eventually became chief draughtsman. In the year 1865 he left to become manager for Messrs. Key & Co., shipbuilders, Kinghorn, Fifeshire, where he remained till 1879, when he removed to Sunderland as manager for Messrs. S. P. Austin & Son, Wear Dockyard. With the latter firm he remained till February, 1897, when, owing to continued ill-health, he resigned his appointment. As a shipbuilder he was an enthusiast, his general and detail knowledge of ships and shipbuilding being exceptionally extensive. In connection with the founding and developing of the North-East Coast Institution of Engineers and Shipbuilders, his energy was untiring, and only those who were behind the scenes knew the amount of labour and time he devoted to it. He was one of its earliest members and the first Life Member. He was on the original formation committee and was elected on the first Council, and continuously held office either as member of Council or Vice-President till the day of his death. In the compiling of the "Statistics of the Comparative Progress of British and Foreign Shipping," published in Vol. IV. of the *Transactions* of the Institution, he did a large amount of very laborious work. The Graduate Section is much indebted to him for the fatherly interest he took in it, and it was largely due to his efforts that its somewhat feeble childhood developed into its present lusty manhood. Athough suffering from a distressing and painful malady, his energy and spirit seemed unlimited, and when the Institution decided to take up the matter of replacing the old measured mile posts at Hartley by the present improved ones he gladly became one of the committee and did a very large share of the work;

much of which was done when, in his condition, he should have been resting and endeavouring to recruit his health. His death, which was not unlooked for by his friends, occurred in London on the 26th April, 1897, he being then in his fifty-sixth year. In him the Institution has lost a prominent member, a hard and able worker, and a real friend.

WILLIAM PUTNAM.

WILLIAM PUTNAM was born in London in the year 1835. He migrated to the North of England at an early age, and was, during the whole of his life, closely connected with the North-East Coast. He started business life in the works of the old Stockton and Darlington Railway Company. After a few years he joined the engineering firm of Messrs. Cowan, Sheldon, & Company, Limited, of Carlisle. About the year 1862 he, on behalf of this firm, came to Darlington to take over the management of the Darlington Forge, with which he was connected up to the time of his death. The Forge had been in existence about six or seven years, under the able management of Mr. Alfred Hollis, prior to Mr. Putnam joining it, and had been chiefly engaged upon railway work, employing about 50 hands and covering about an acre of ground. Mr. Putnam being a man of energy and keen business foresight set to work to lay down plant, by means of which he could meet the requirements of marine engineering and shipbuilding in the district. In 1873, soon after the passing of the Companies Act, the works were incorporated in a private limited liability company, with Mr. Putnam as managing director, a position which he held until his death; and under his able management the Forge grew into one of the largest concerns of its kind, employing

MR. SHARP'S REPLY TO THE DISCUSSION ON HIS PAPER ON "THE RESISTANCE AREAS OF TRANSVERSE SECTIONS."

21, WARDO AVENUE, MUNSTER ROAD,
LONDON, S.W.,
August 5th, 1897.

DEAR MR. DUCKITT,

I much regret that change of residence caused me not to receive circulars and letters, thereby preventing my being present at the meeting to reply to the discussion of my paper on "The Resistance Areas of Transverse Sections;" also, pressure of work has considerably delayed the writing of my reply.

In answer to Mr. Thompson and Professor Weighton, the diagrams represent a "graphic method of integration," and give the same results as found by the integral calculus. A more lengthy description of the construction of the resistance areas is given in the Appendix.

Replying to the friendly criticism of Mr. Brown, the correctness of inclining the neutral axis, instead of being at right angles to the plane of bending, is admitted, a point which was overlooked in laying down the diagrams of certain unsymmetrical sections. It will be apparent, however, on reference to the Plates, that as the contour of the figure converges to a point, the difference is hardly appreciable.

Mr. Atherton has evidently gone through the paper *seriatim*, but he does not appear to have brought a great amount of intelligence to bear upon the subject. Beginning with unnecessary repetitions of portions of the paper, the first sentence calling for any reply is where "he failed to see how they could do anything else." It is impossible to fix the safe load as some fraction of the breaking load, for the very reason that we do not know what the breaking load is in the majority of cases. This is brought home very forcibly in observing the results obtained from experiments upon beams of various sections; for the modulus of rupture (even with the same metal, and the samples as near alike as it is possible to get them) varies according as the material is placed abundantly around the neutral axis, or the opposite.

Coming to the definition of the title of the paper, Mr. Atherton has entirely failed to make out a case why it should be called "equivalent area" in preference to "resistance area." Taking the actual area of the section (in any of the figures) and comparing it with the part shown hatched, in no sense can the one be said to be equivalent to the other, as the word "equivalent" admits of one meaning only; it certainly becomes equivalent to something ultimately, and then only after being put through certain processes. It was this misapplication of the word which caused the substitution of resistance area for equivalent area in the paper, the term being well known to the writer; indeed, it is used in the second volume of our own *Transactions* and subsequently. Again, if the definitions given by Mr. Atherton are analysed, they will be found to be one and the same thing, for he gives in the one instance—

$$\left.\begin{array}{l}\text{The half of the safe resistance area} \times \\ \quad\text{resistance arm}\end{array}\right\} = \begin{array}{c}\text{the moment of}\\ \text{resistance.}\end{array}$$

And in the other instance he gives—

$$\left.\begin{array}{l}\text{The half of the equivalent area} \times \text{the} \\ \quad\text{arm} \times \text{maximum safe stress}\end{array}\right\} = \begin{array}{c}\text{the moment of}\\ \text{resistance.}\end{array}$$

In the first case a force scale is introduced (which is nothing more nor less than allocating a force to each unit of area) compensated for in the second case by multiplying by a maximum safe stress per unit of area.

The sentence which is unintelligible to Mr. Atherton I will explain again, and hope it will be then understood. We have three connected bodies whose magnitudes are 5, $3\frac{3}{4}$, and 3 lbs. say, their relative positions are indicated by the three small circles in Fig. A, page 108, these circles are also their centres of gravity; it is required to find their resultant centre of gravity. Proceed as directed at the bottom of page 107, and we get the position as shown by the large circle, the magnitude being the sum of the three.

Could anything be more absurd than Mr. Atherton's way of "testing nection with marine engineering are decidedly empirical, the Council might take the initiative by arranging to have discussions (with experiments if necessary) on several of the most controversial subjects.

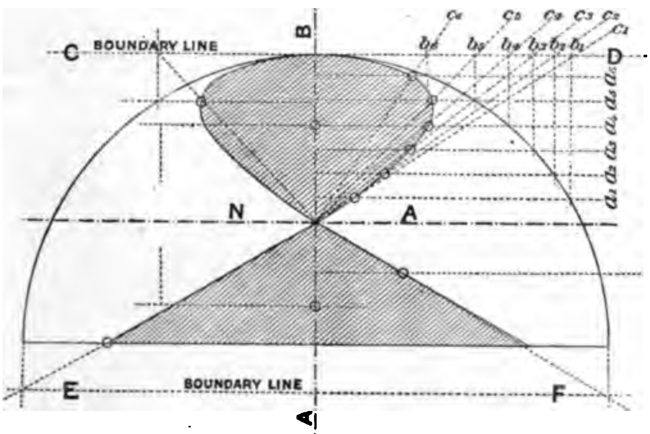
In conclusion, I beg to thank those gentlemen, who have shown interest in the paper, by taking part in the discussion, both adverse and complimentary.

Yours faithfully,

A. E. SHARP.

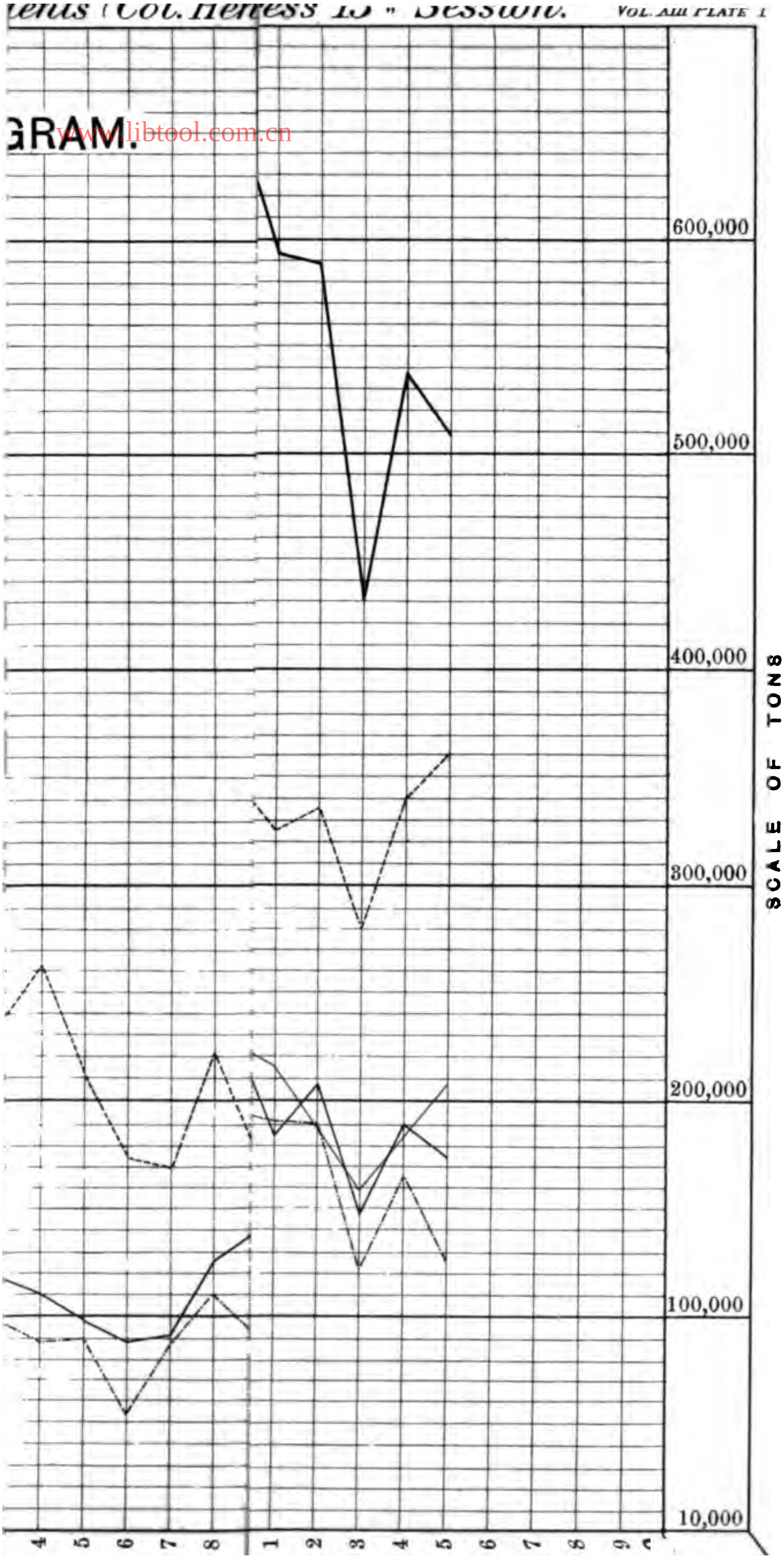
APPENDIX.

Referring to Fig. 10 A, the portion shown hatched is obtained from the 3 inch semicircle in the following manner (see sketch) (the construction is the same for any other figure):—



Find the centroid of the semicircle, this has been found to be at the intersection of the lines A B and N A; draw a line parallel to N A and tangent to that portion of the semicircle farthest from N A, in this case C D, draw also E F parallel to N A, and the same distance from it as C D. Draw ordinates a_1, a_2, a_3, a_4, a_5, a_6, and where ordinates cut the semicircle project lines to cut C D at b_1, b_2, b_3, b_4, b_5, b_6. From the point of intersection of b_1 with C D, b_2 with C D, etc., draw lines c_1, c_2, c_3, c_4, c_5, c_6 to centroid.

The intersections of a_1 c_1, a_2 c_2, etc., are the points through which the curve is drawn, and determine the contour of the hatched portion.


GRAM.
600,000
500,000
400,000
300,000
200,000
100,000
10,000
SCALE OF TONS
4
5
6
7
8
1
2
3
4
5
6
7
8
9

To illustrate Mr. G.D. Weirs' Remarks on Mr. J.F. Walliker's Paper on "The Maintenance & Repairs of Marine Boilers."

Fig. 1.

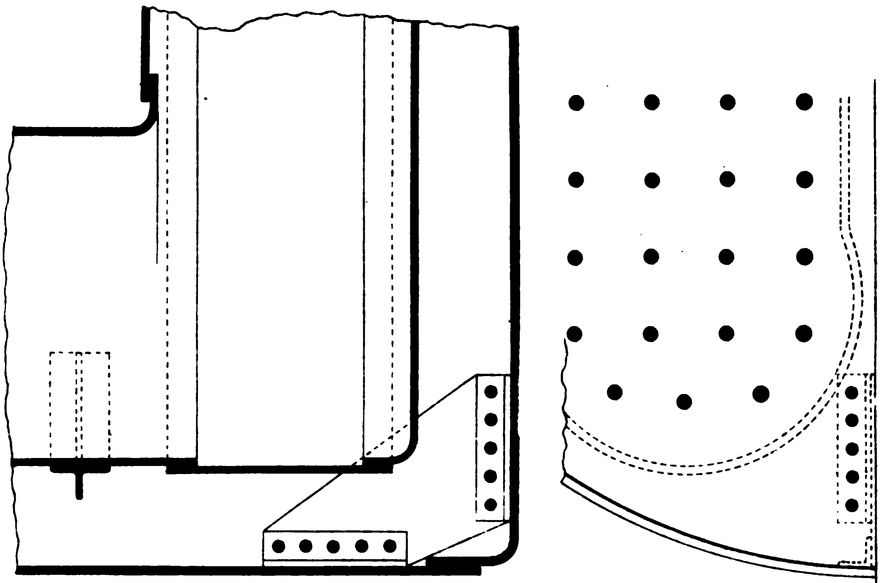
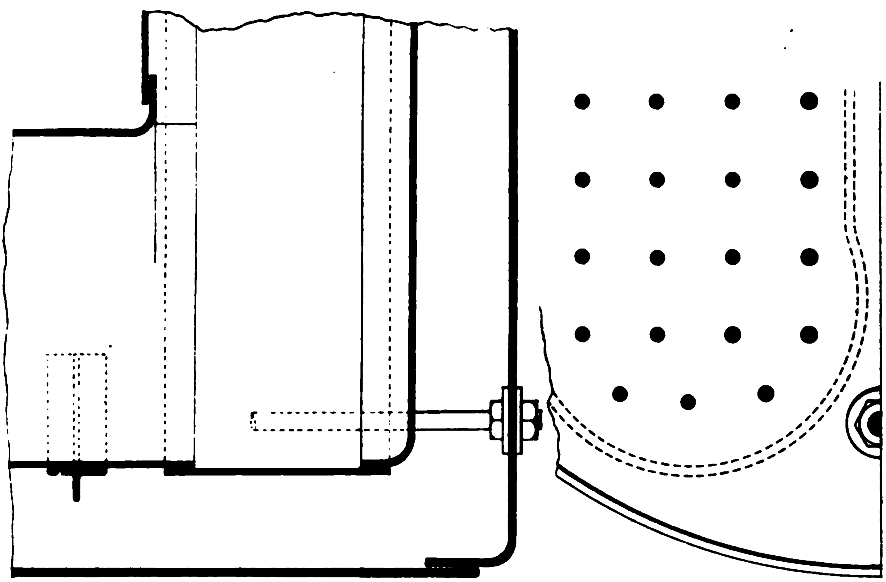


Fig. 2.



Andw. Reid & Compy. Ltd. Newcastle on Tyne

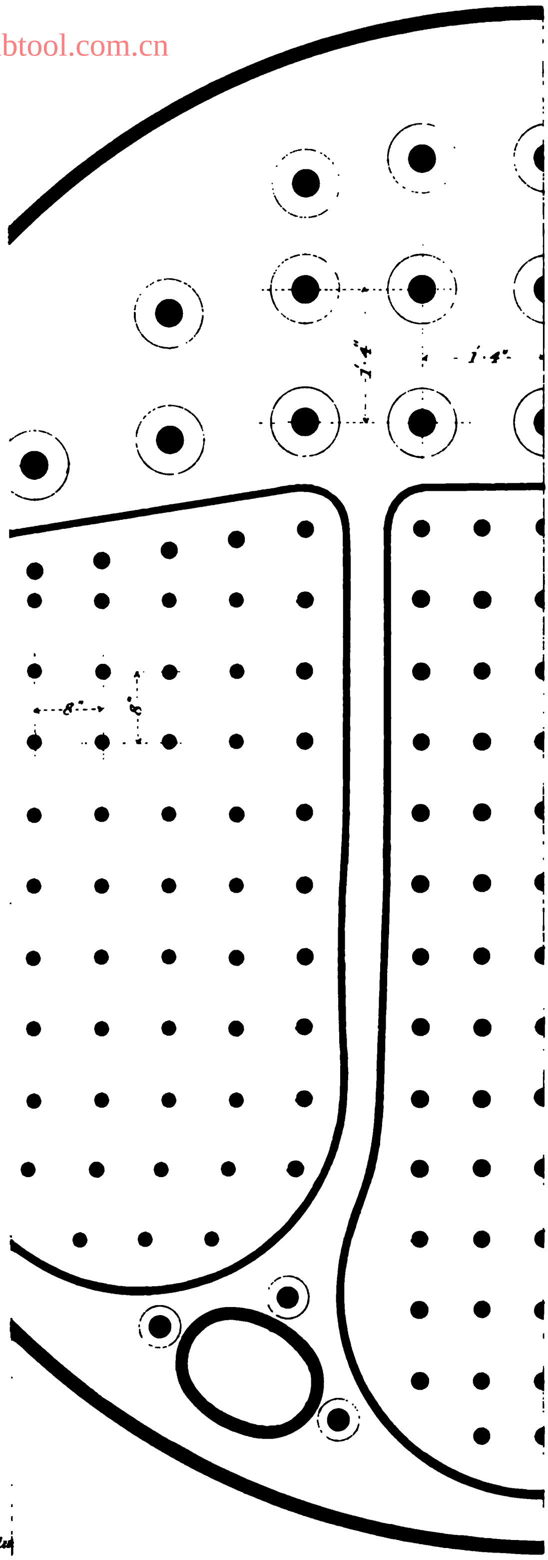
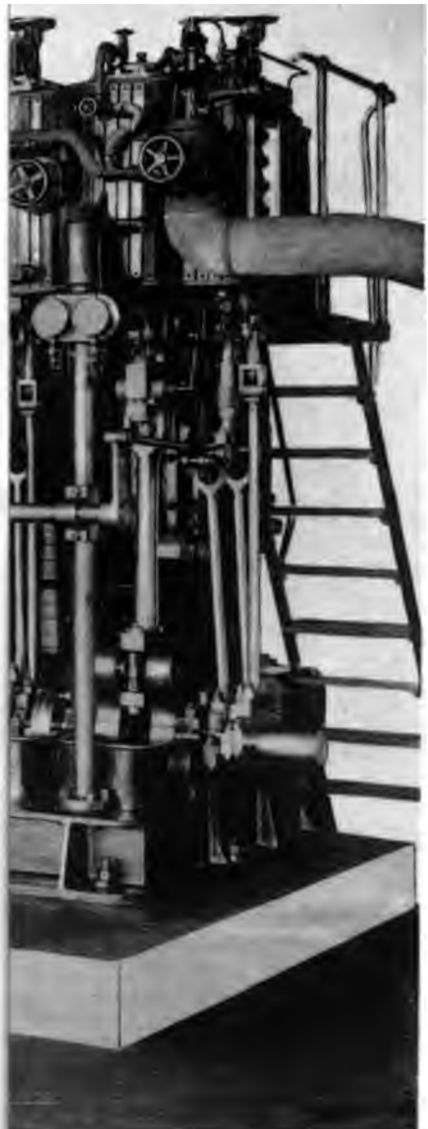


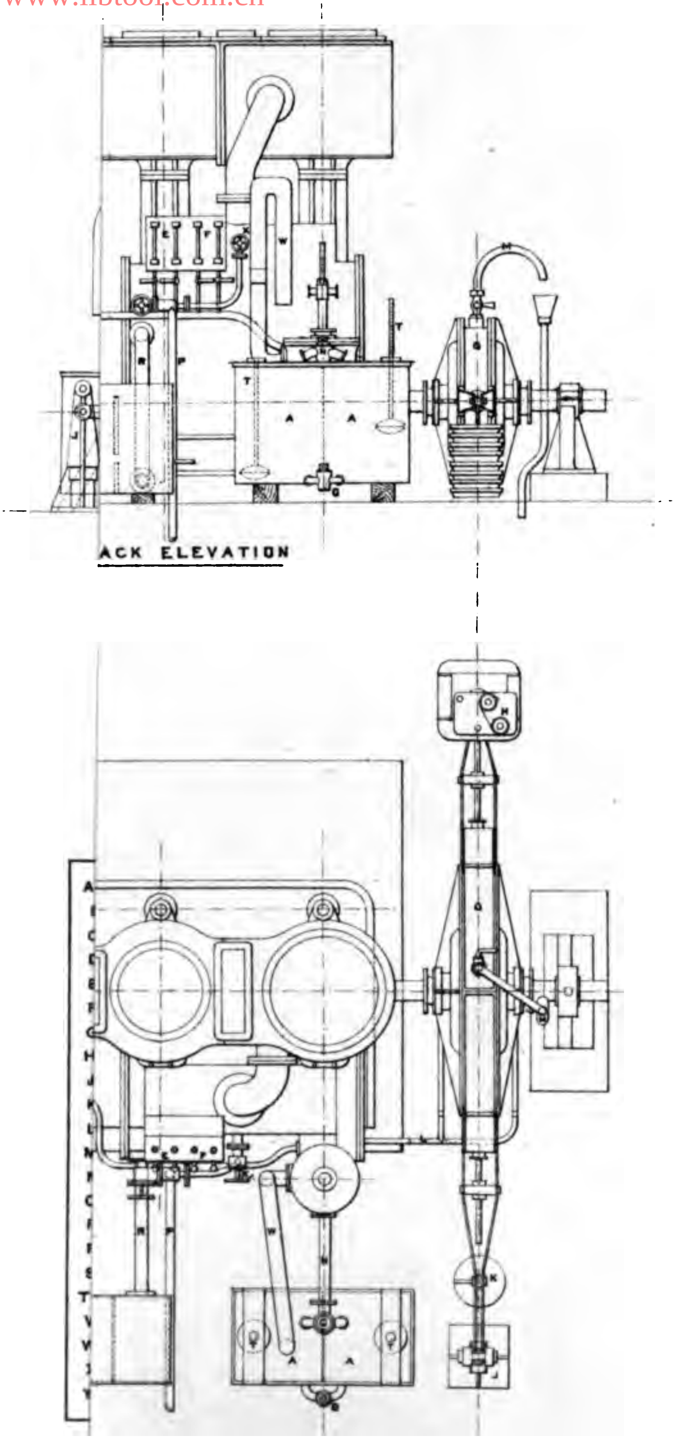
FIG. 2.

Andw Reid & Co. Newcastle-on-Tyne



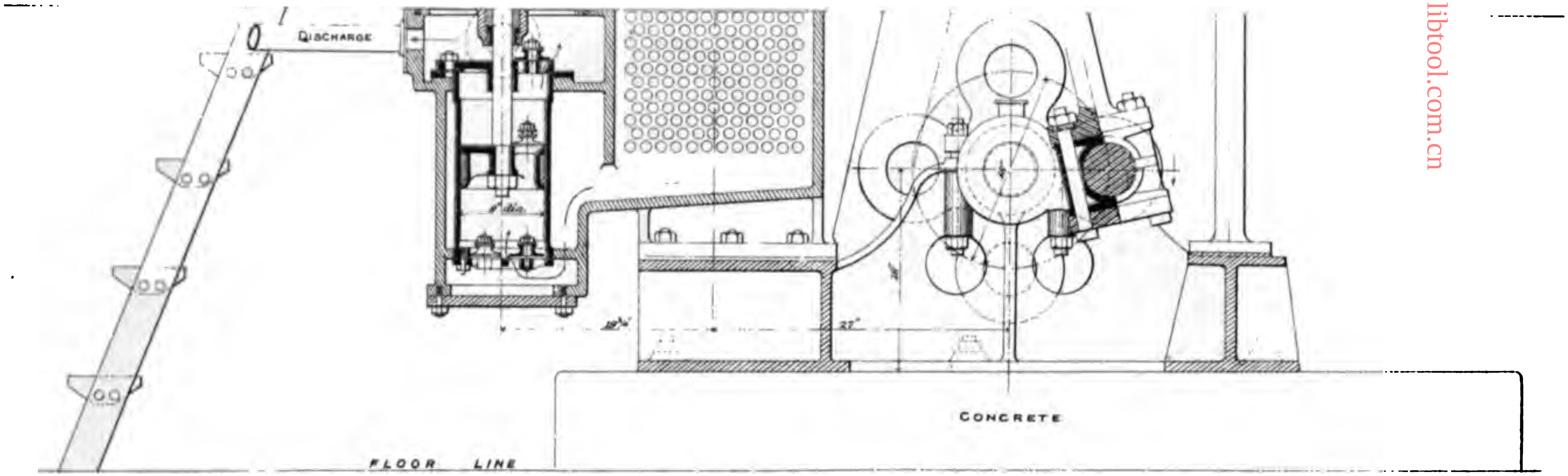
Andw Reid & Compy. Ld Newcastle on Tyne

Andw Reid & Compy Ld Newcastle on Tyne

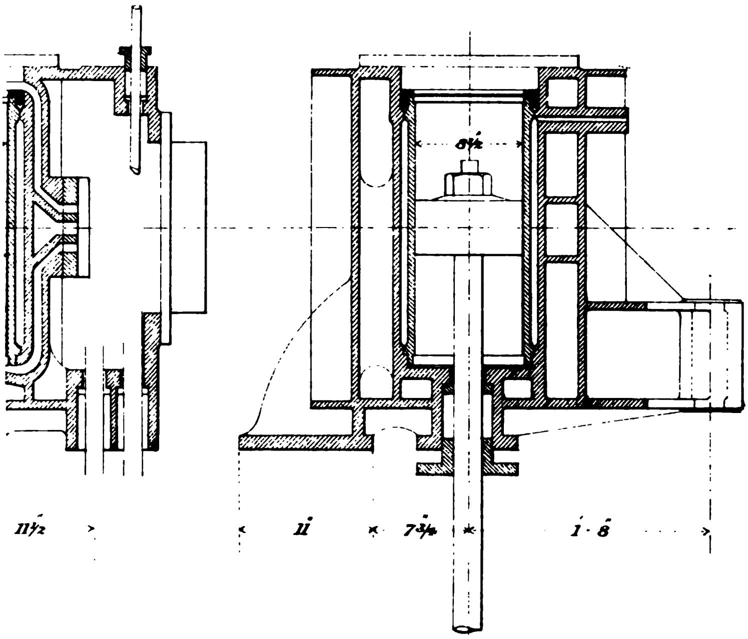


And^w Reid & Comp^y L^td Newcastle on Tyne

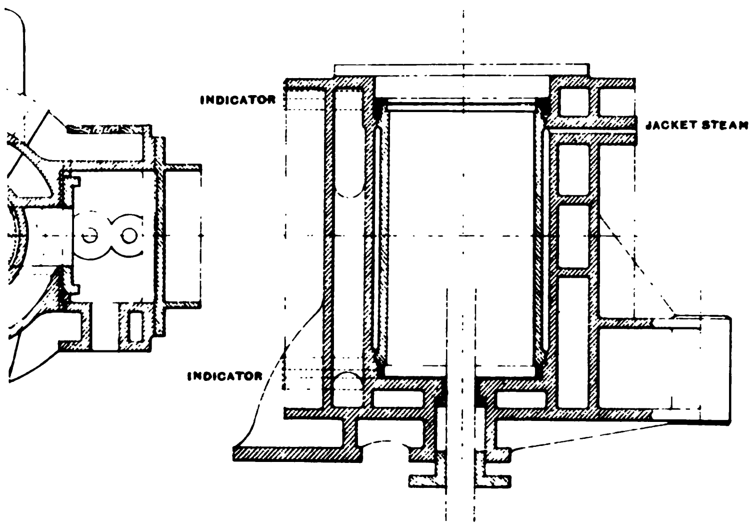
To illustrate Professor Weighton's Paper on "The Experimental Engines at the Durham College of Science, Newcastle on Tyne."



SCALE 3/4" - 1 FOOT



Cross Section through H.P.



Cross Section through 1st I.P.

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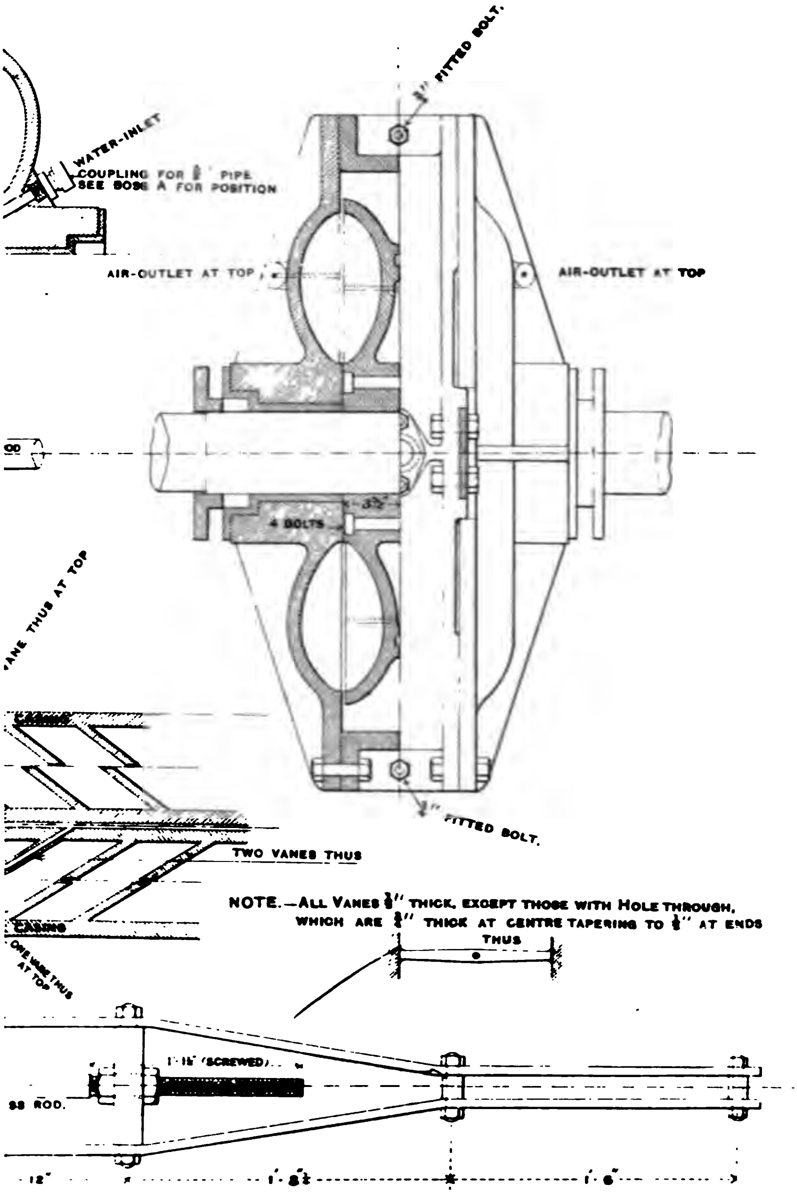

...E, 1 Inch = 1 Foot.

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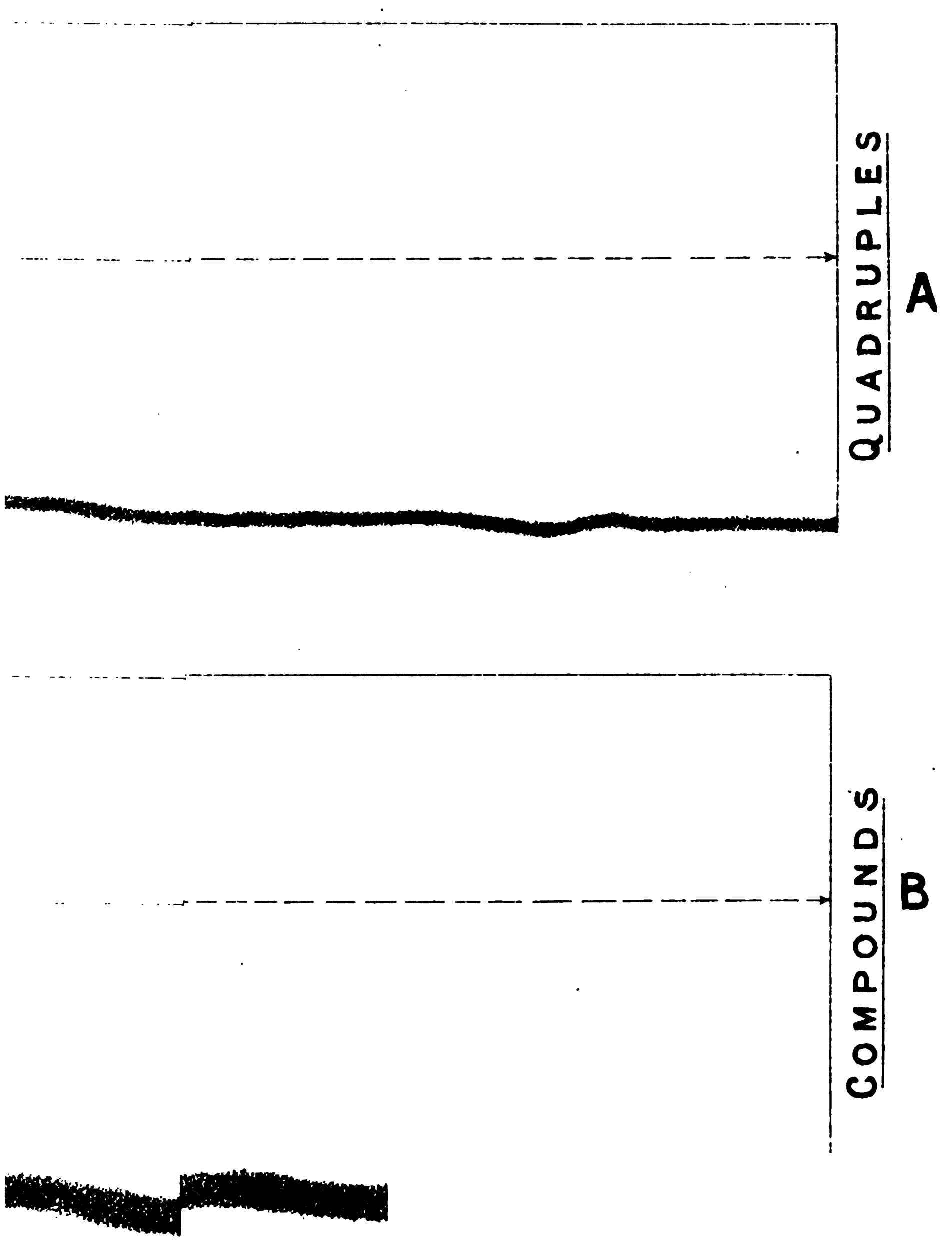
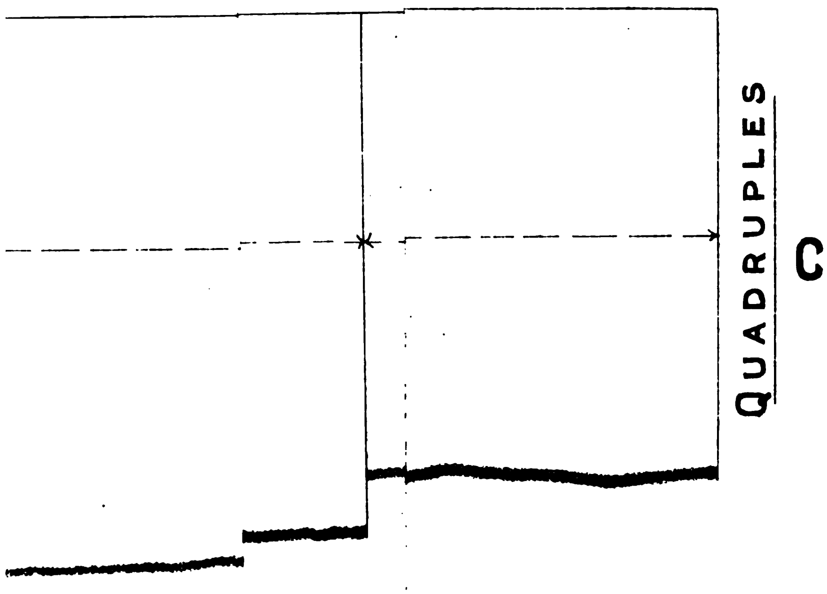
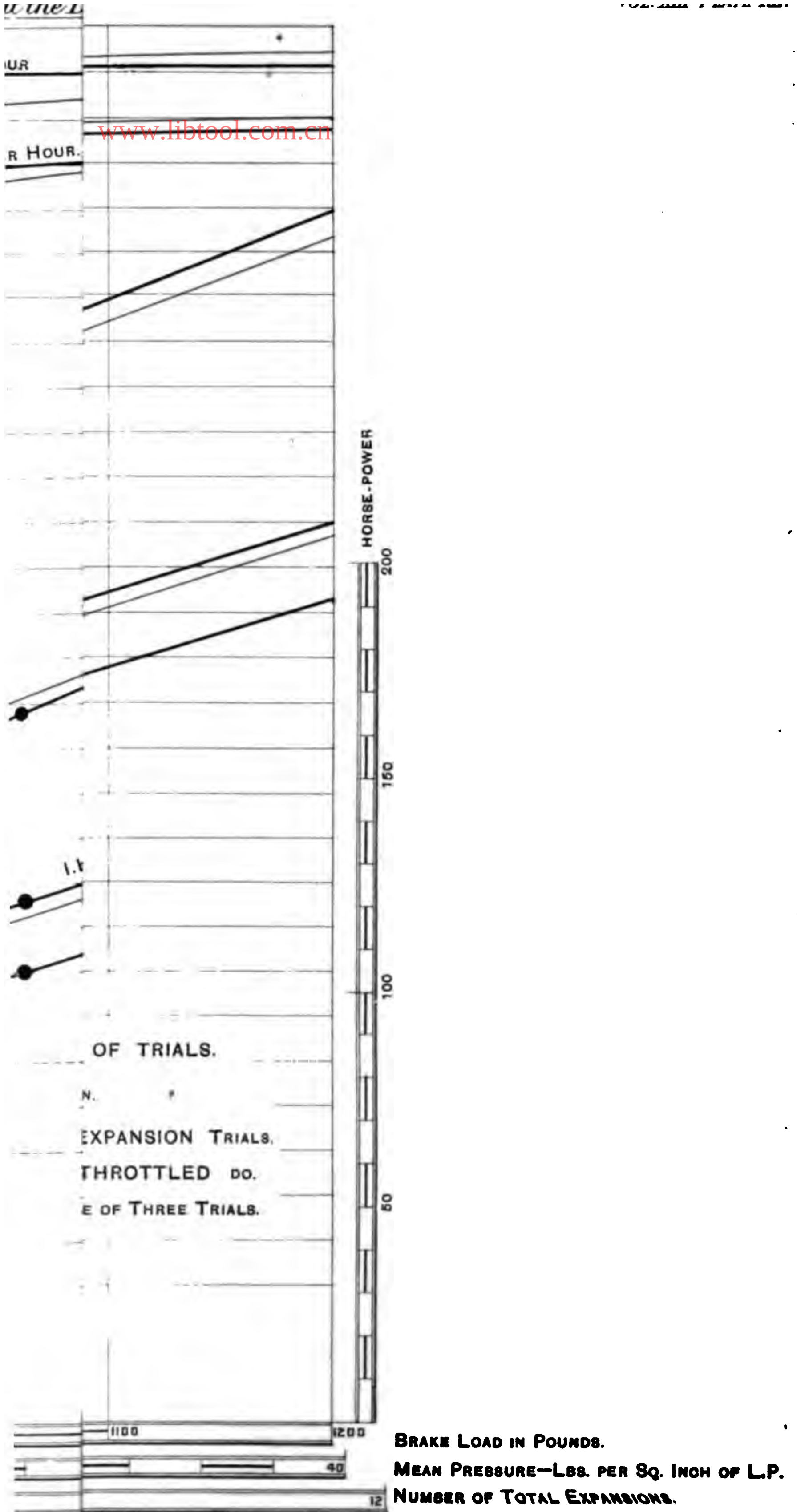
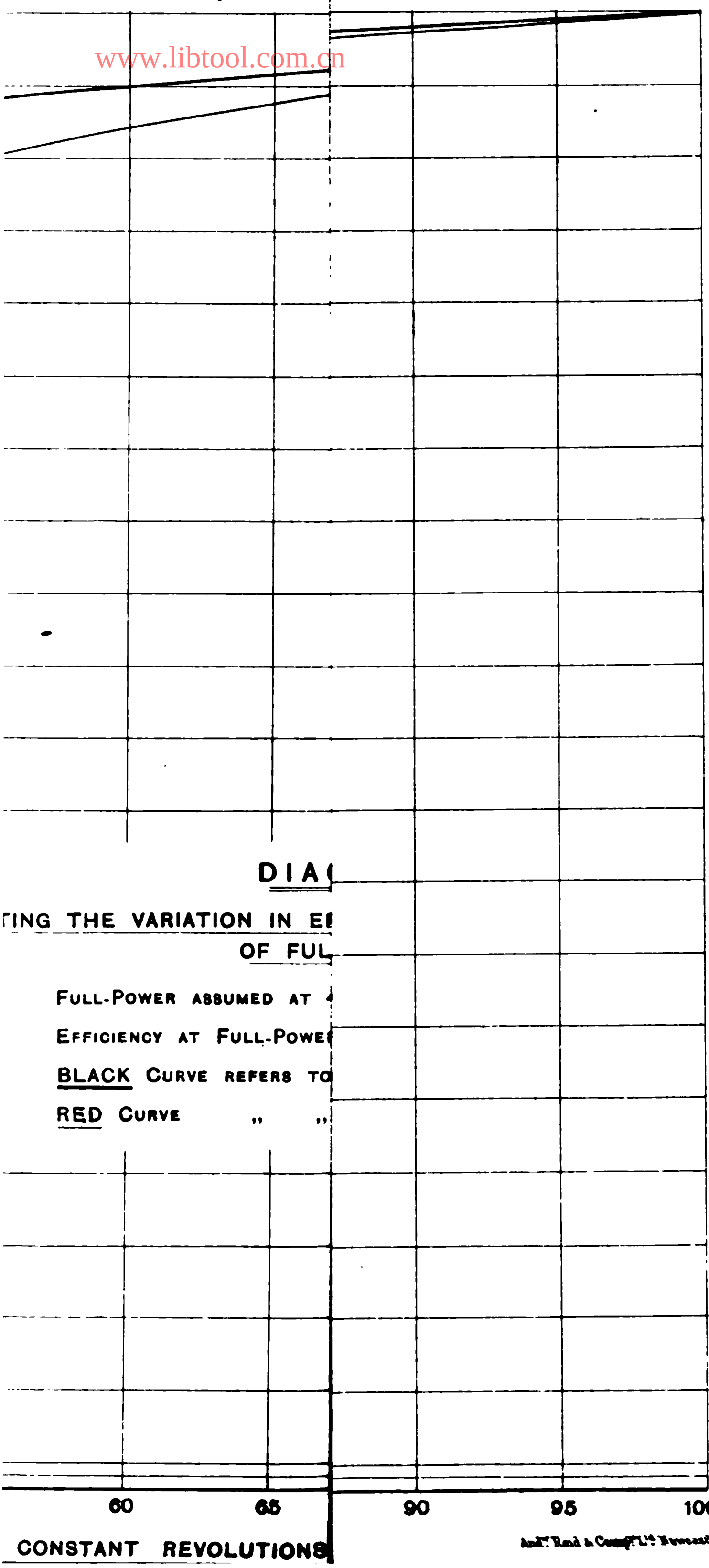

QUADRUPLES
A
COMPOUNDS
B

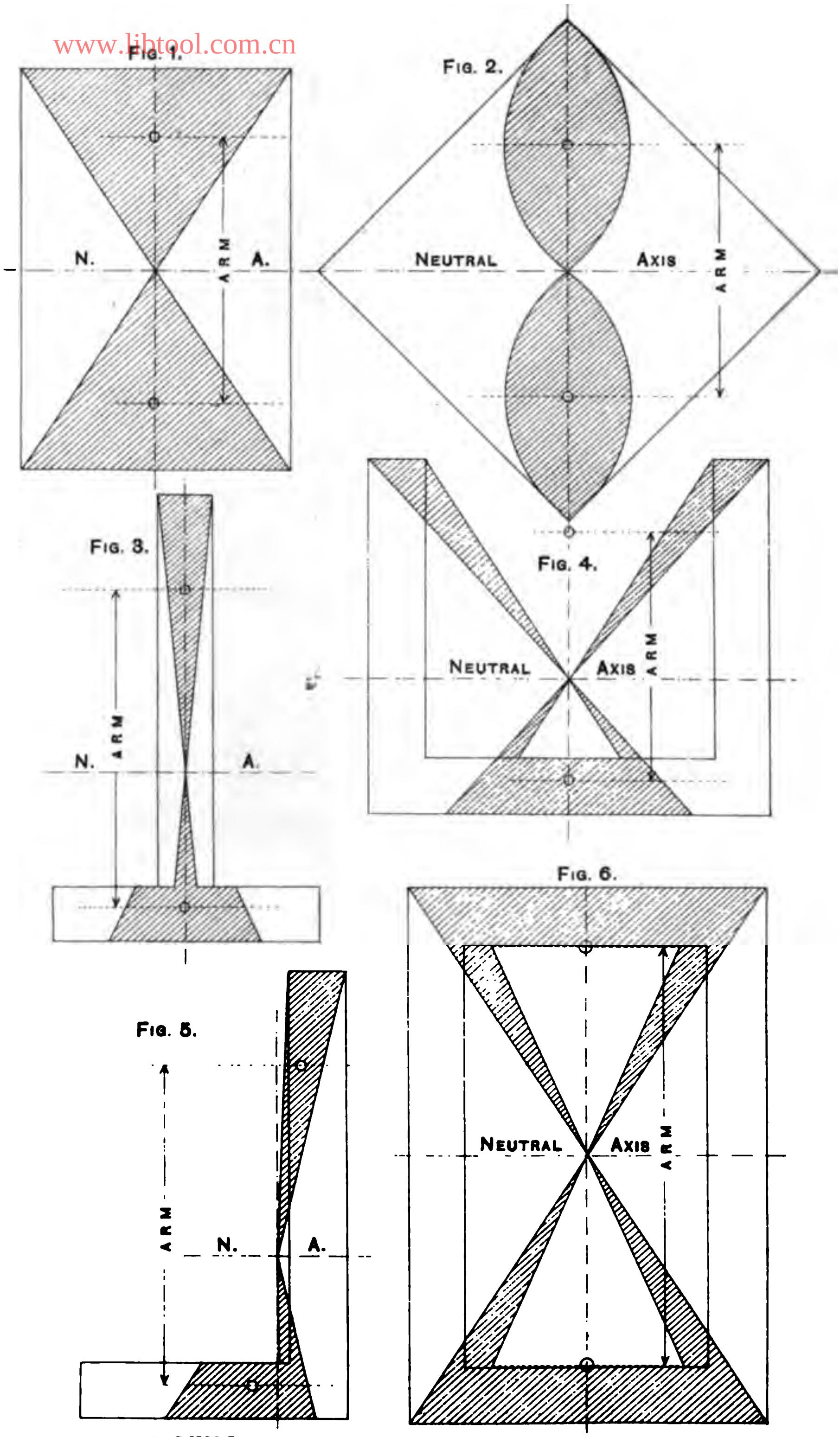

QUADRUPLES
C


UR
R HOUR.
OF TRIALS.
N.
EXPANSION TRIALS.
THROTTLED DO.
E OF THREE TRIALS.
HORSE-POWER
200
150
100
50
1100
1200
40
12
BRAKE LOAD IN POUNDS.
MEAN PRESSURE—LBS. PER SQ. INCH OF L.P.
NUMBER OF TOTAL EXPANSIONS.



Andw. Reid & Compy. Ld. Newcastle on Tyne

To illustrate Mr A. E. Sharp's Paper on "The Resistance Areas of Transverse Sections."



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To illustrate Mr. A. E. Sharp's Paper on "The Resistance Areas of Transverse Sections."

Fig. 7.

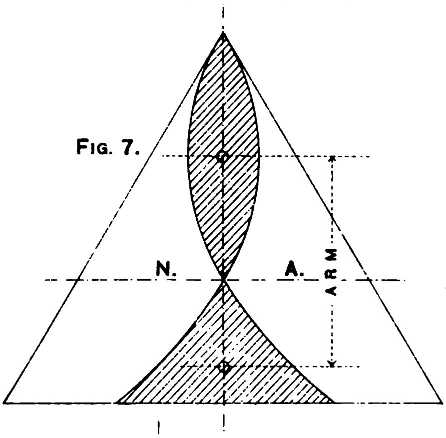


Fig. 8.

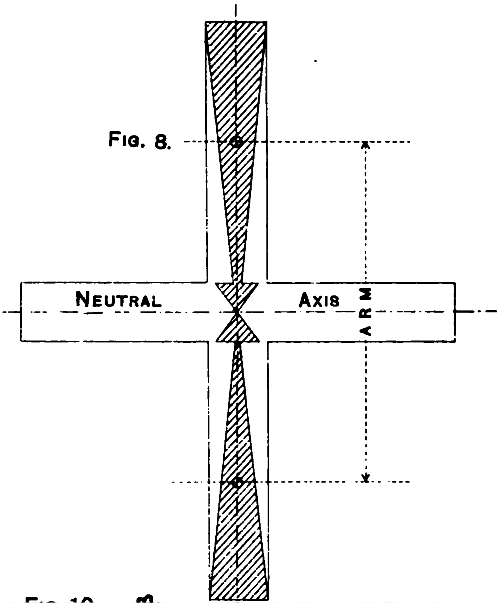


Fig. 9.

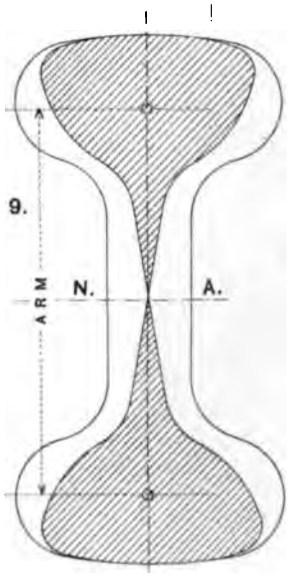


Fig. 10.

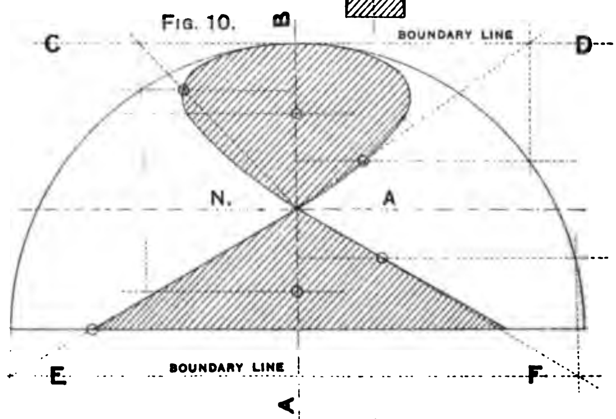


Fig. 11.

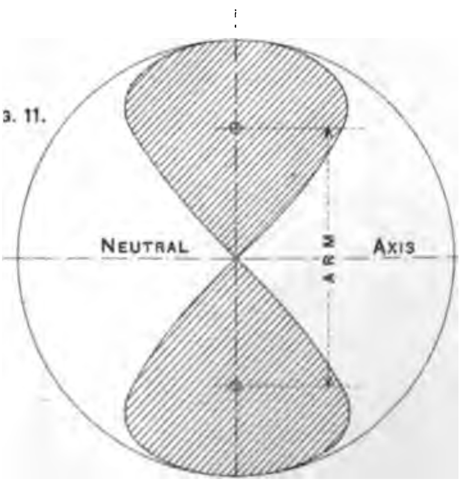
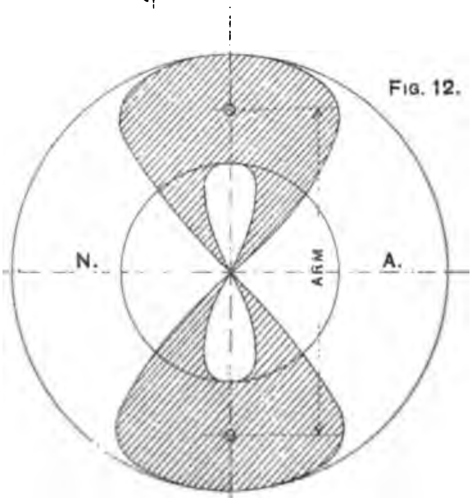


Fig. 12.



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To illustrate Mr A. E. Sharp's Paper on "The Resistance Areas of Transverse Sections."

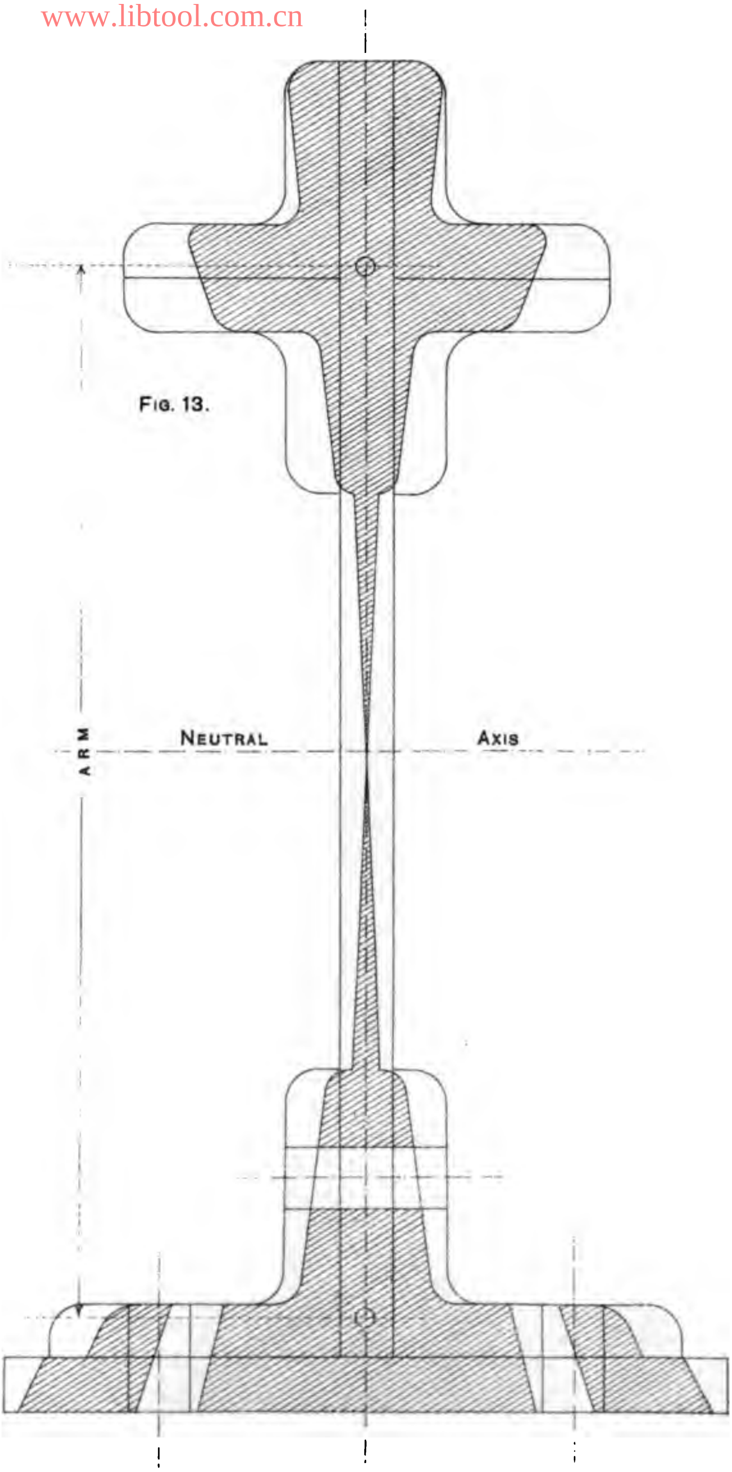

FIG. 13.

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To illustrate Mr A. E. Sharp's Paper on "The Resistance Areas of Transverse Sections."

FIG. 14.

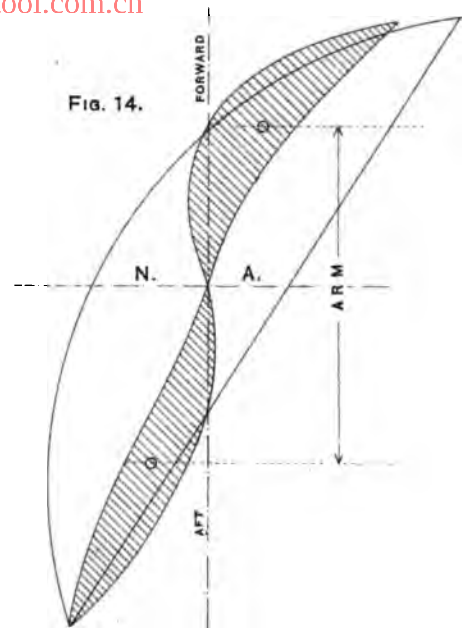


FIG. 15.

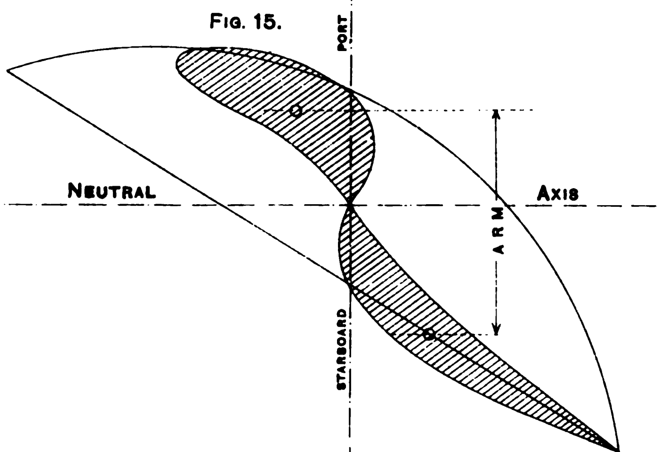
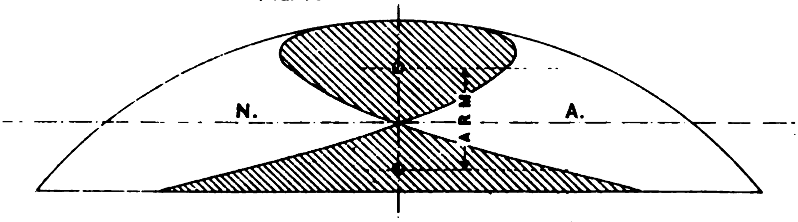


FIG. 16.



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To illustrate Mr A. E. Sharp's Paper on "The Resistance Areas of Transverse Sections."

Fig. 17.

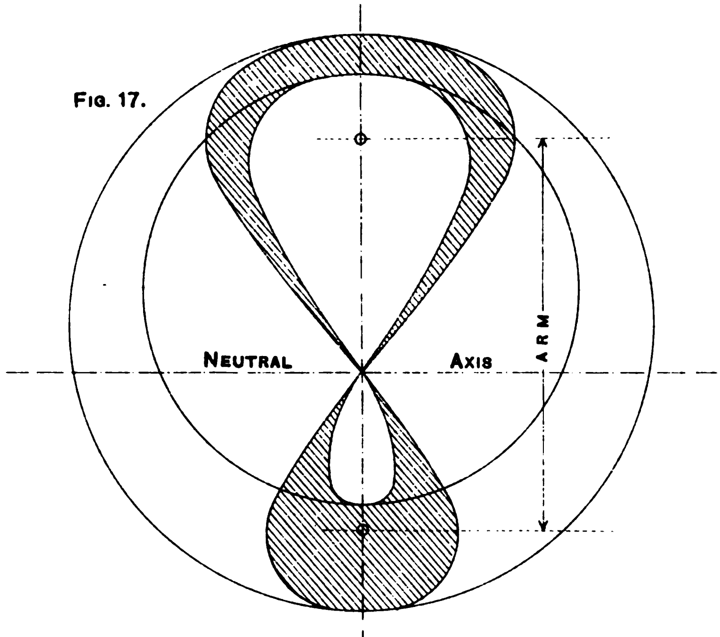
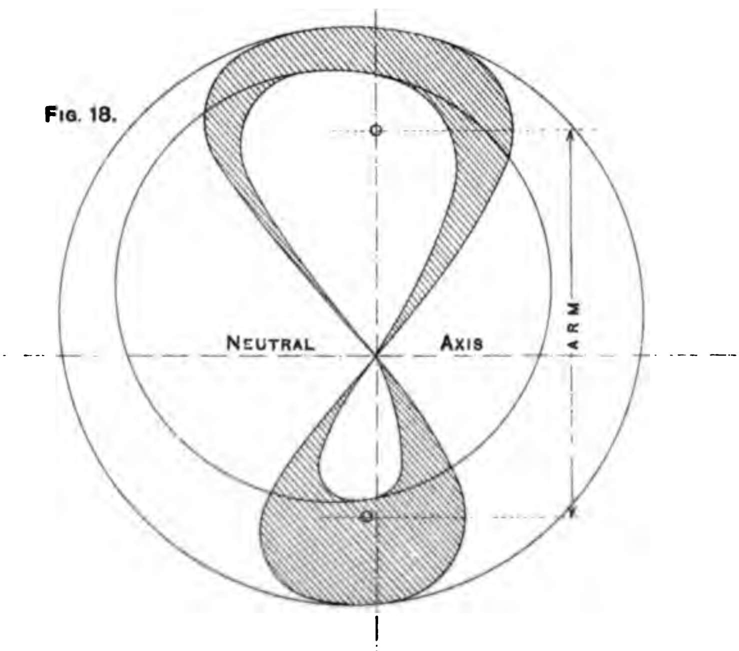


Fig. 18.



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To illustrate Mr A. E. Sharp's Paper on "The Resistance Areas of Transverse Sections."

Fig. 19.

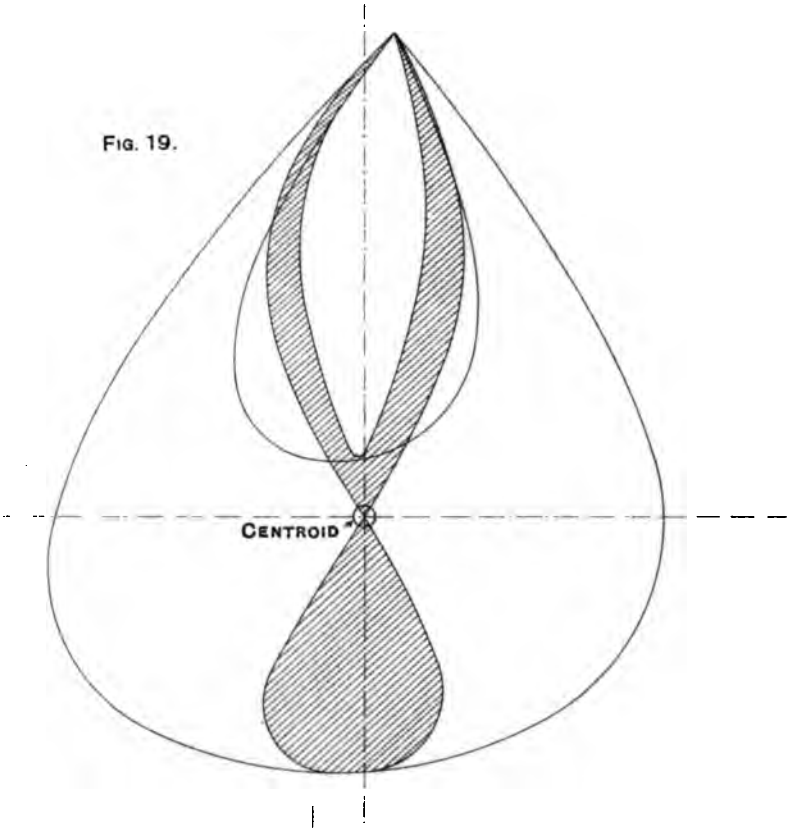
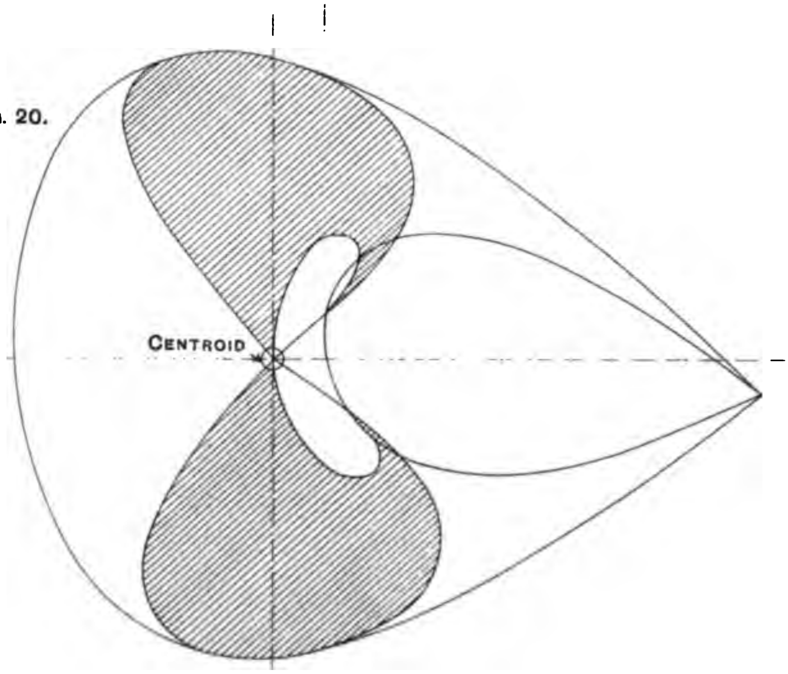


Fig. 20.



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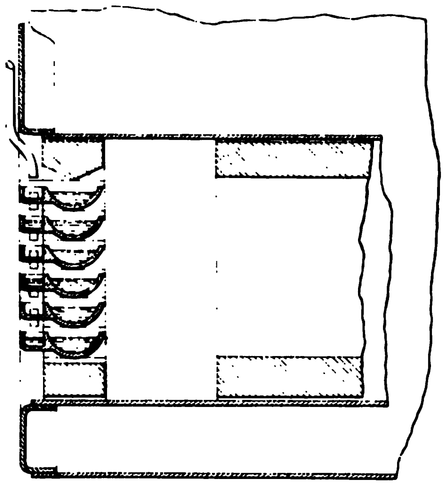

Fig. 1.—Cup Furnace.

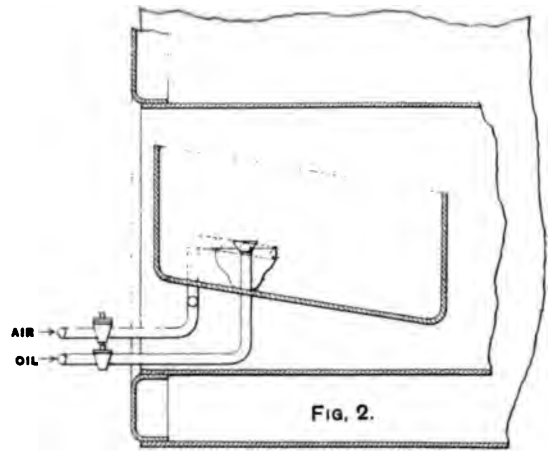

Fig. 2.

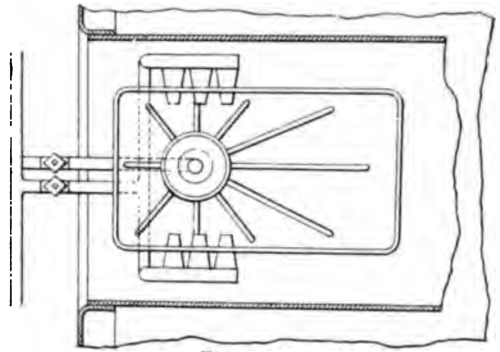

Fig. 3.—Plan.

Figs. 2 & 3.—Bidle Pan Furnace, 1862.

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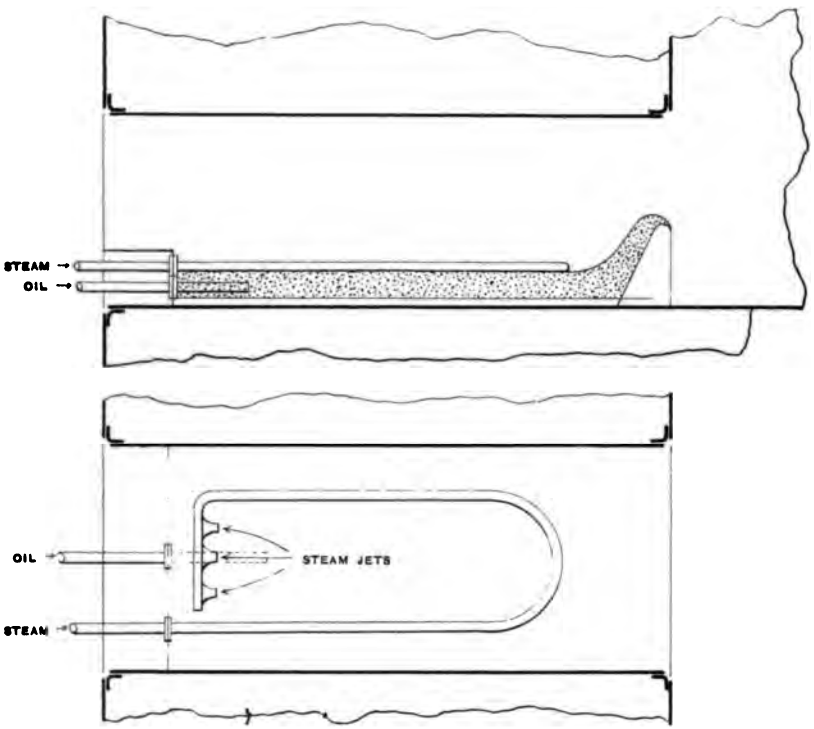
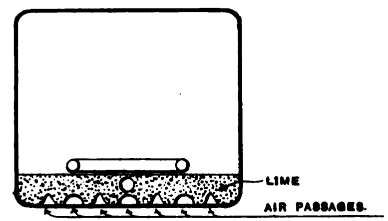


PLAN.



SECTION.

FIG. 4.—RICHARDSON, 1864.

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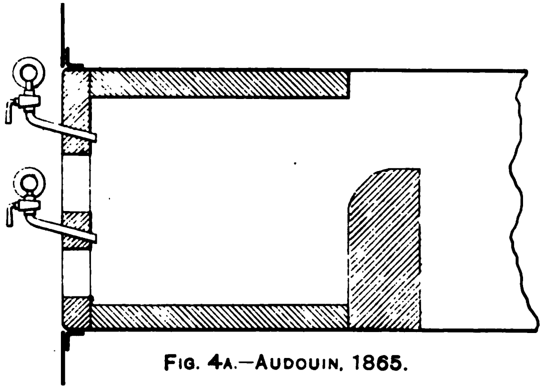

FIG. 4A.—AUDOUIN, 1865.

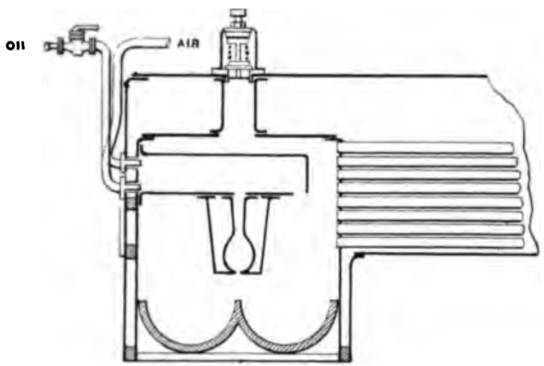

FIG. 5.—SHAW & LINTON, 1862.

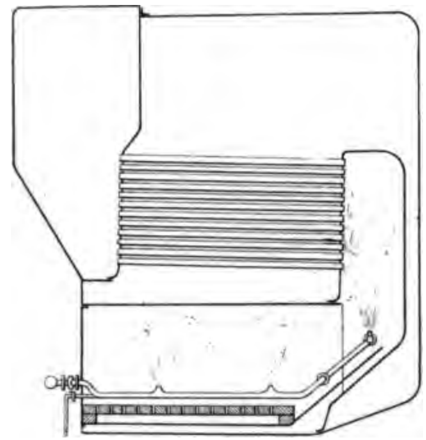

FIG. 6.—DORSETT & BLYTHE, 1868.

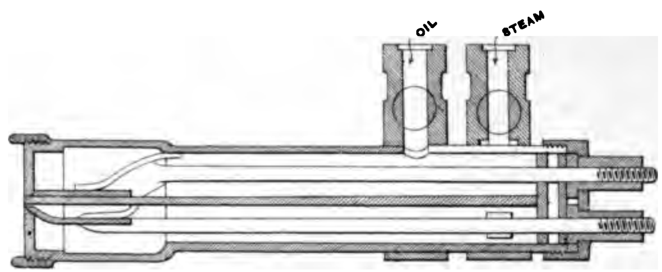

FIG. 7.—LENZ, 1870

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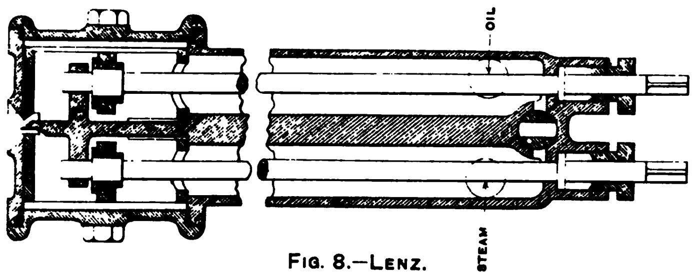

FIG. 8.—LENZ.

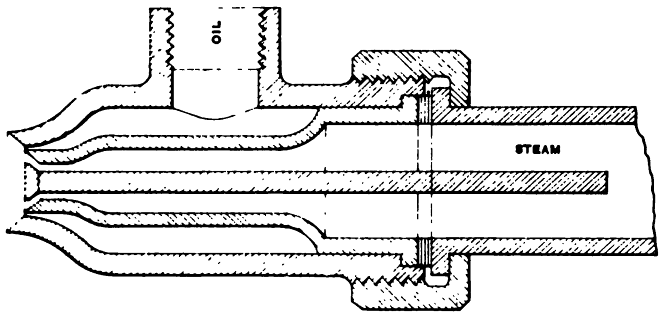

FIG. 9.—KORTING, 1872.

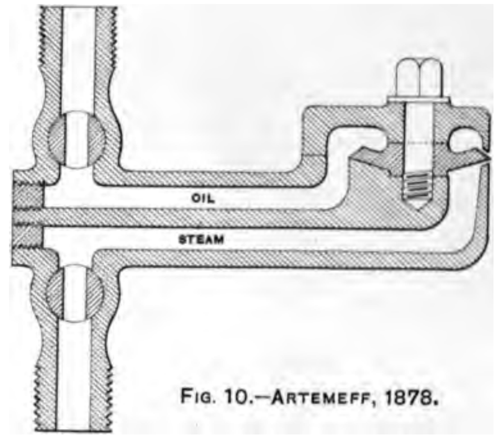

FIG. 10.—ARTEMEFF, 1878.

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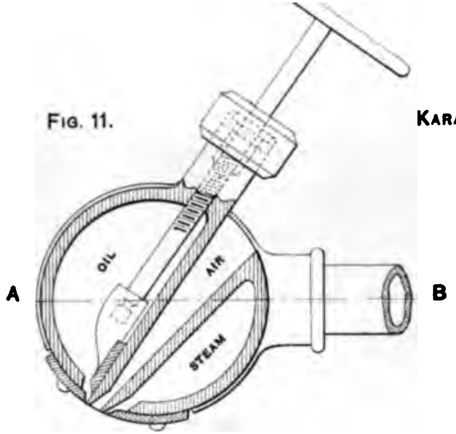
Fig. 11. Karapetoff, 1880.



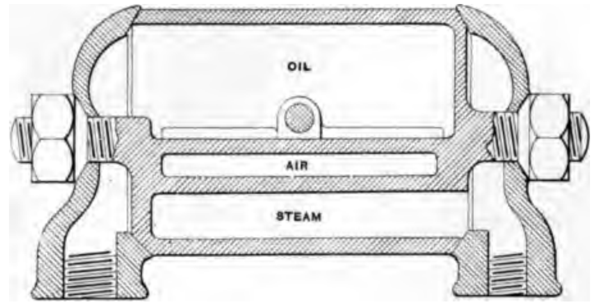


Fig. 12.—Section through A B

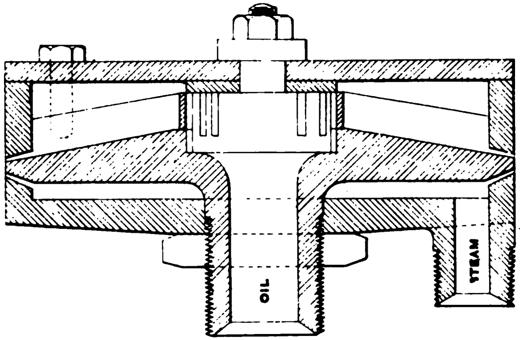


Fig. 13.—Brandt, 1880.

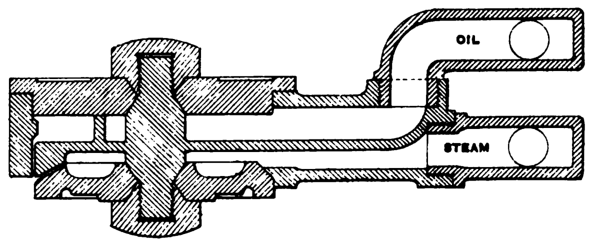


Fig. 14.—Bloomer & Korebut-Dachkeveich, 1886.

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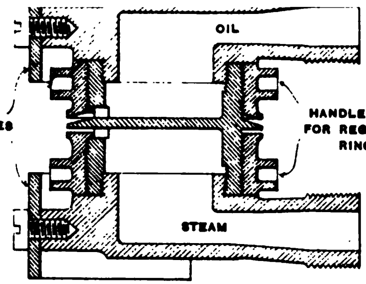

Fig. 15.—Kauffmann.

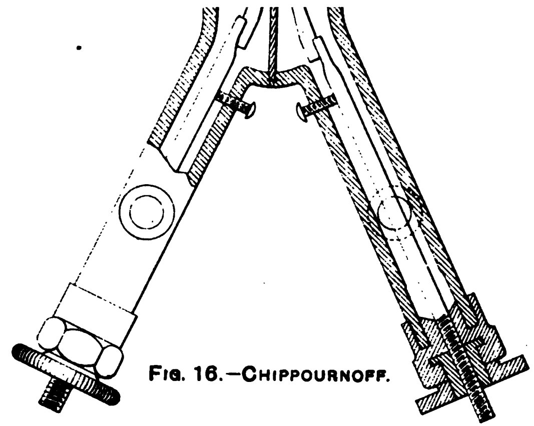

Fig. 16.—Chippournoff.

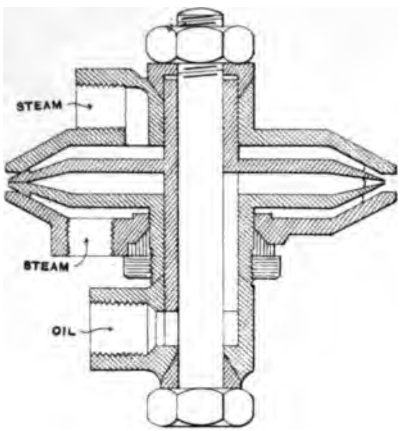

Fig. 17.—Berseneff, 1891.

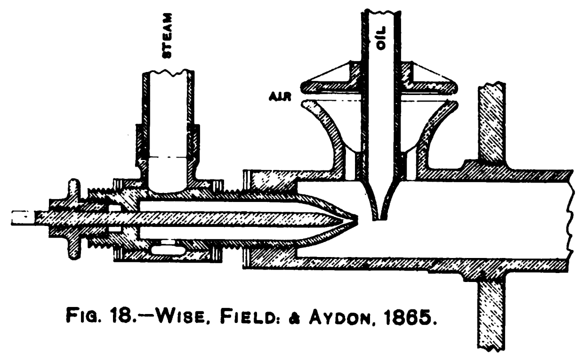

Fig. 18.—Wise, Field & Aydon, 1865.

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To illustrate Mr. R. Wallis's Paper on "Liquid Fuel."

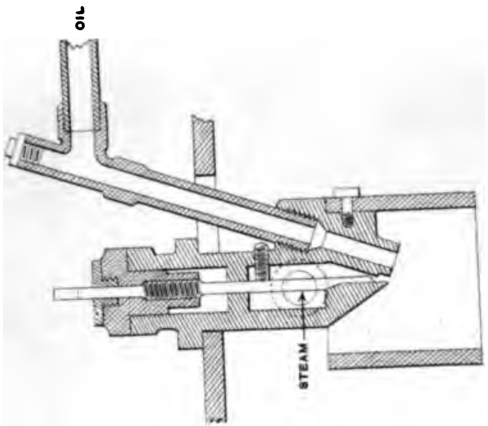

Fig. 19.—Aydon & Selwyn; 1868.

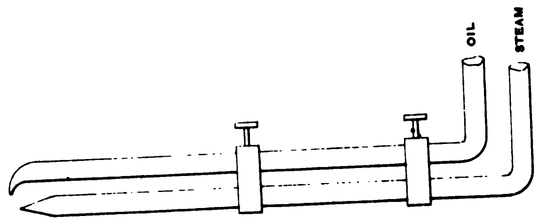

Fig. 20 —Benkston, 1874.

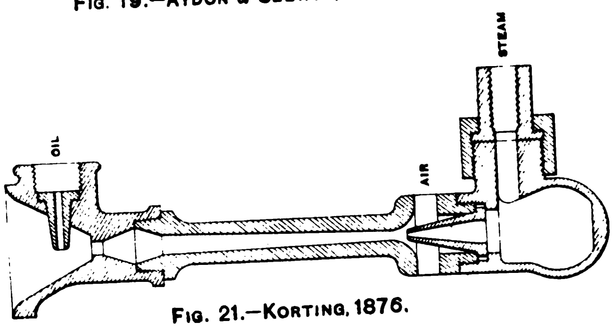

Fig. 21.—Korting, 1876.

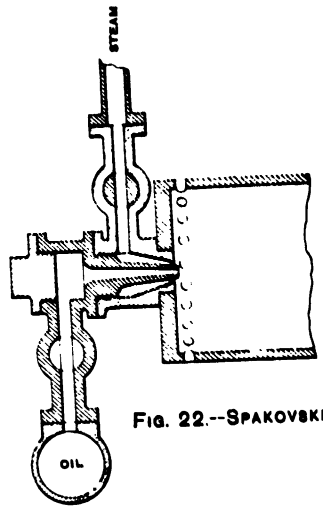

Fig. 22.—Spakovski, 1870.

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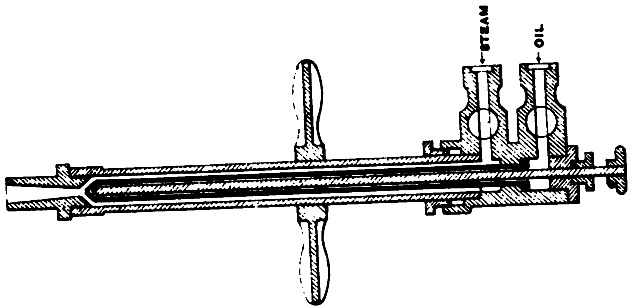

Fig. 23.—Lenz, 1872.

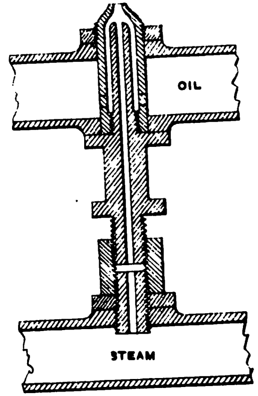

Fig. 24.—Urquhart, 1874.

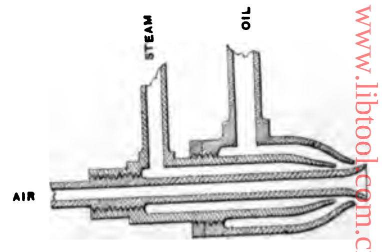

Fig. 25.—Salisbury, 1878.

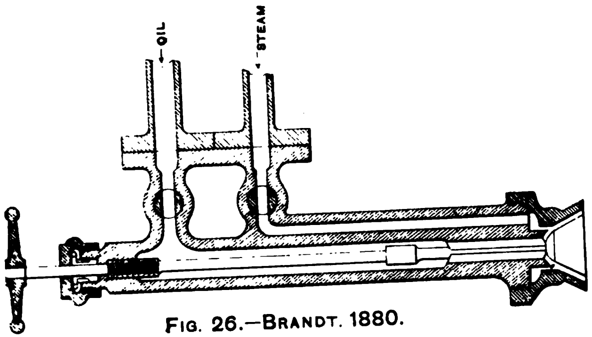

Fig. 26.—Brandt, 1880.

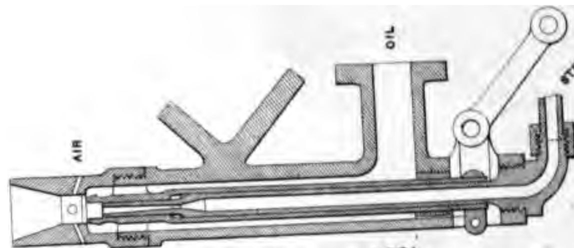

Fig. 27.—Korting, 1881.

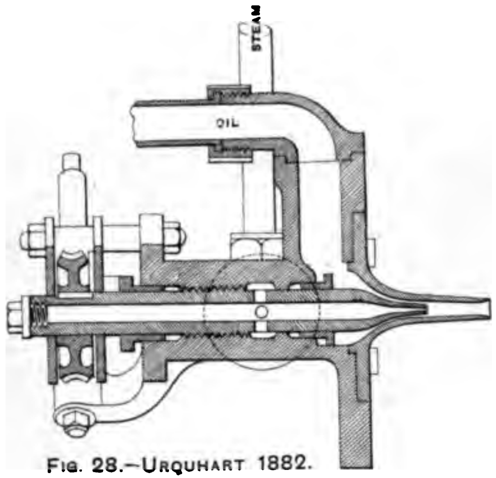

Fig. 28.—Urquhart 1882.

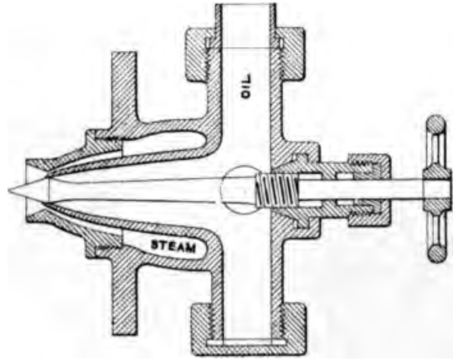

Fig. 29.—D'Allest, 1885.

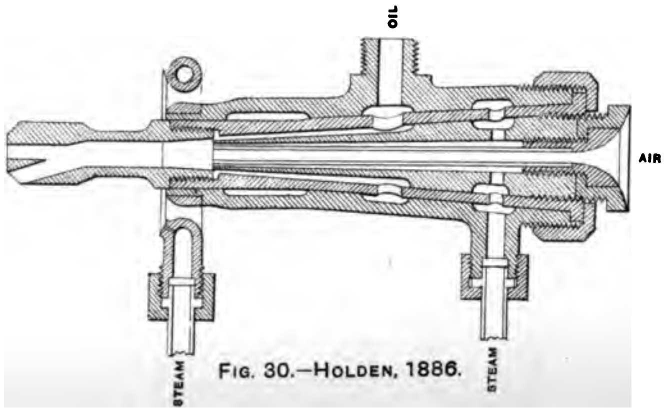

Fig. 30.—Holden, 1886.

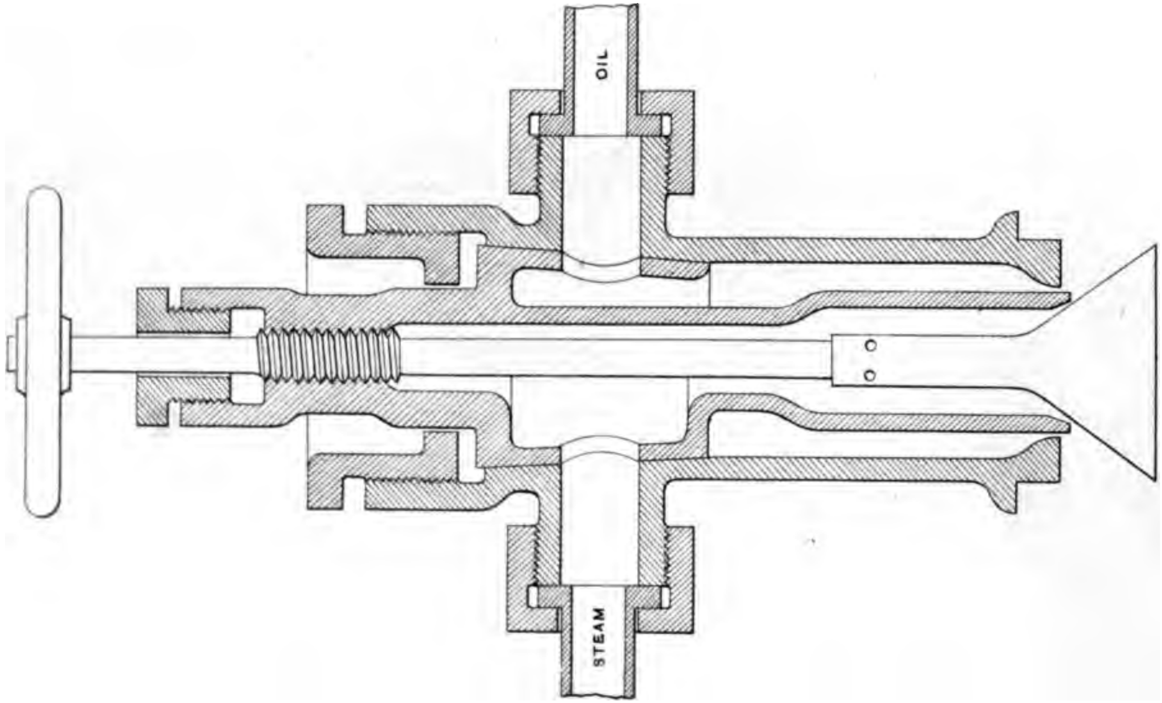

FIG. 81.—DUNDER.

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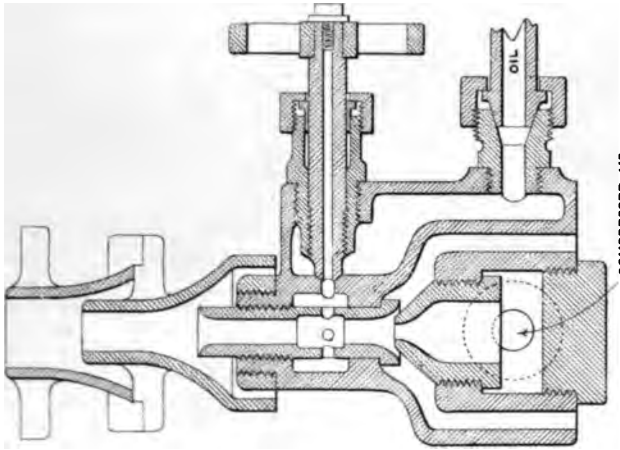


FIG. 32.- STEWART & FARMER, 1894.

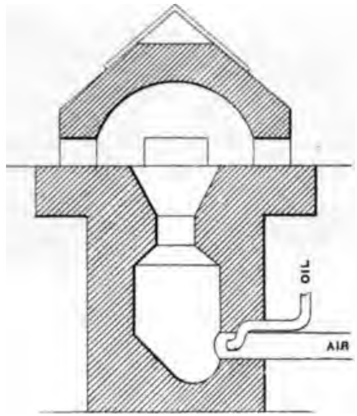
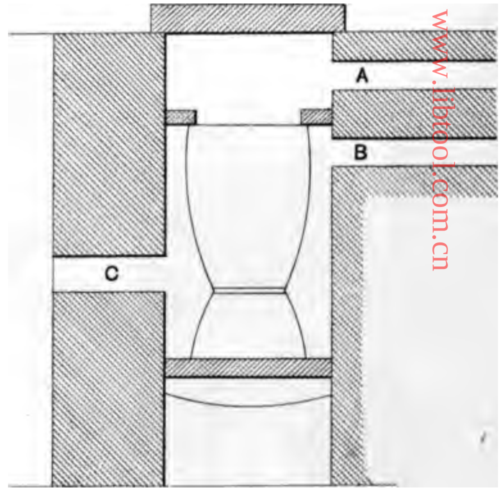


FIG. 36.—OIL FUEL FORGE.



A.—FLUE FOR FUMES OF ALLOYS.
B.—FLUE FOR PRODUCTS OF COMBUSTION.
C.—OPENING FOR INSERTING SPRAYER.

FIG. 37.—CRUCIBLE FURNACE FOR OIL FUEL

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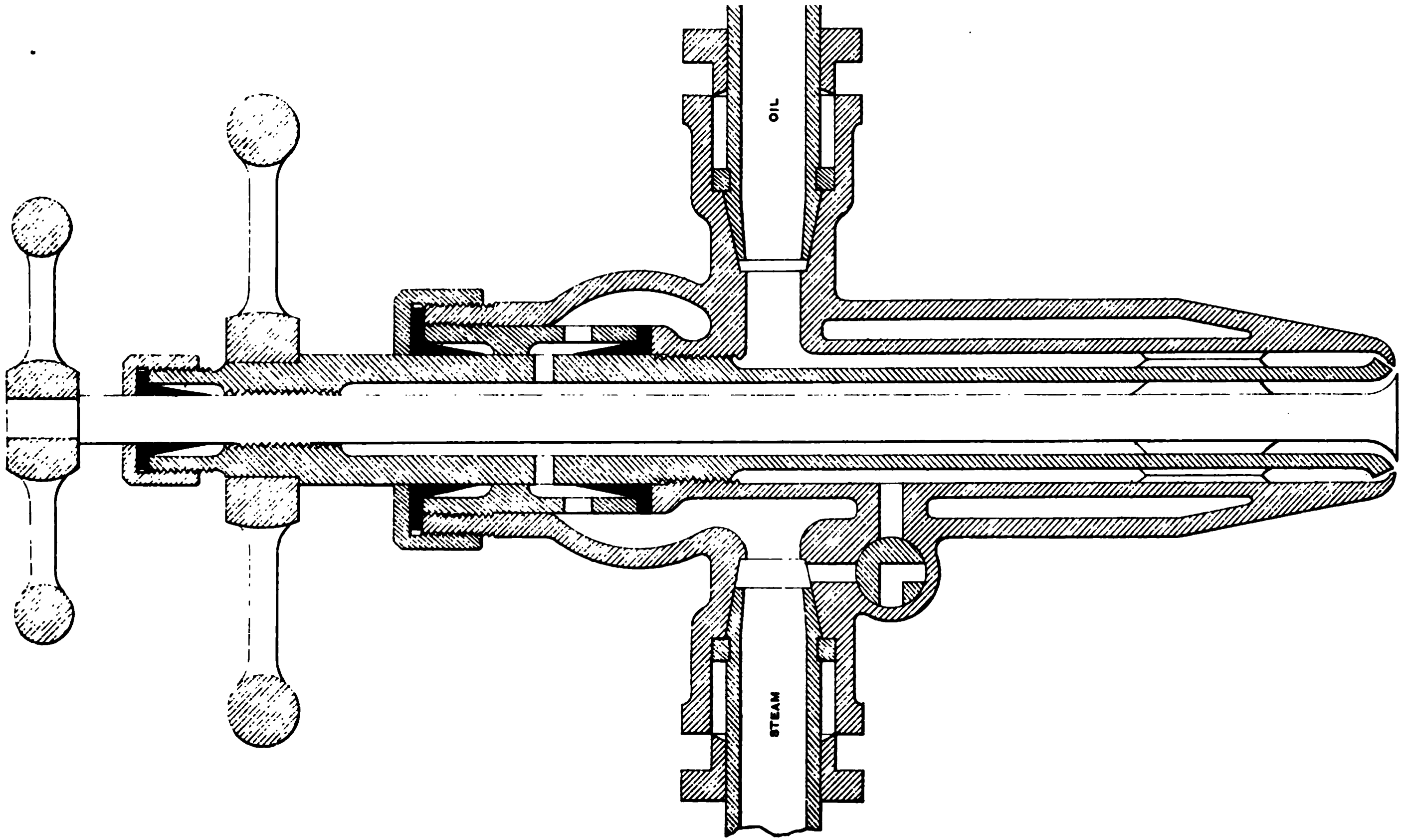

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FIG. 33.—RUSDEN & EELES, 1896.

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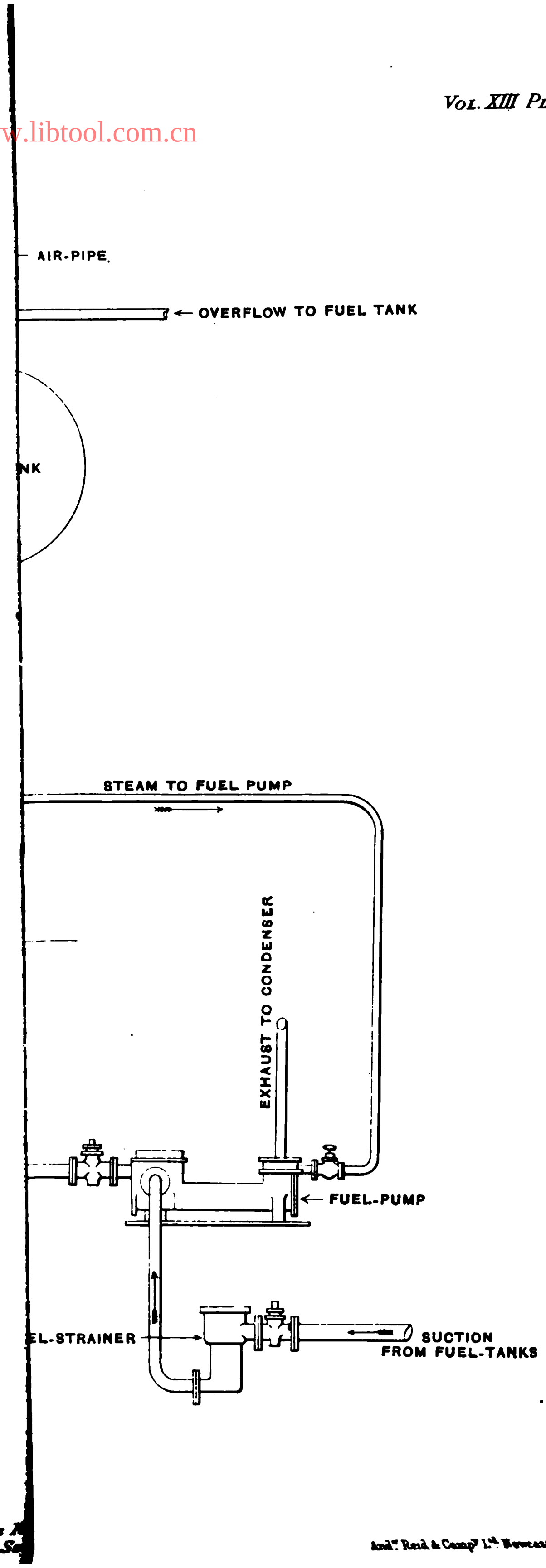

Andw. Reid & Compy. Ld. Newcastle on Tyne

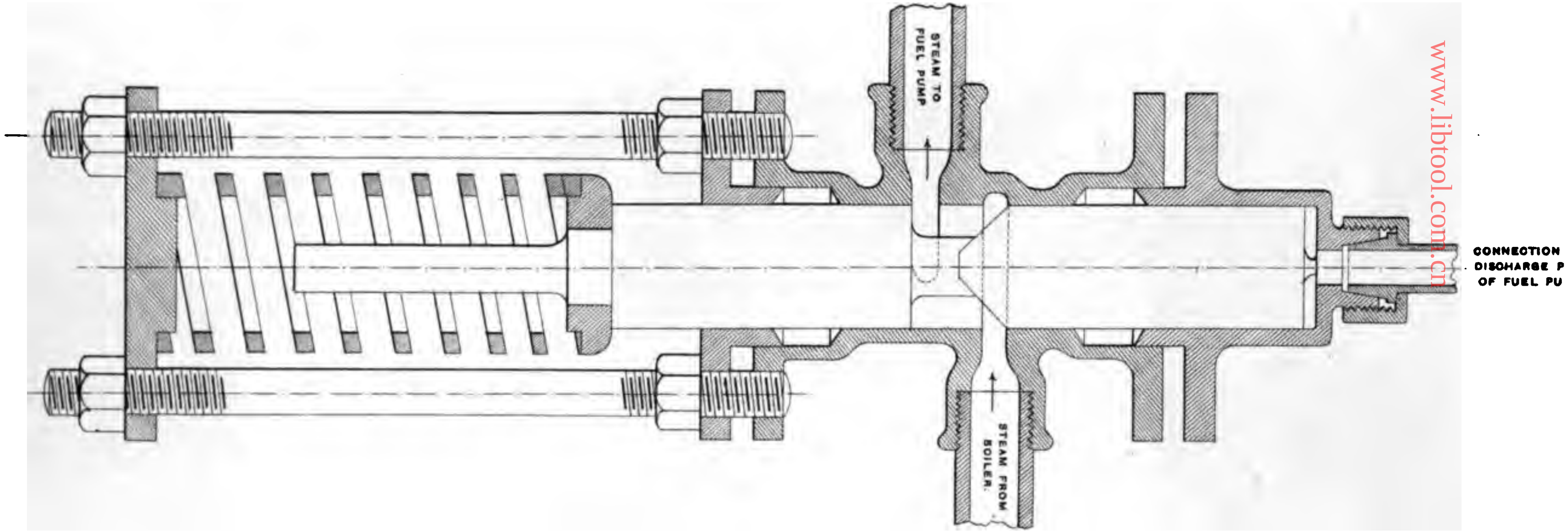

Fig. 35. Rusden & Eeles. Automatic Control Valve.

Andw Reid & Compy Ltd Newcastle on Tyne.

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FIG.

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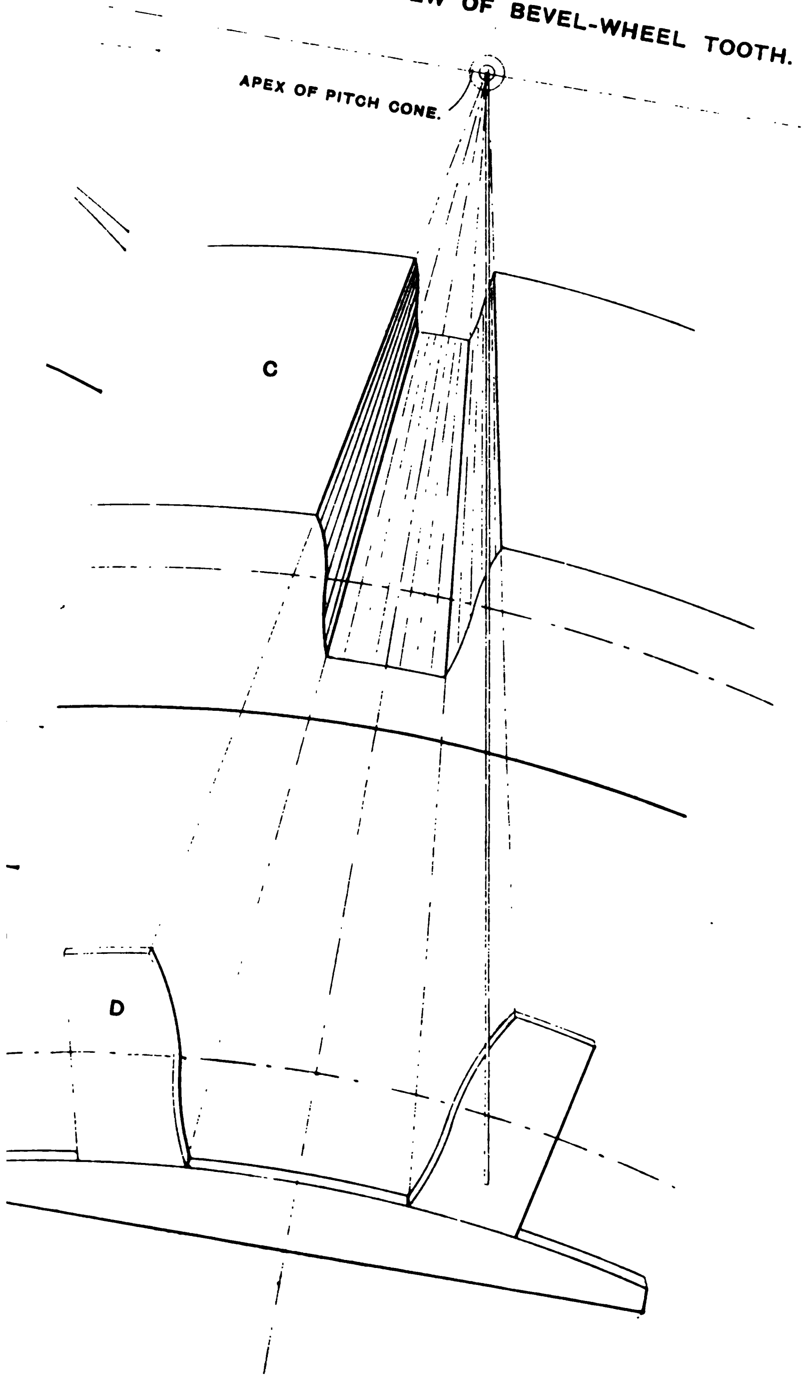
FIG. 2.

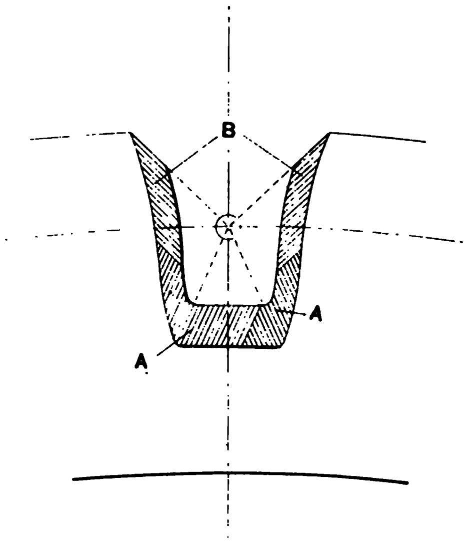
BIRD'S EYE VIEW OF BEVEL-WHEEL TOOTH.

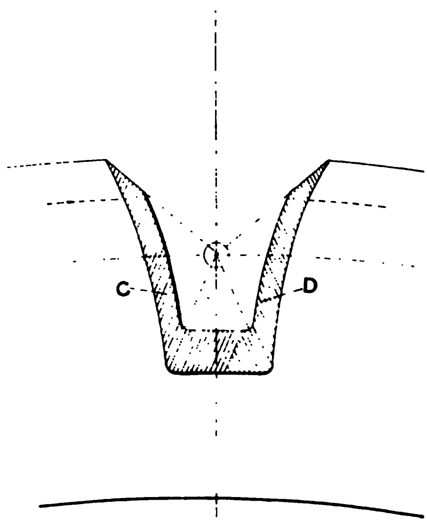


Andw Reid & Compy Ld Newcastle on Tyne

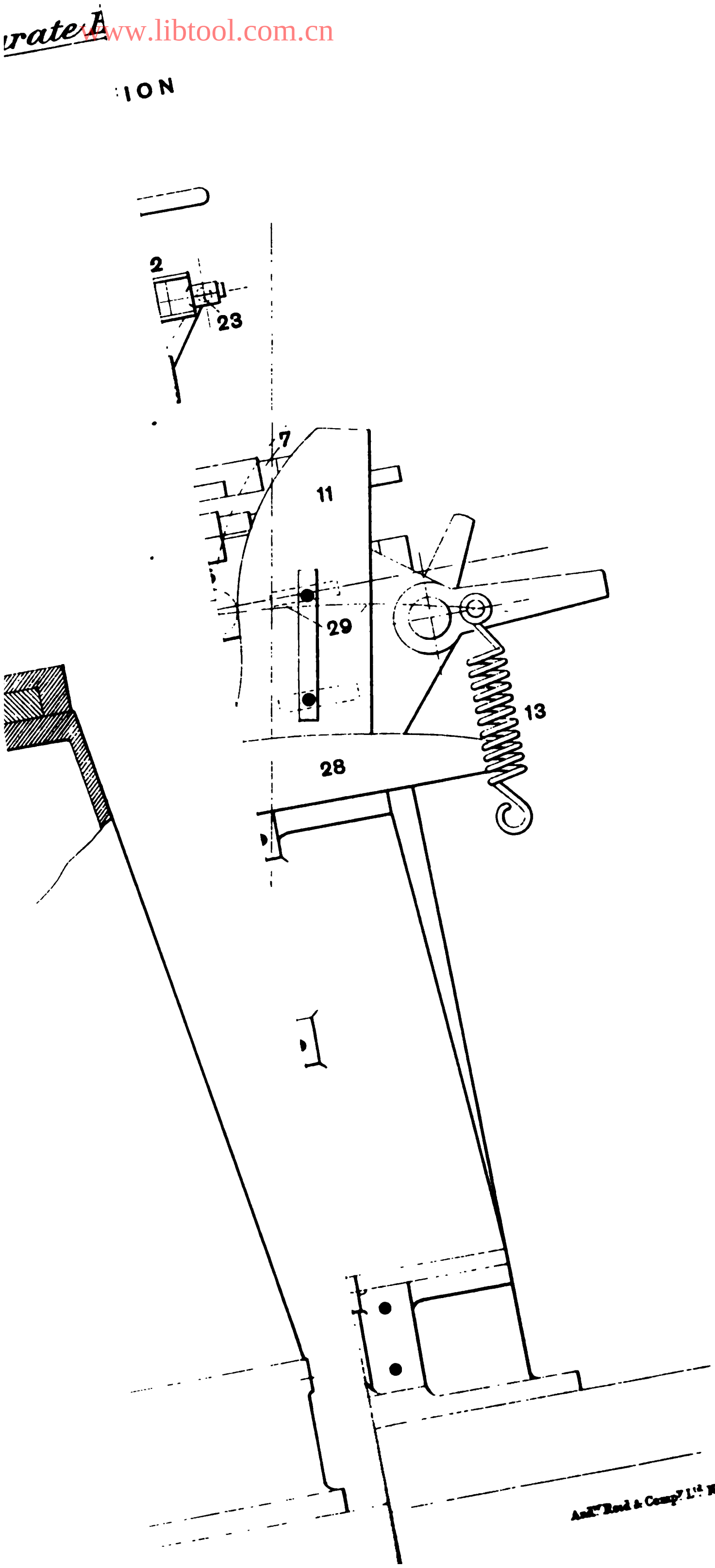
'HEEL TEETH.

E

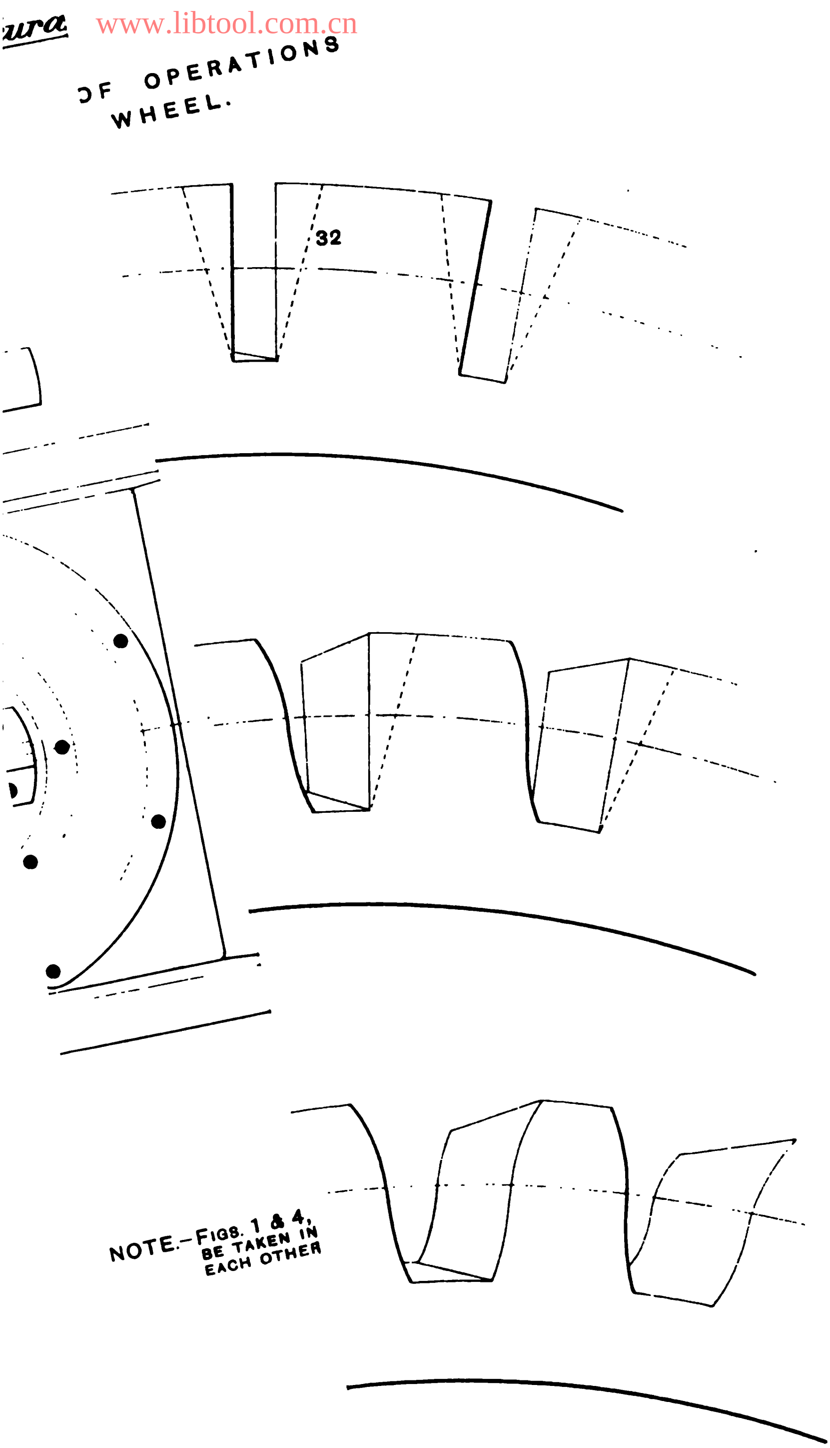




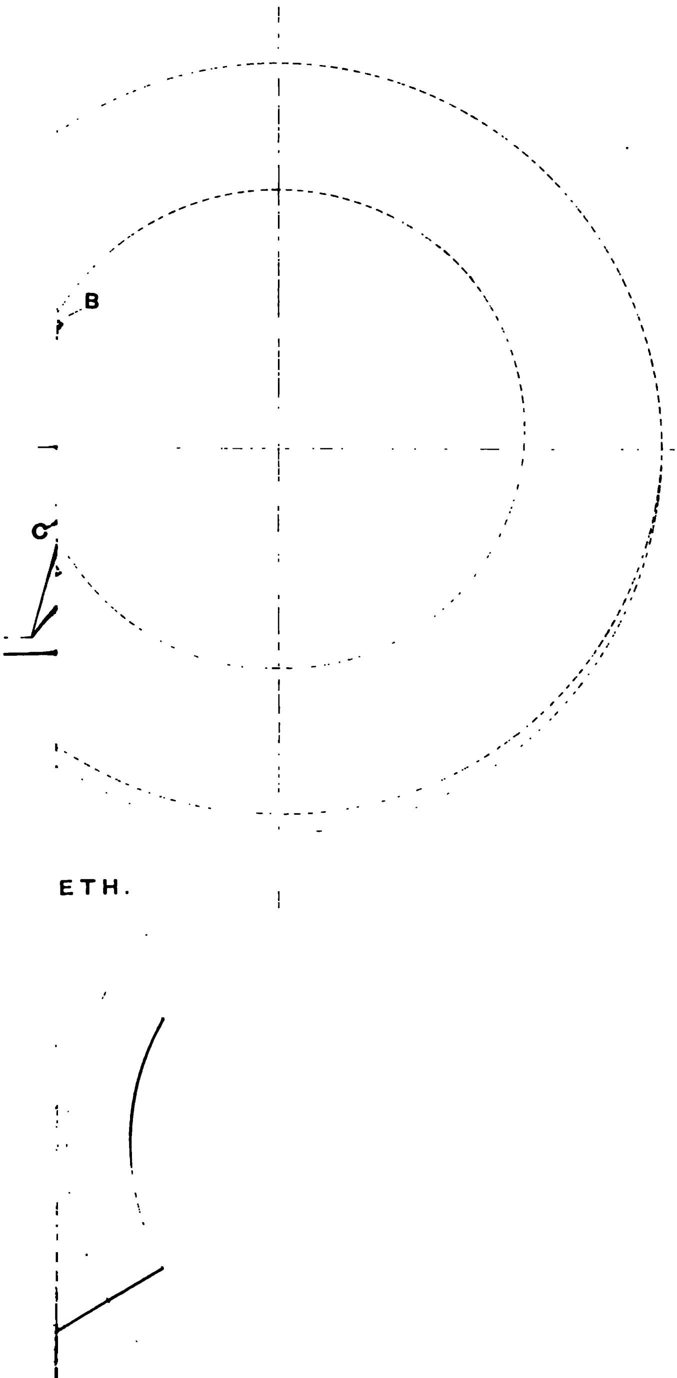
Andw. Reid & Compy. Ld. Newcastle on Tyne



Andw Reid & Compy Ld Newcastle on Tyne



Andw Reid & Compy Ld Newcast



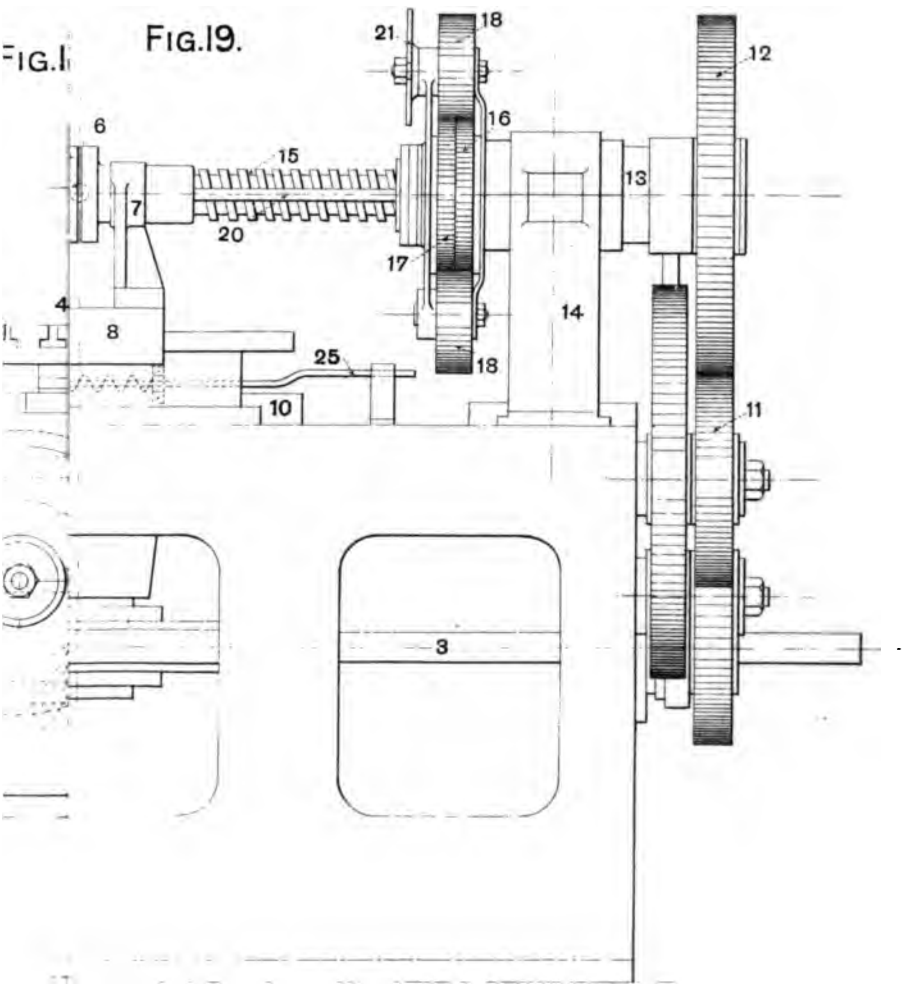
Andw Reid & Compy Ld Newcastle on Tyne

IN
WH

ING ONT ELEVATION.

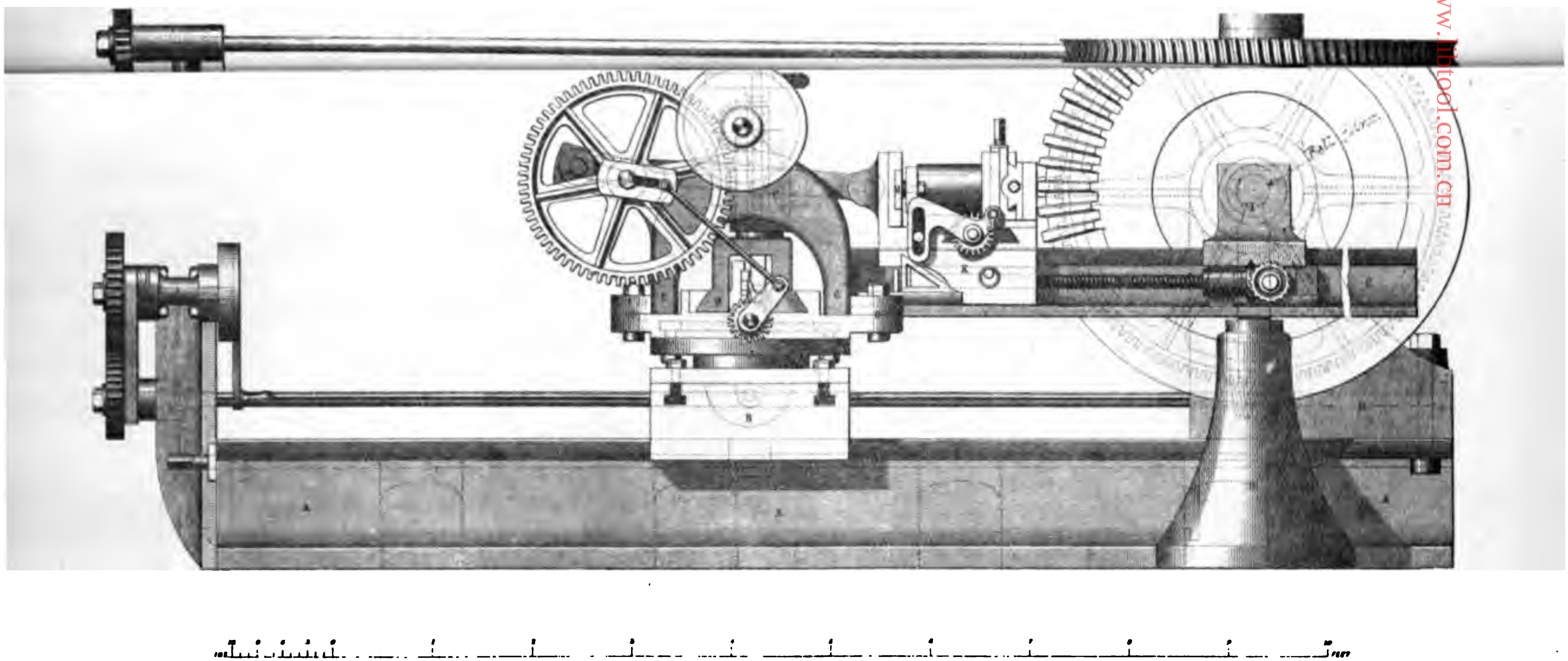
FIG.1

FIG.19.



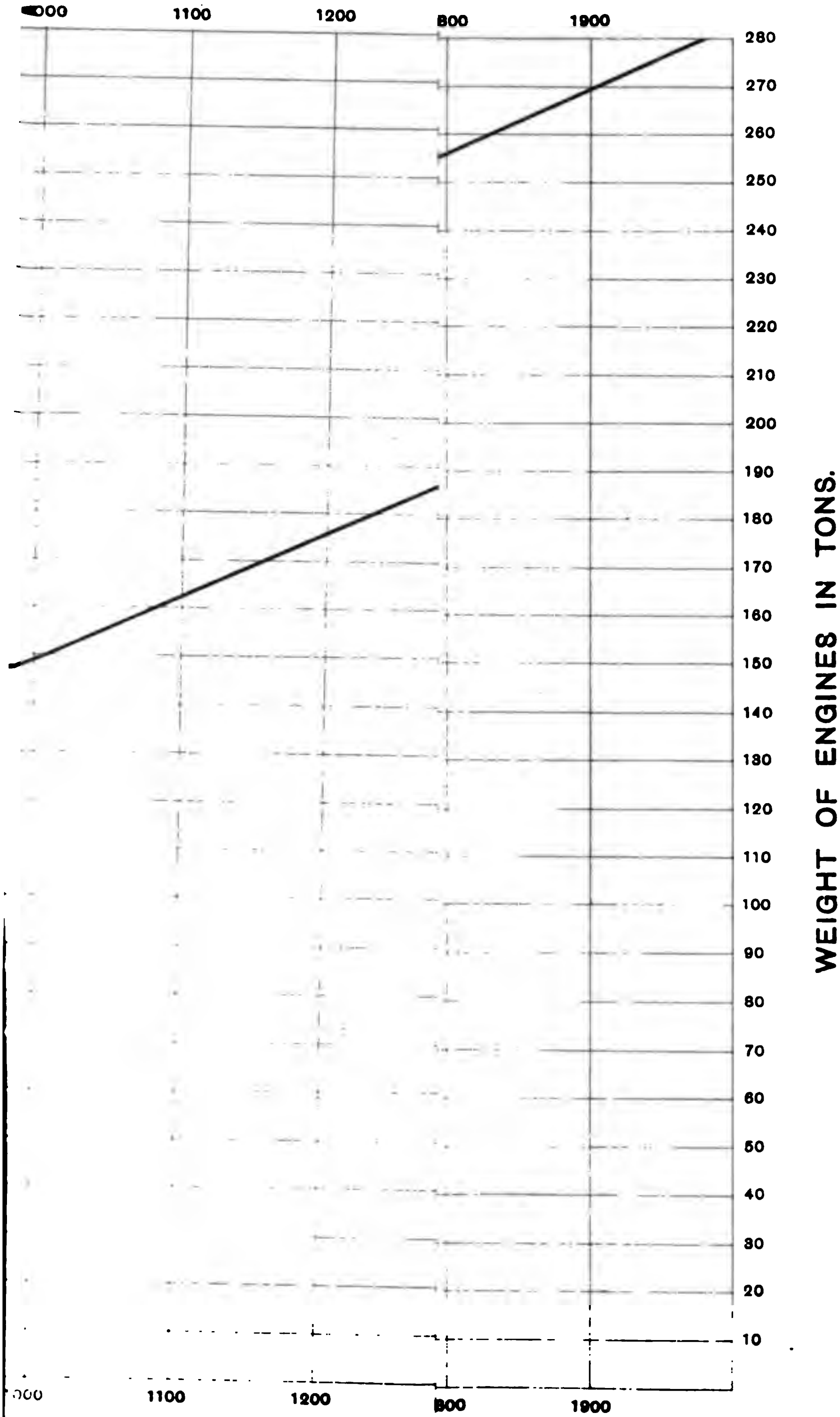
Andw Reid & Compy Ltd Newcastle on Tyne.

To illustrate Mr W. H. Atherton's Remarks on Mr J. H. Gibson's Paper on "The Machine Cutting of Accurate Bevel and Worm Gears."



Andw Reid & Compy Ltd Newcastle on Tyne

IN TONS ×(STROKE IN FE



N TONS ×(STROKE IN FEE

And^w Reid & Comp^y L^td Newcastle on Tyne

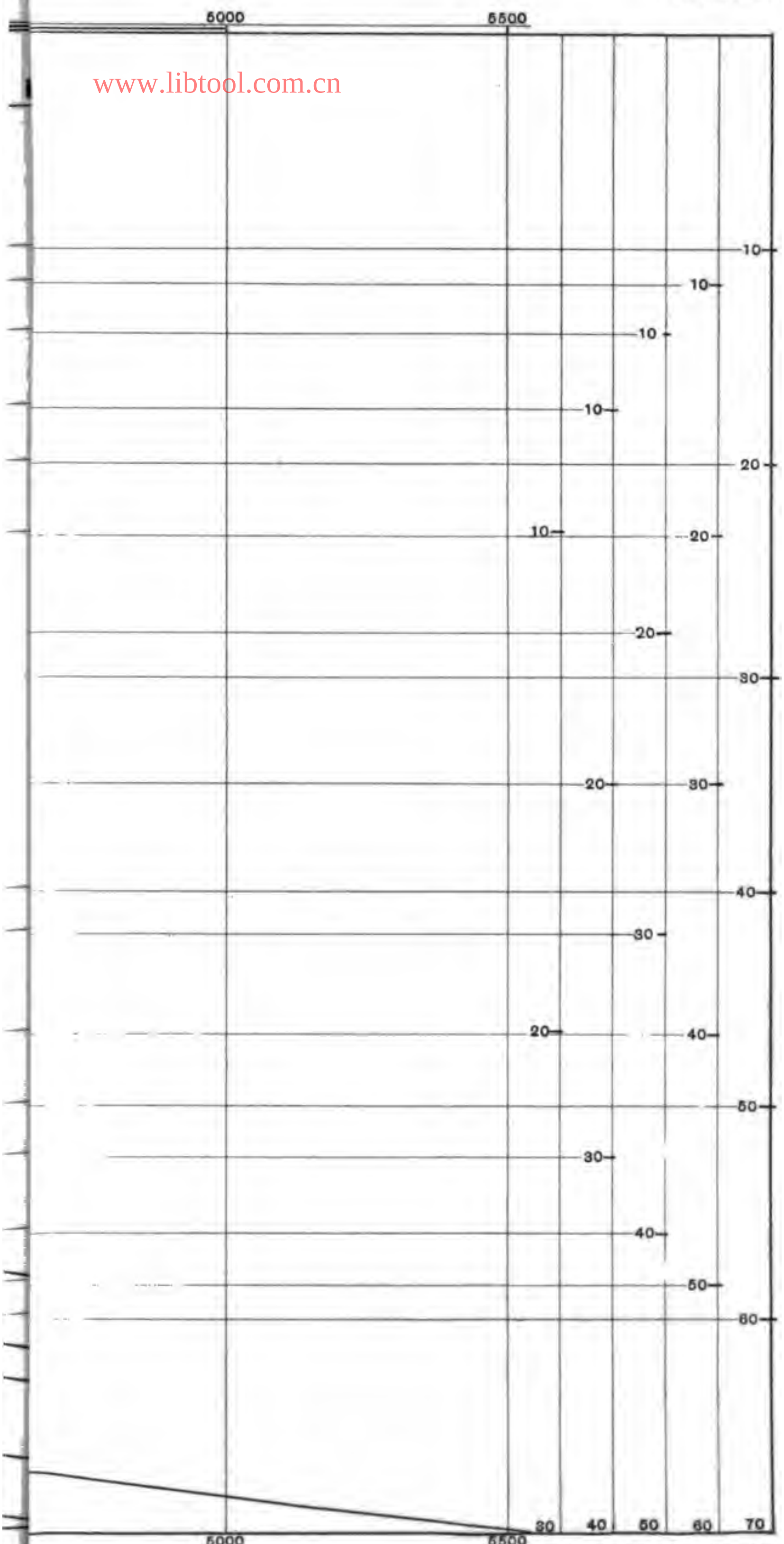


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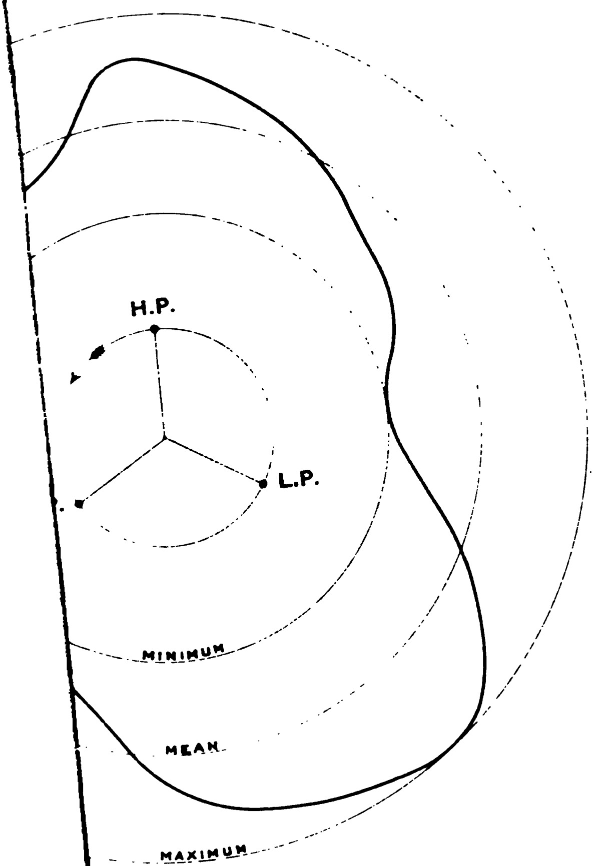
Fig. 2.



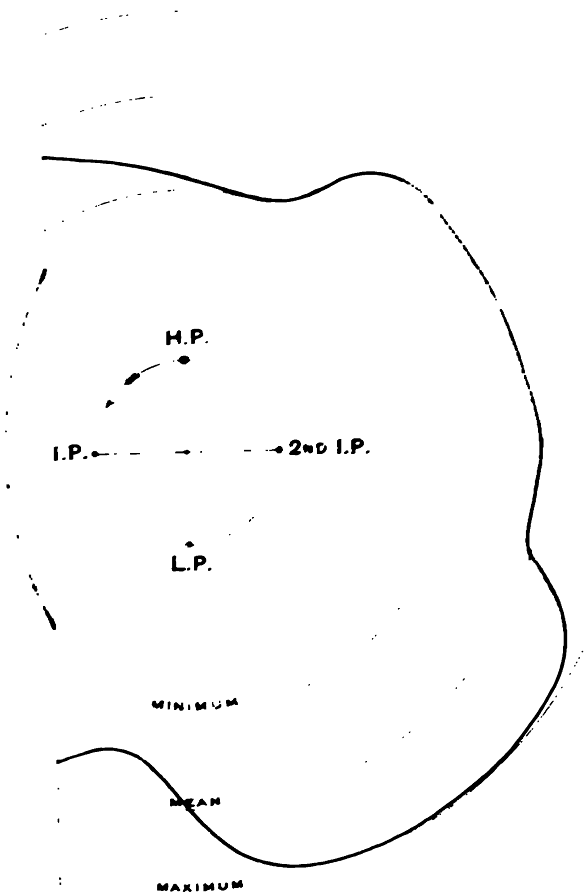
TURNING MOMENTS.

Maximum > Mean. 33%.
Minimum < Mean. 29%.
Total Variation. 62%.

GE.
I.
OADS.

Andw Reid & Compy Ld Newcastle on Tyne

FIG. 4



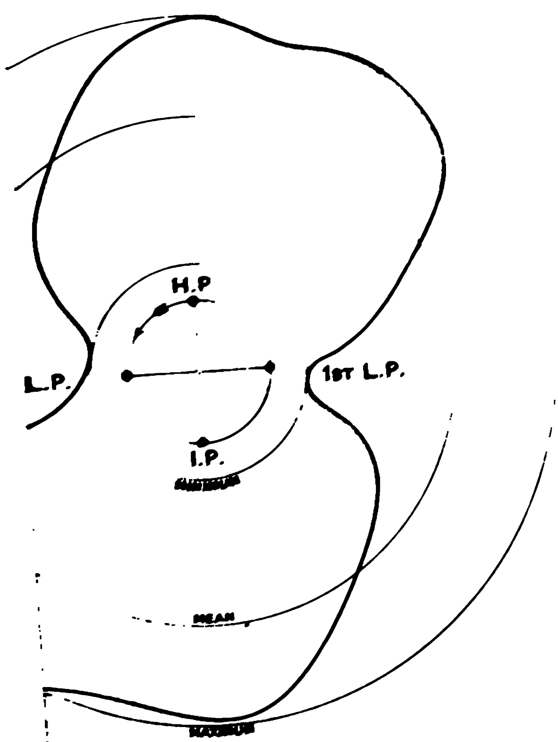
STAGE.
2 × 49.
75.
L LOADS.

TURNING MOMENTS.

MAXIMUM > MEAN. 23%.
MINIMUM < MEAN. 27%.
TOTAL VARIATION. 50%.

And.w Reid & Comp.y L.td Newcastle on Tyne

Fig. 6.



3 STAGE.

x 34½ x 34½.
= 75.
itial Loads.

TURNING MOMENTS

Maximum ~ Mean, 39%
Minimum ~ Mean, 60%
Total Variation, 99%.

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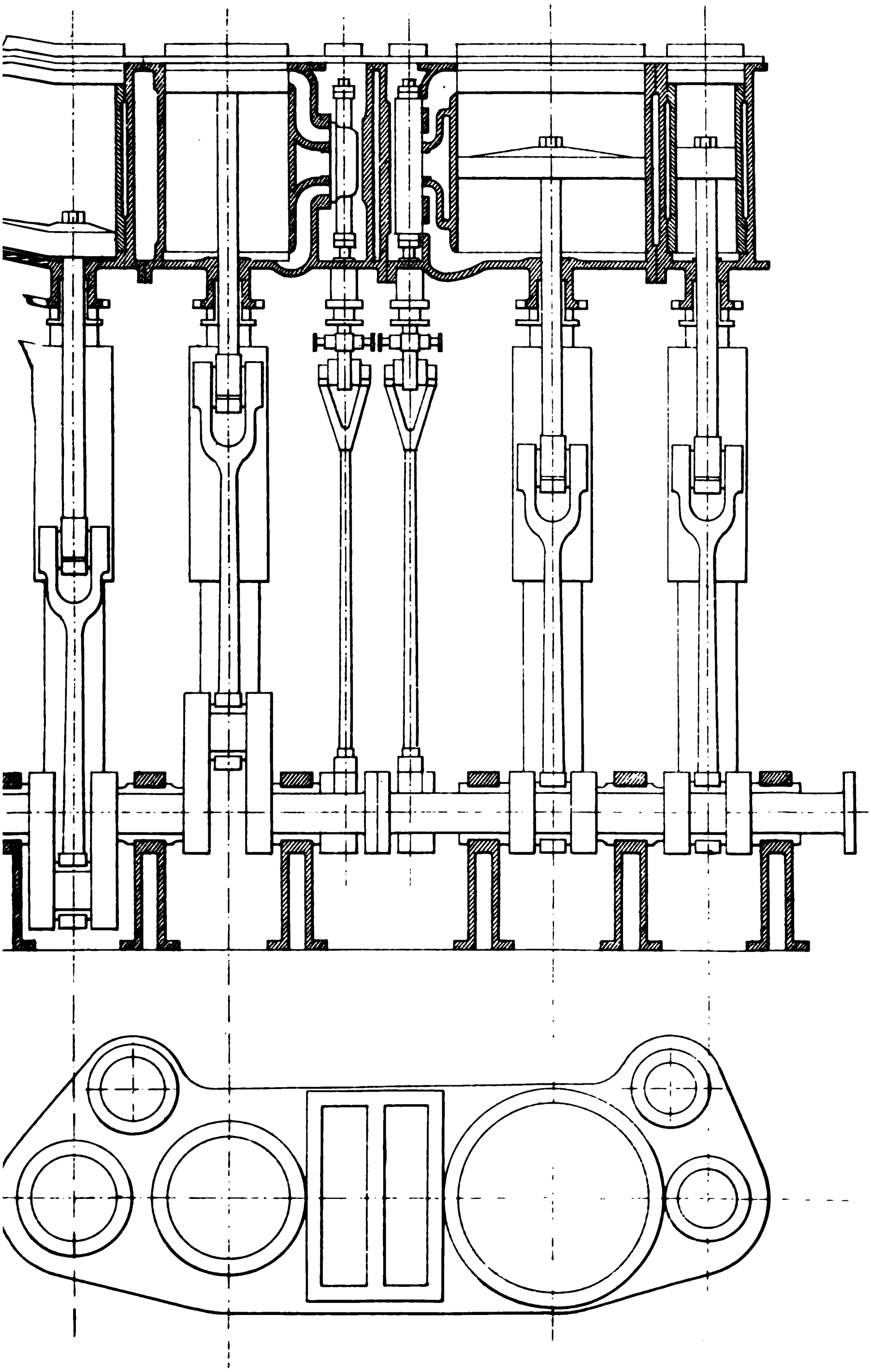
To illustrate Mr. W. R. Cummins's Paper on "High Pressures for Marine Engines."



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Session XIII

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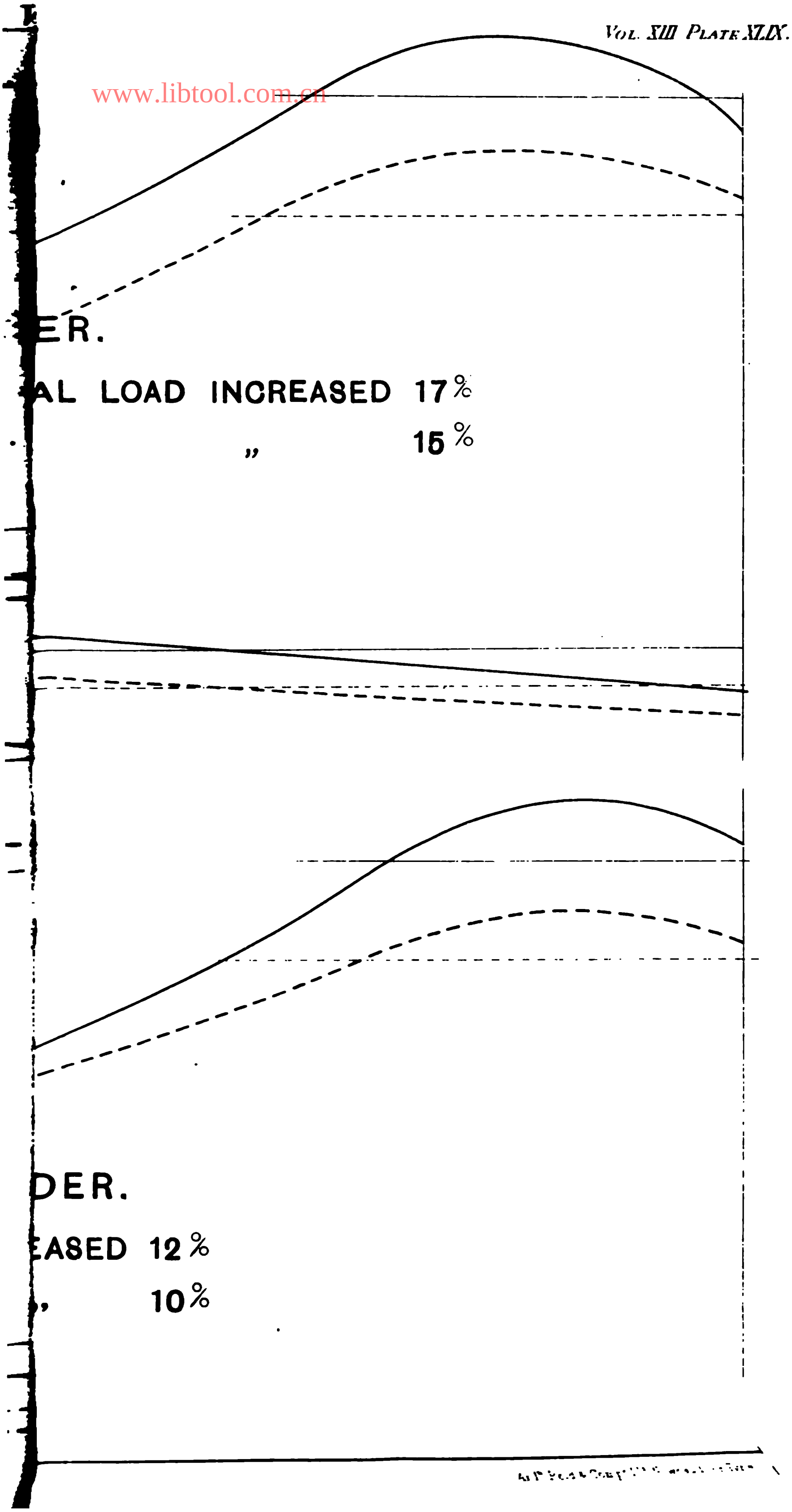
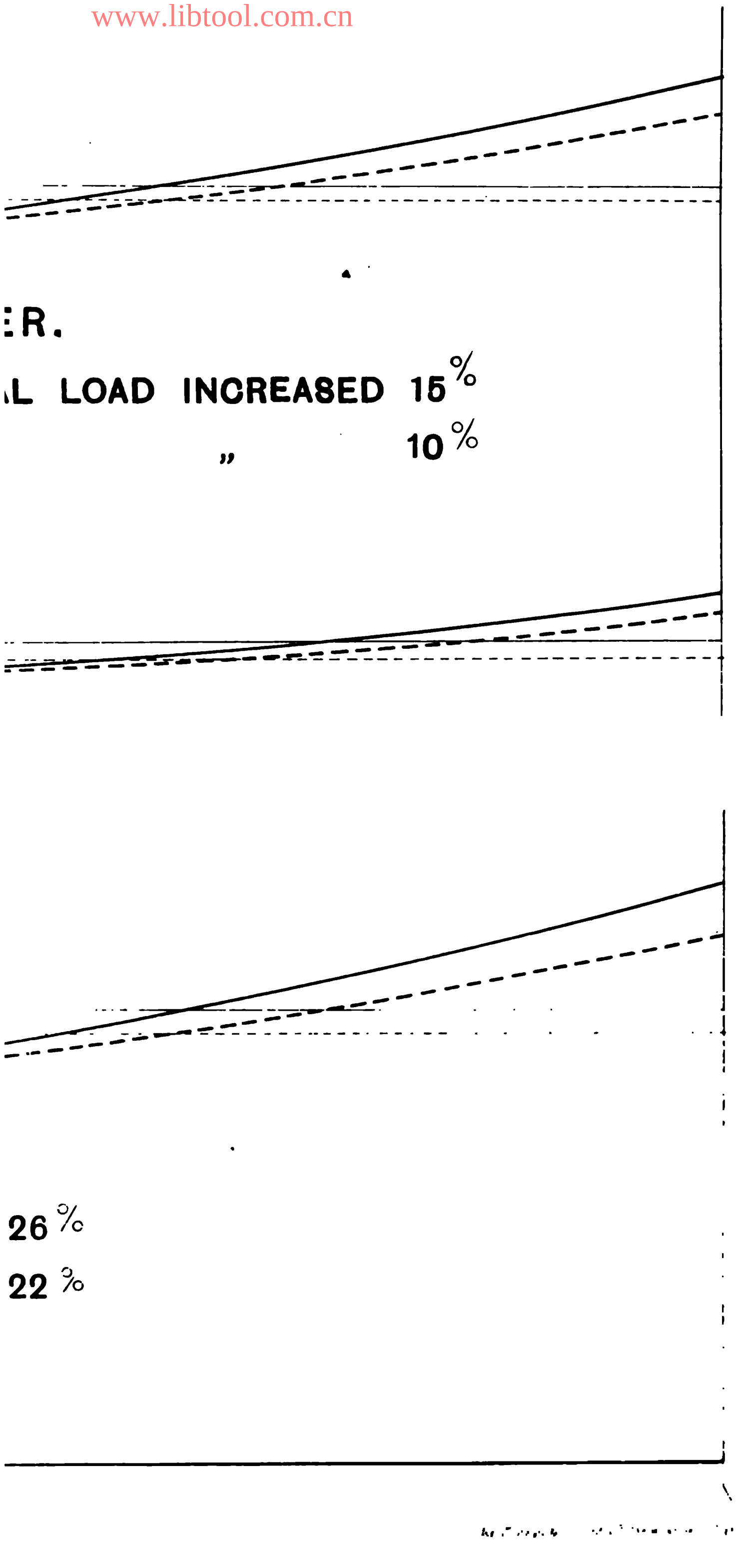

ER.
AL LOAD INCREASED 17%
" 15%
DER.
EASED 12%
" 10%



ER.
L LOAD INCREASED 15%
„ 10%
26%
22%

To illustrate Mr. D. B. Morison's Paper on "Improvements in Stamp Mills for Quartz Crushing"

STAMP MILL OF THE 16TH CENTURY.

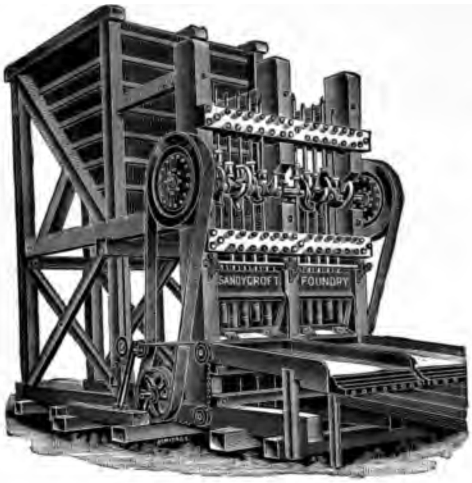
ERECTING A STAMP MILL ON THE RAND, SOUTH AFRICA.

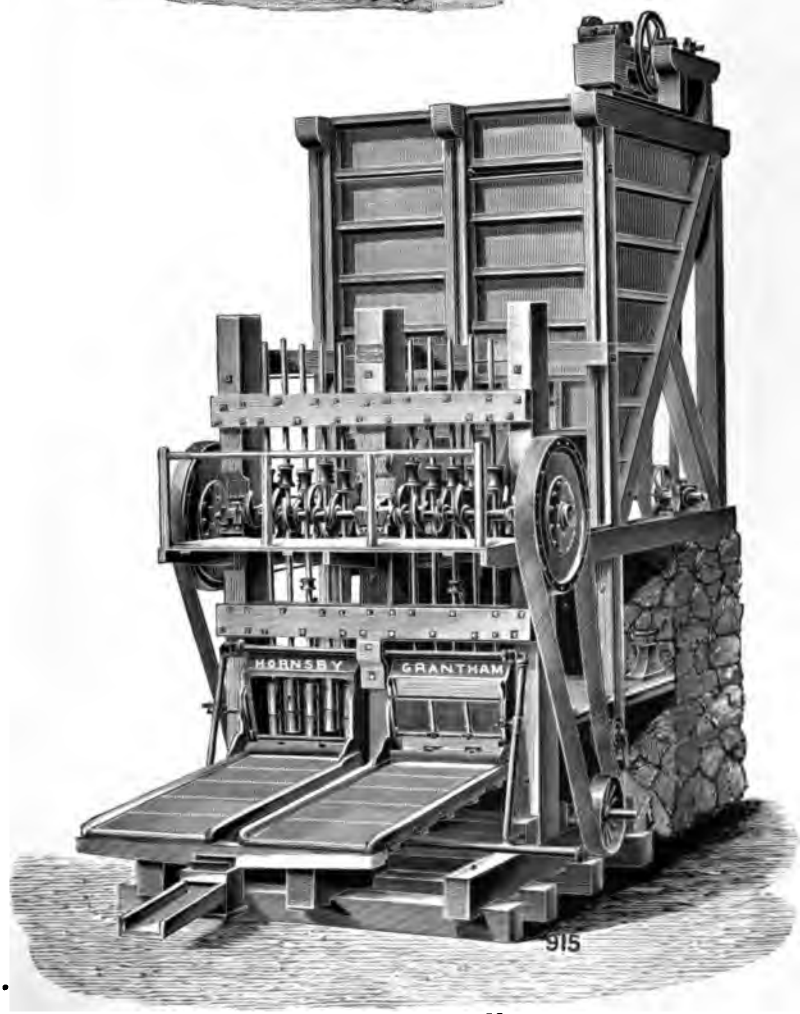
To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

OPERATION OF FOOT-POWER MILL.

QUARTZ CRUSHER AS USED IN THE MALAY PENINSULA.

illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."



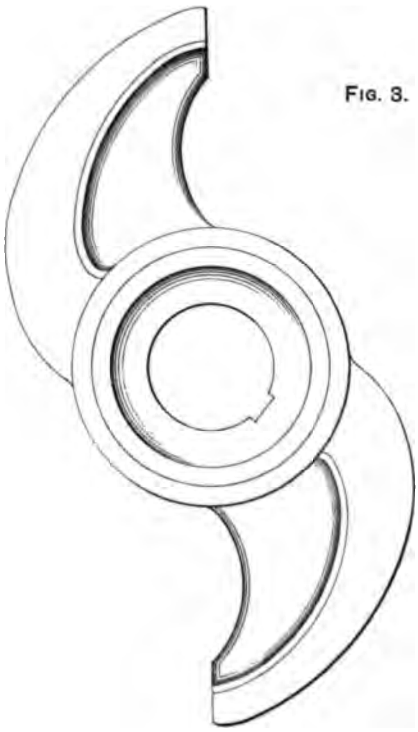


CALIFORNIAN STAMP MILL.

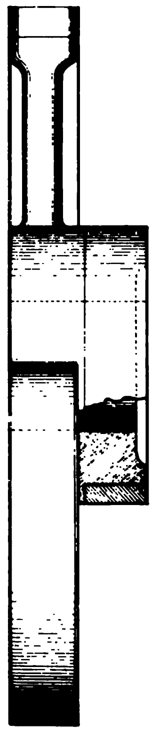
ings N.E.C.I. of E & S., 1896-7, Session XIII.

To illustrate Mr. D. B. Morison's Paper on
"Gravitation Stamp Mills for Quartz Crushing."

FIG. 3.



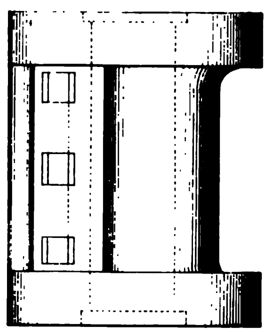
SIDE VIEW.



FRONT VIEW.

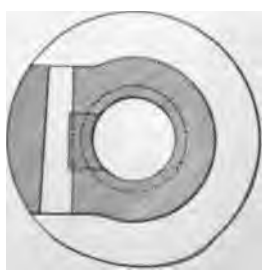
Scale, 1½ Inches to 1 Foot.

FIG. 1.



SIDE VIEW.

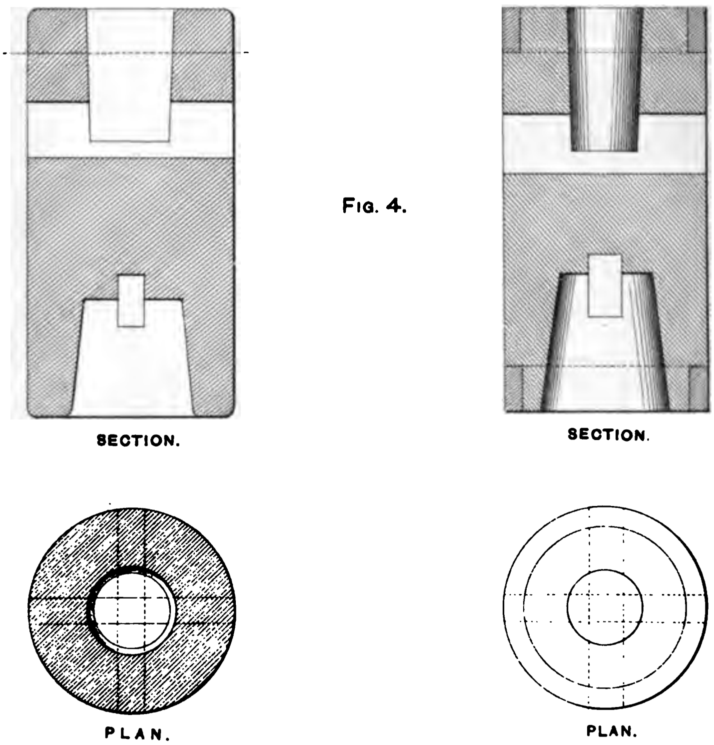
FIG. 2.



PLAN.

To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

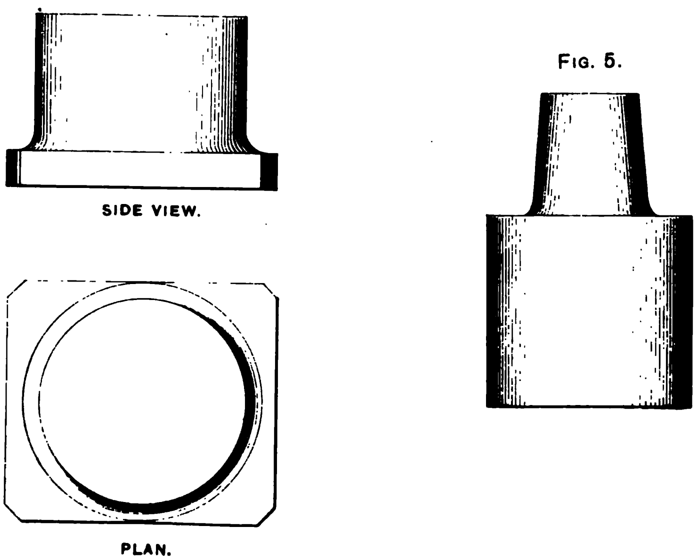
Fig. 4.

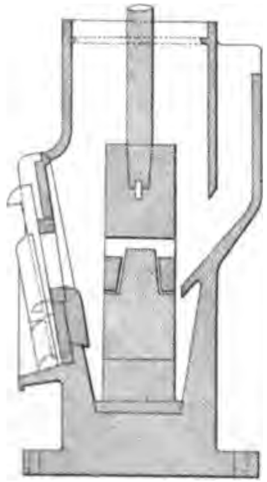


Scale, 1½ Inches to 1 Foot.

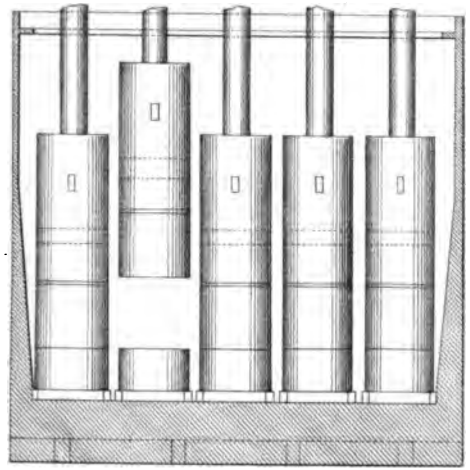
Fig. 6.

Fig. 5.



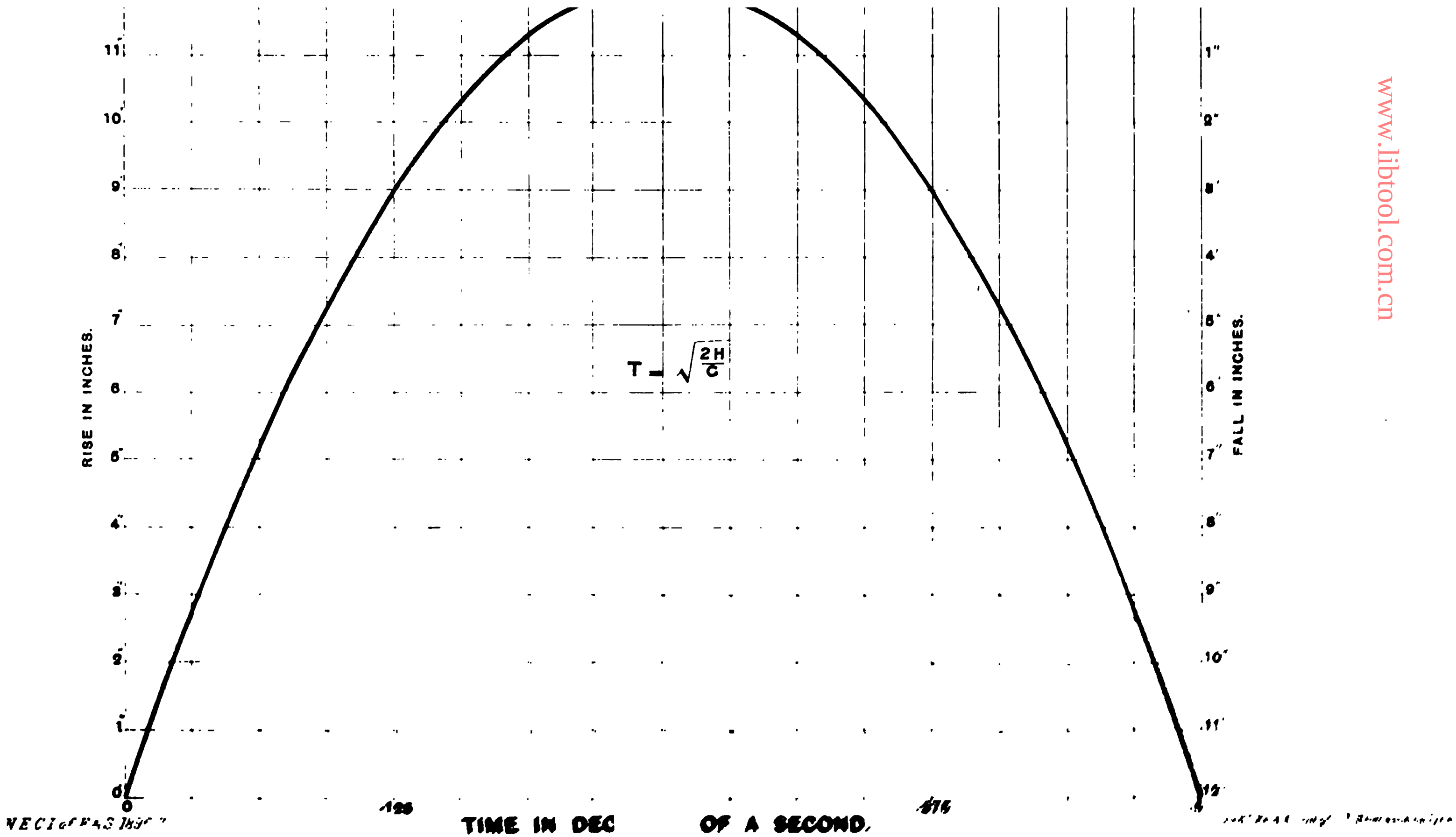


CROSS SECTION THROUGH CENTRE.



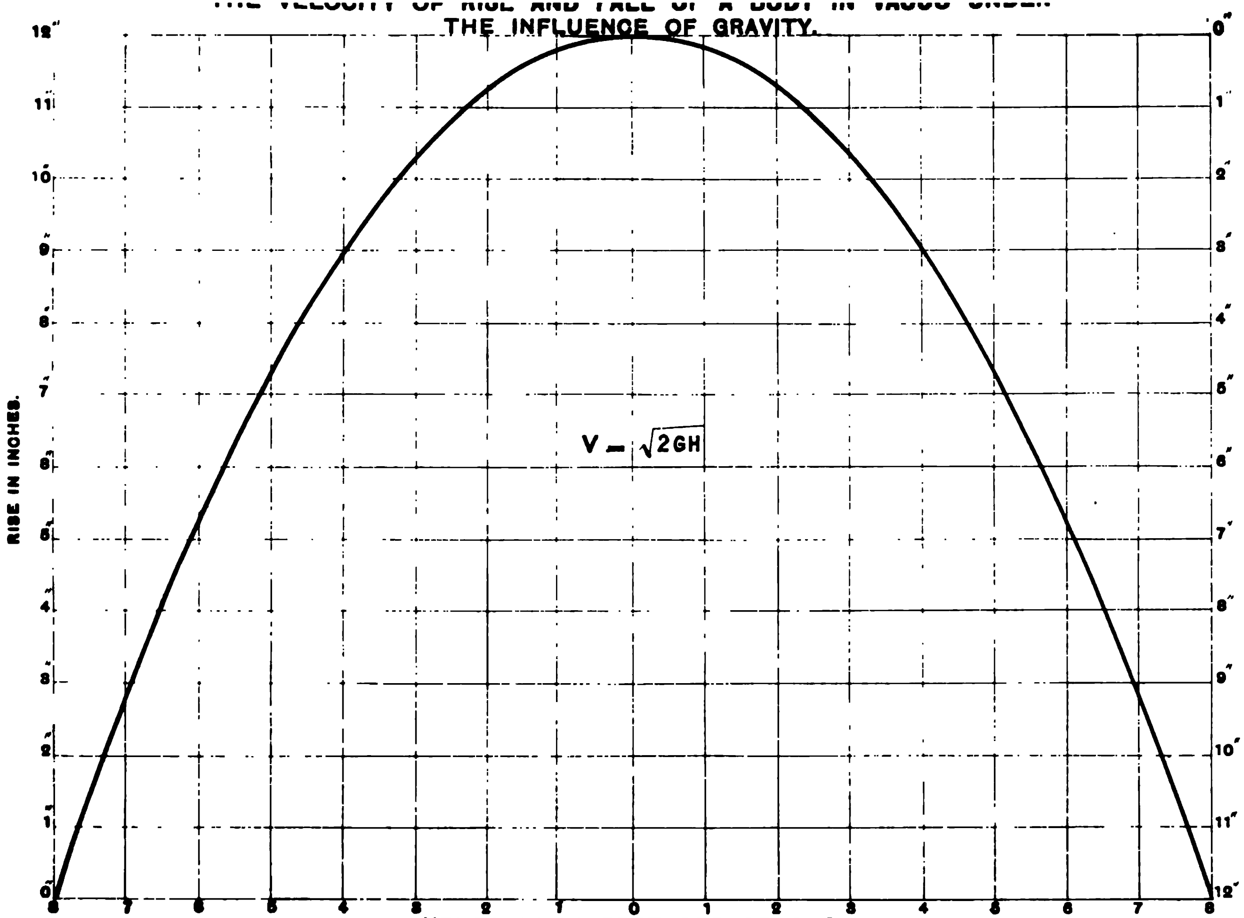
MORTAR BOX.

Scale, 1½ Inches to 1 Foot.



RISE IN INCHES.
FALL IN INCHES.
$T = \sqrt{\frac{2H}{C}}$
TIME IN DEC OF A SECOND.

THE INFLUENCE OF GRAVITY.



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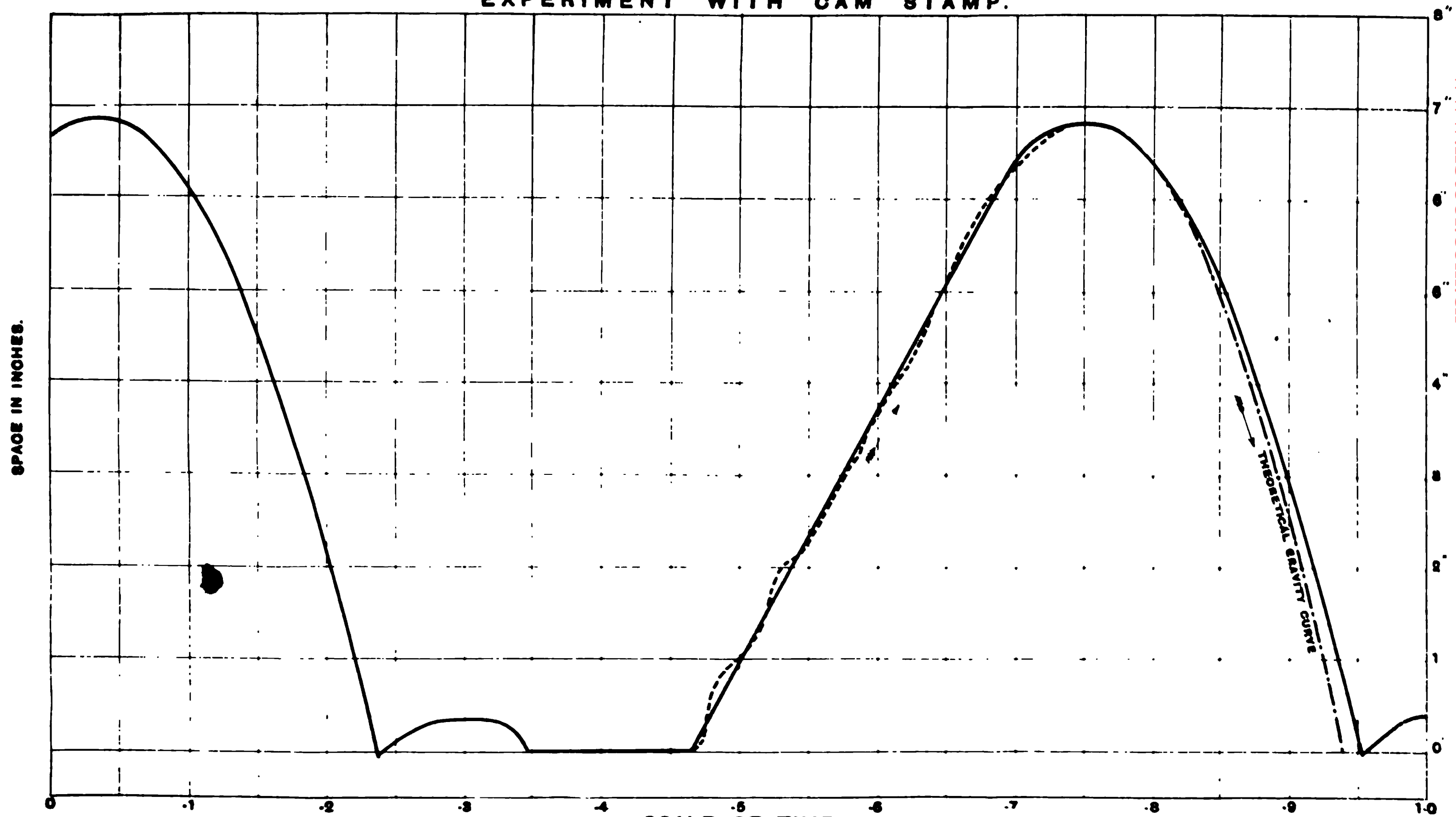
EXPERIMENT WITH CAM STAMP.



SCALE OF TIME.

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Session XIII

TAPPET SET TO GIVE 6¼" LIFT. WET CRUSHING —DROPS PER MINUTE = 82.

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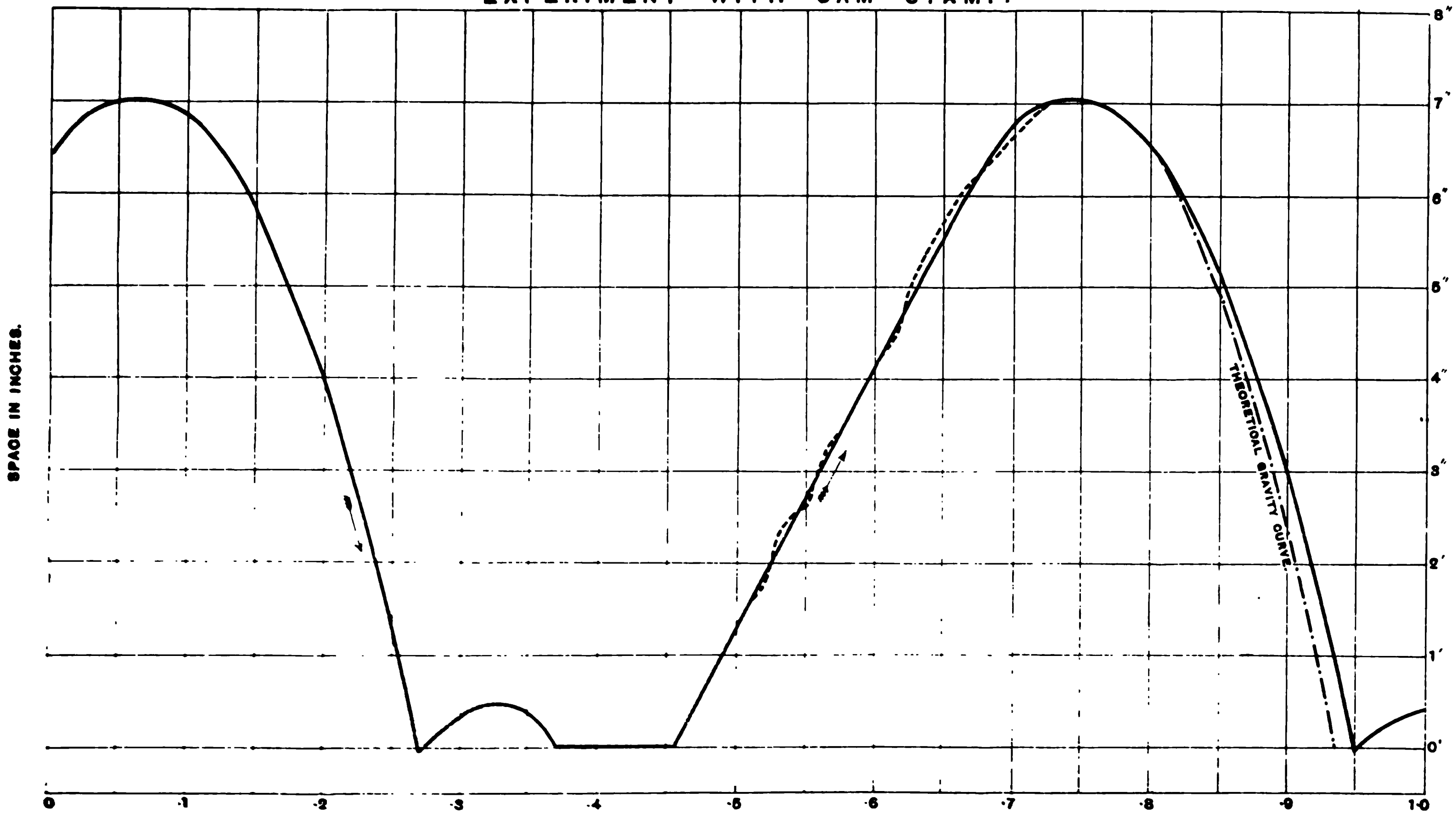
EXPERIMENT WITH CAM STAMP.

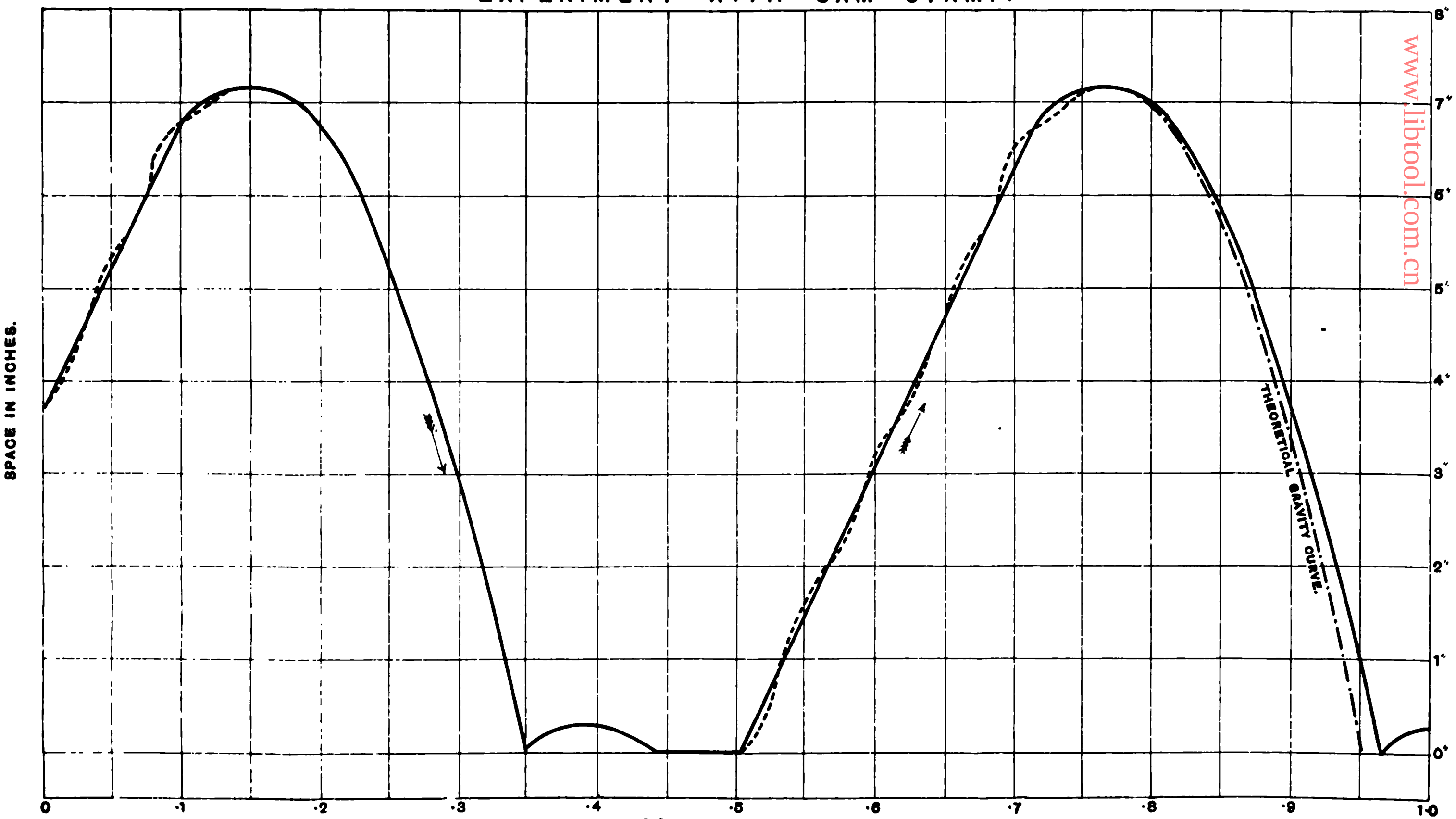


SCALE OF TIME.

TAPPET SET OF GIVE 6½ LIFT. WET CRUSHING.—DROPS PER MINUTE = 88.

Ard

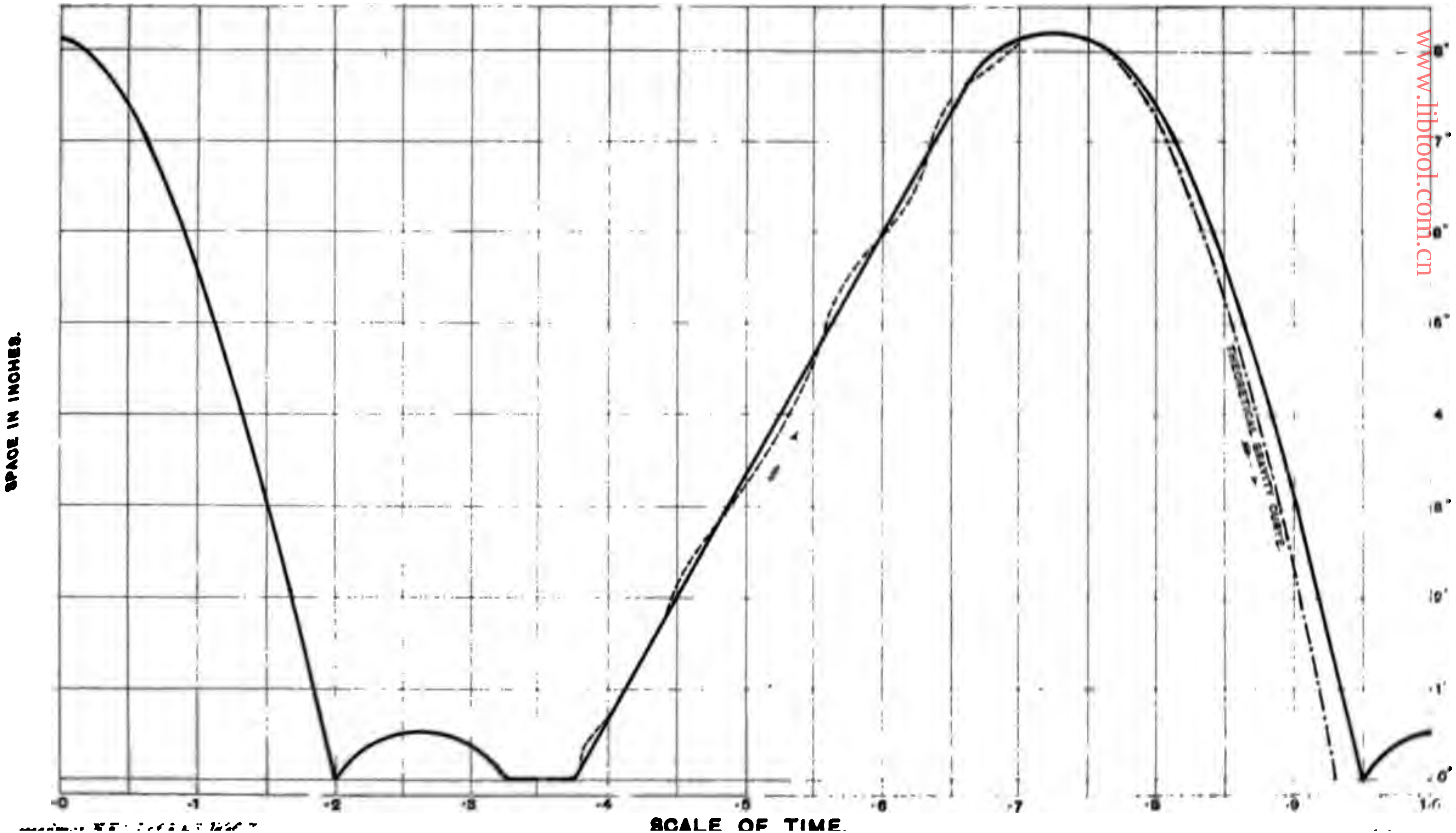
EXPERIMENT WITH CAM STAMP.

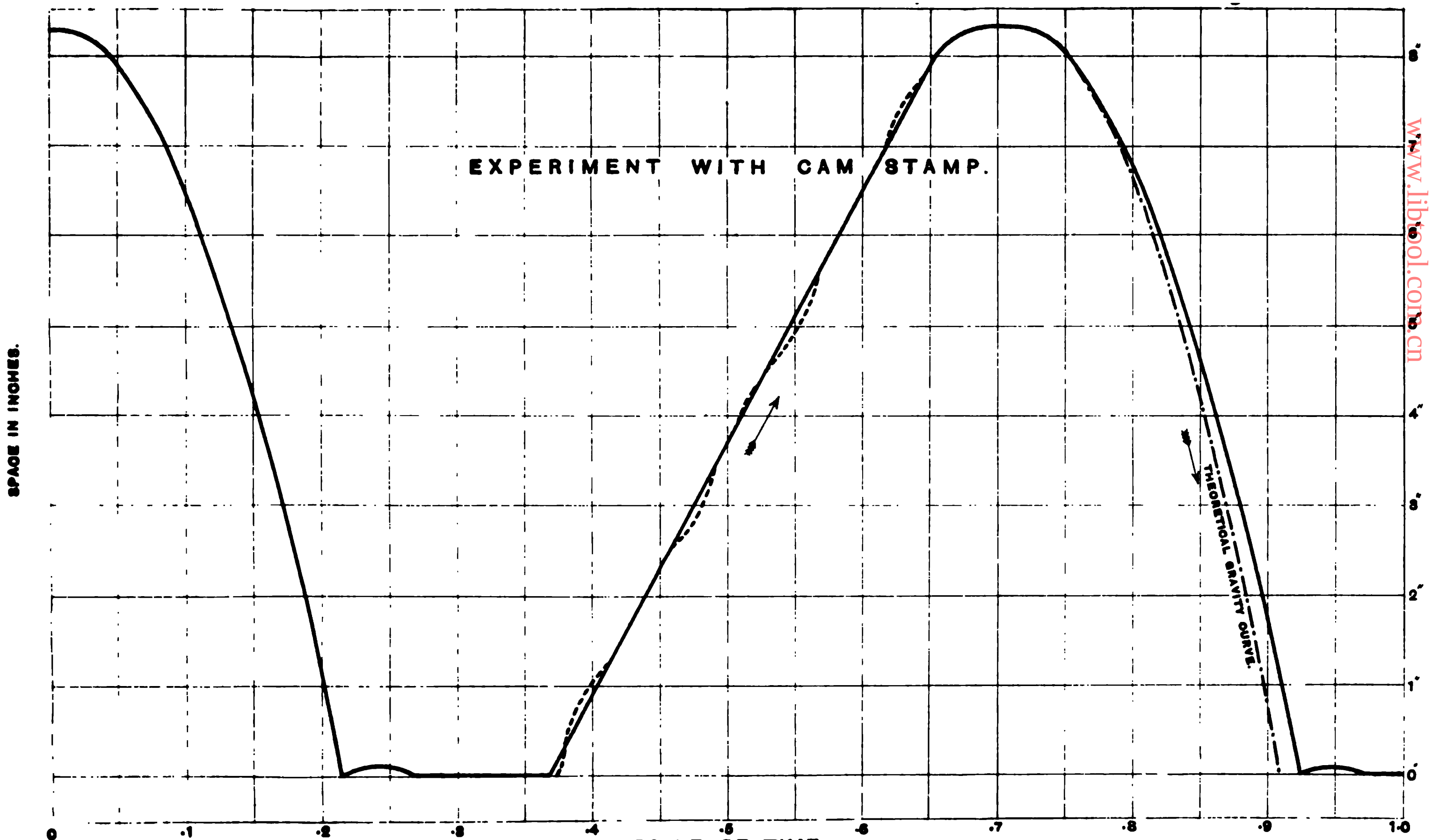


SCALE OF TIME.

To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

EXPERIMENT WITH CAM STAMP.





SCALE OF TIME.

TAPPET SET TO GIVE 8" LIFT. WET CRUSHING.—DROPS PER MINUTE = 84.

Trans. N.E.C. I. of E. & S. 1896-7. Session XIII

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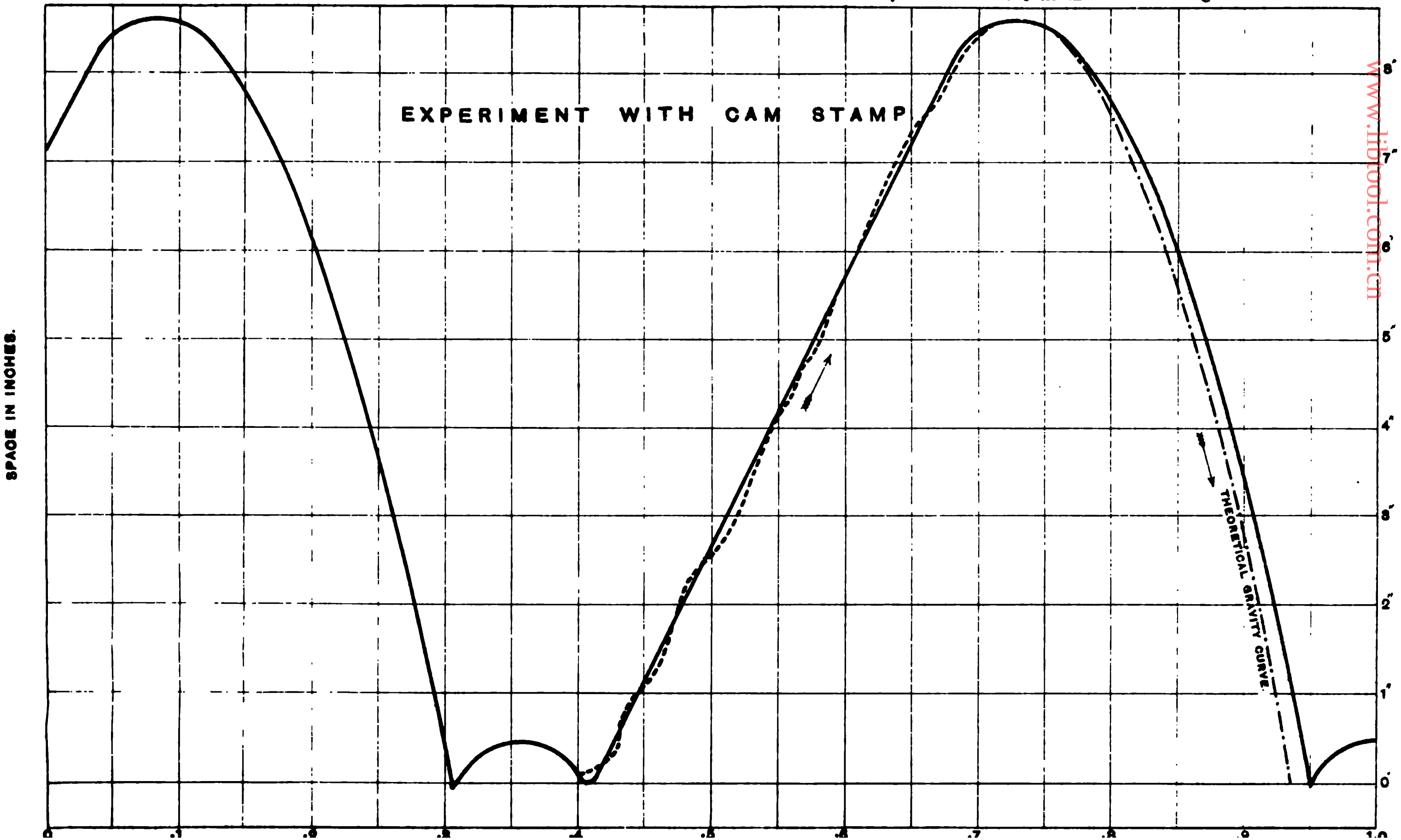
To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."



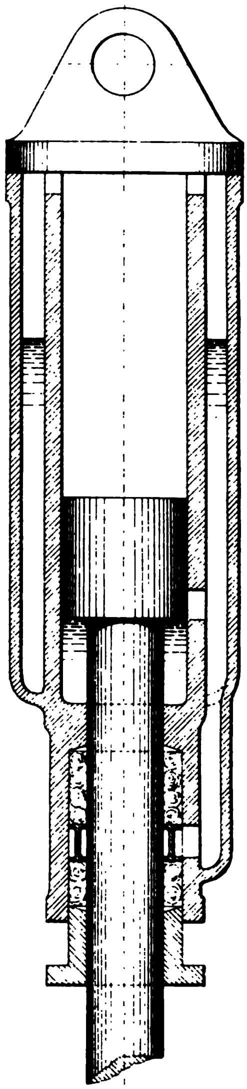
To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

MORISON'S HIGH SPEED STAMP (FRONT VIEW).

To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

MORISON'S HIGH SPEED STAMP (BACK VIEW).

To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

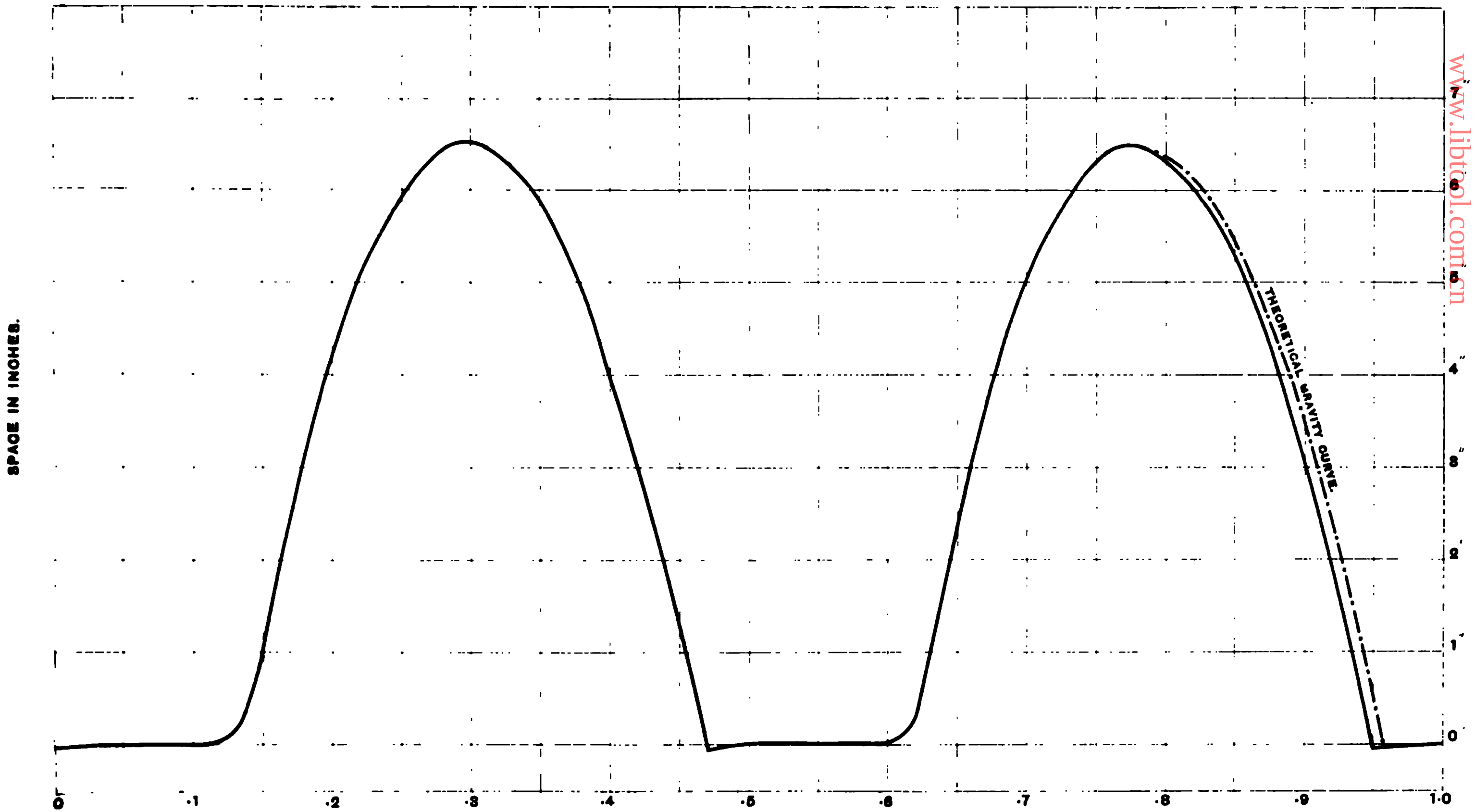


MORISON'S HIGH-SPEED STAMP.

SECTION OF CYLINDER.

To illustrate Mr. D. B. Morison's Paper on 'Gravitation Stamp Mills for Quartz Crushing'.

EXPERIMENT WITH MORISON'S HIGH-SPEED STAMP.

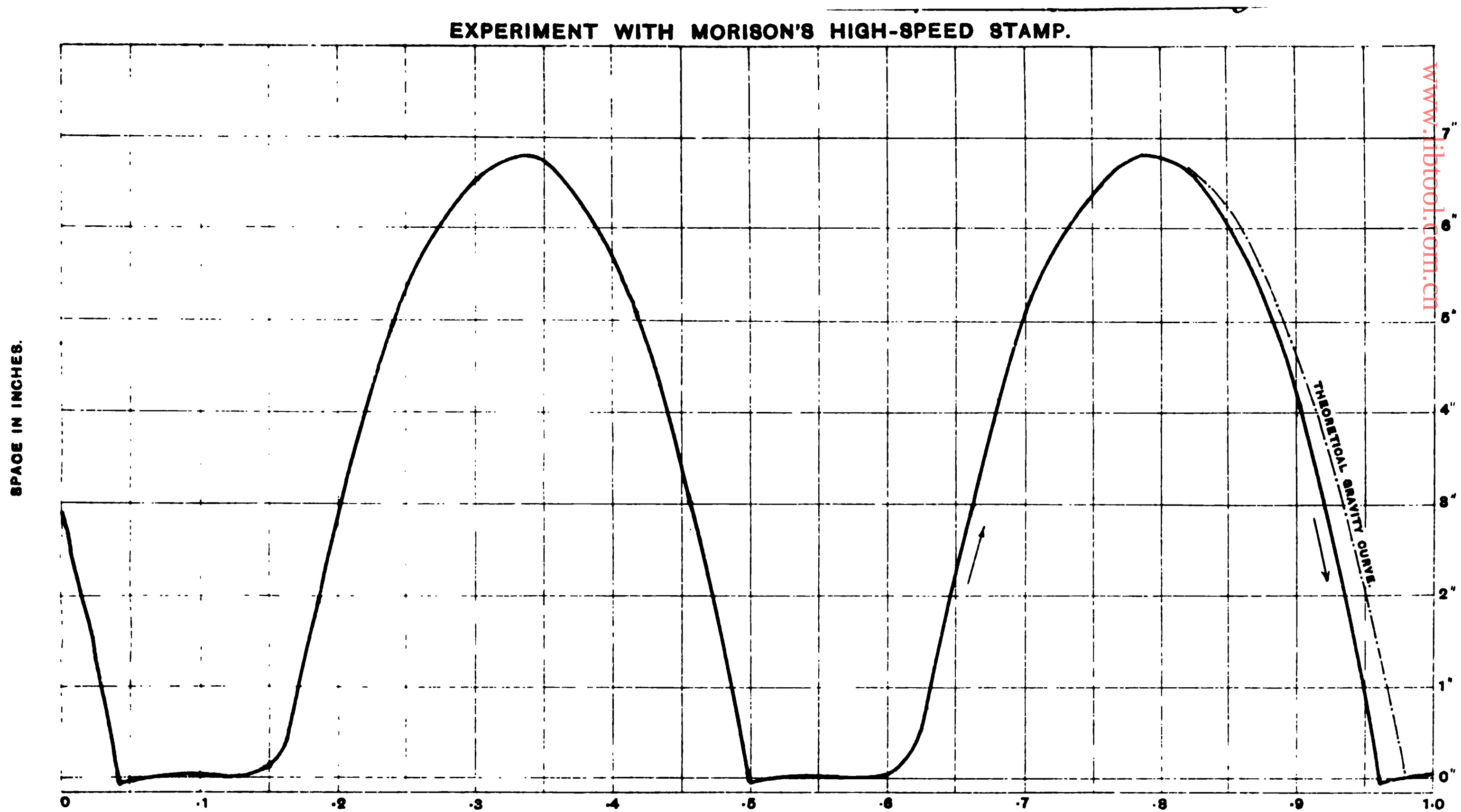


SCALE OF TIME.

WET CRUSHING. DROPS PER MINUTE = 125.

Plate XIII

EXPERIMENT WITH MORISON'S HIGH-SPEED STAMP.



SCALE OF TIME.

Proceedings N E C I of E & S 1896 7

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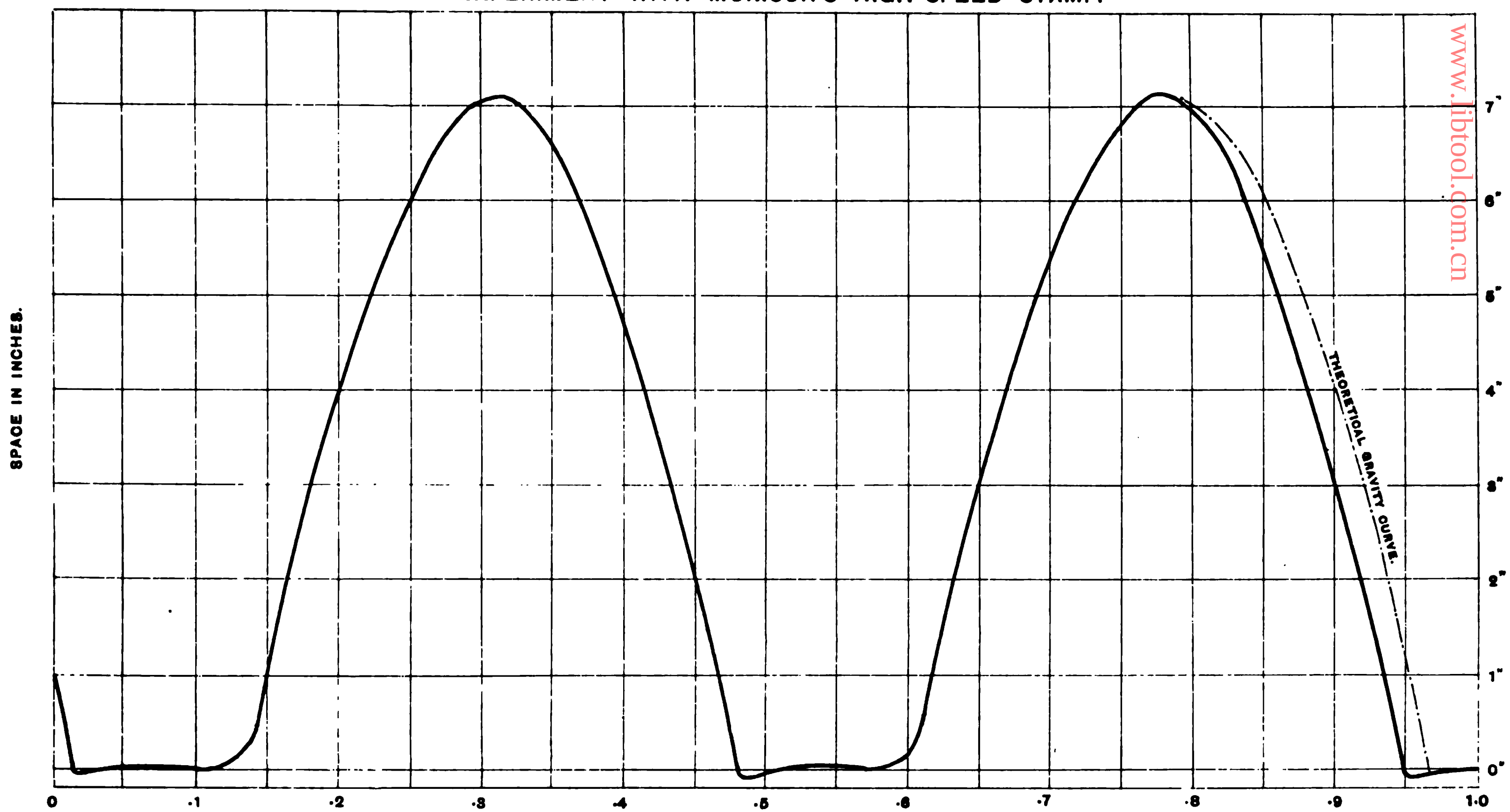
To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

EXPERIMENT WITH MORISON'S HIGH-SPEED STAMP.



SCALE OF TIME.

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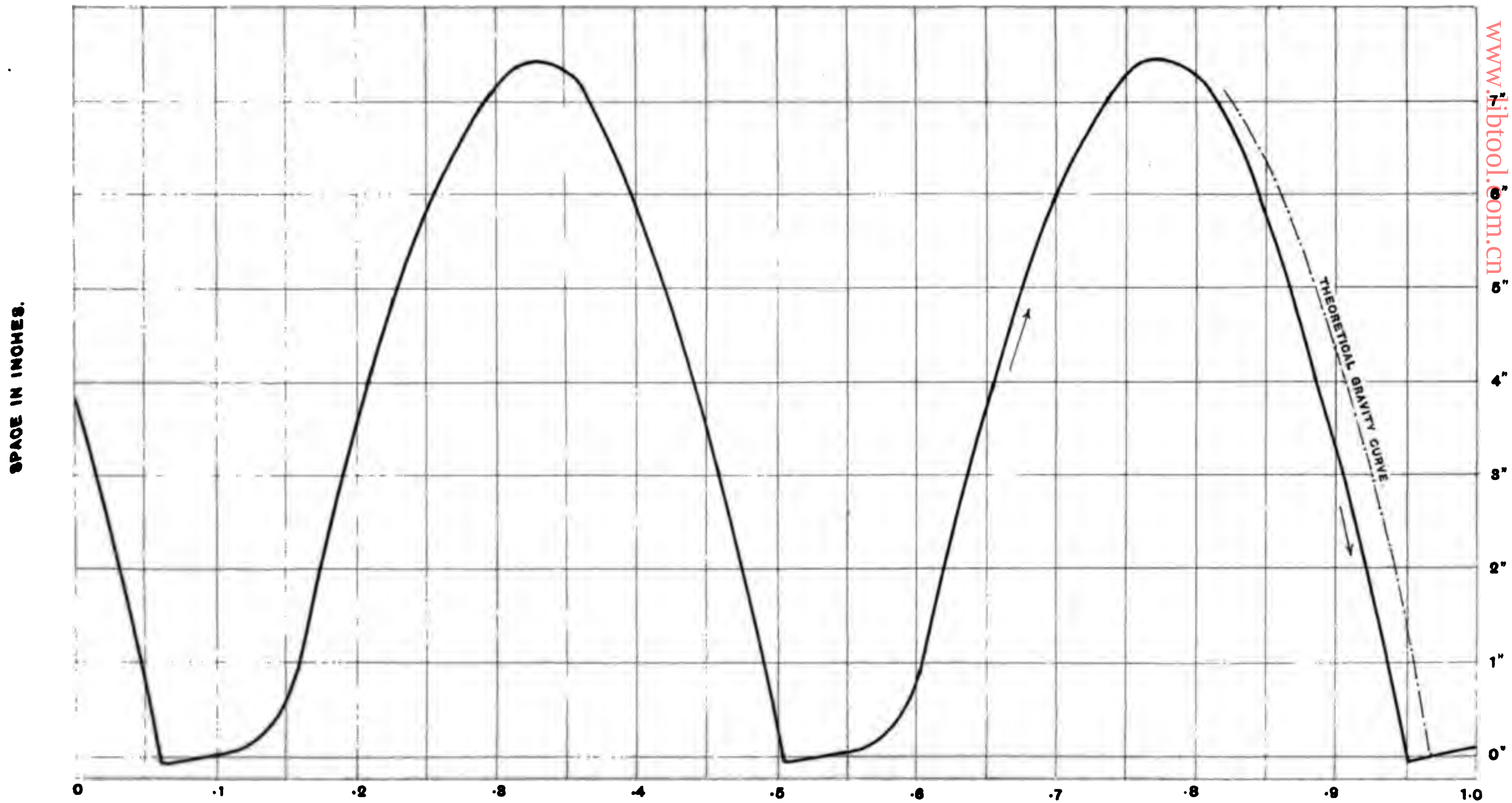
Andw Reid & Compy Ltd Newcastle on Tyne

To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

EXPERIMENT WITH MORISON'S HIGH-SPEED STAMP.



SCALE OF TIME.

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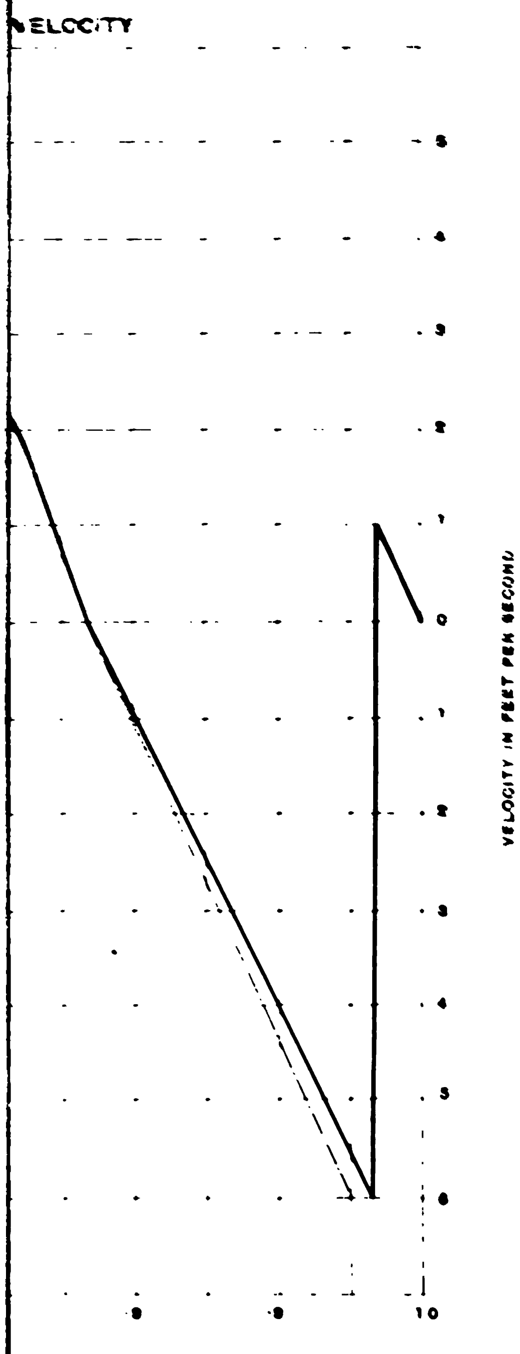
To illustrate Mr. D. B. Morison's Paper on "Gravitation Stamp Mills for Quartz Crushing."

THREE-PHASE GENERATOR OF 500 E.H.P., AT 240 REVS.

THREE-PHASE MOTOR OF 65 E.H.P

...Mills for Quartz Crushing.



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