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VISIT
of the
N. E. C. INST. OF ENGINEERS & SHIPBUILDERS
20TH OCTOBER 1888.

MAP · OF · THE
HARTLEPOOLS.

ANDREW REID, LITH. NEWCASTLE.

TRANSACTIONS

OF THE

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

·Founded·
·1884·

EDITED BY THE SECRETARY OF THE INSTITUTION.

VOLUME V.

FIFTH SESSION, 1888-89.

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ERRATUM.

Omission, page 259:—*After President's remarks on alteration to Bye-Law 6, insert* "The alteration to Bye-Law 6 was agreed to."

ADVERTISEMENT.

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MANCHESTER ASSOCIATION OF ENGINEERS.—The Technical Education of Engineers. The Thermo-Dynamic Analysis of the Gas Engine. Electric Lighting from Central Stations. The Economy of Health in Workshops. Ring Spinning Machinery. Modern Machine Tools. The Modern Cotton Carding Engine. Steam Boiler Legislation. Material Used in Boiler Construction. Locomotive Engines. Pipes for the Thirlmere and Bombay Water Works. Knop's Turbine. Ammonia Still, and Process of Manufacturing Sulphate of Ammonia, and Coke Oven and Ammonia Still. The Anderton Hydraulic Lift. On Four Large Steam Engines. Etc.

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SOUTH WALES INSTITUTE OF ENGINEERS, Cardiff, *Vol.* 16, *No.* 1.—Vaughton's Electric Miners' Safety Lamp. Description of the Barry Dock and Railways. Perret's Furnace or Water-cased Grate for burning Dust Fuel. *No.* 2, November, 1888.—Discussion on Perret's Water-cased Grate for Burning Dust Fuels. Endless Rope Haulage. Sinking Appliances at Llanbradach. Application of Electricity to Underground Haulage. *No.* 3, March, 1889.—Discussion on Application of Electricity to Underground Haulage. Discussion on the Hydro-Dynamic Pump. An Expansion Joint for Air, Steam, and Water Pipes. Apparatus for Automatically Controlling Bessemer Steel Converters and Centre Cranes, etc. Also Bye-Laws and Regulations, revised March, 1889.

PROCEEDINGS OF THE UNITED STATES NAVAL INSTITUTE, Annapolis, M.D., *Vol.* XV., *No.* 1, 1889.—Naval Reserves and the Recruiting and Training of Men. Sheathed or Unsheathed Ships? Naval Coast Signals. Notes on the Literature of Explosives. Progressive Naval Seamanship. Etc. *No.* 2, 1889.—Outline of a Scheme for the Naval Defence of the Coast. Collisions at Sea. Right of Way at Sea. Notes on the Literature of Explosives. Domestic Steel for Naval Purposes. Cruise of the U.S.S. "Vandalia." On the Efficacy of Oil for Subduing the Violence of Broken Water. Etc. *No.* 3.—Recollections of the Mexican War. Naval Administration. Comparison of Hotchkiss and Hebler Rifles, with Arguments favouring the Reduction of Caliber. *No.* 4.—The Necessity and Objects of a Naval War College. Notes on Steel Inspection of Structural and Boiler Material. An Essay on the Tactics of the Gun as Discoverable from Type War Ships. A Study on Fighting Ships. Naval Administration. A Proposed System of Messing the Crews of our Men-of-War. Notes on the Literature of Explosives. Professional Notes.

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„	„	„ VI.—July-Dec., 1868	......
„	„	Practical Mechanics' Journal, 2nd series, Vol. VIII.—April, 1863 - March, 1864	......
„	„	„ 3rd series, Vols. I. and II.—April, 1865 - March, 1867	......
„	„	„ 3rd series, Vols. III. and IV.—April, 1867 - March, 1869	......
„	„	„ 3rd series, Vol. V.—April, 1869 - March, 1870	......
„	„	Mechanics' Magazine, Vols. XI. and XII.—Jan.-Dec., 1864	......
„	„	„ Vols. XIII. and XIV.—Jan.-Dec., 1865	......
„	„	„ XV. and XVI.—Jan.-Dec., 1866	......
„	„	Engineering, Vol. XXXIV.—July-Dec., 1882*	......
„	„	„ Vol. XXXV.—Jan.-June, 1883*	......
„	„	„ Vol. XXXVI.—July-Dec., 1883*	......
„	„	„ Vol. XXXVII.—Jan.-June, 1884*	......

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* Unbound.

Date.	Donor.	Name of Book.	Author.
1889. Feb.	Duckitt, John ...	Engineering, Vol. XXXVIII.—July-Dec., 1884*	......
”	” ...	„ Vol. XXXIX.—Jan.-June, 1885*	......
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” ”	” ” ...	„ Vols. XVIII.-XXIV., 1877 to 1883 (inclusive)	......
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” ”	”	Boilers, their Construction and Strength	” ”

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4, St. Nicholas' Buildings West, Newcastle-upon-Tyne.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

List of Members, July, 1889.

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(A.)	Agent and Accountant.	**(N. A.)**	Naval Architect.
(C. E.)	Civil Engineer.	**(R. M.)**	Rope Manufacturer.
(E.)	Engineer and Boilermaker.	**(S.)**	Shipbuilder.
(F. M.)	Forge Master.	**(S. O.)**	Ship Owner.
(I. & S. M.)	Iron and Steel Merchants and Manufacturers.	**(SUR.)**	Engineer and Ship Surveyor.

HONORARY MEMBERS.

		ELECTED.
The Right Hon. Lord Armstrong, C.B., LL.D., F.R.S., Cragside, Rothbury		Nov. 1884
The Right Honourable the Earl of Ravensworth, Ravensworth Castle, near Gateshead-on-Tyne		Nov. 1884
W. H. White, Esq., The Admiralty, Whitehall, London	(N A)	Nov. 1884

LIFE MEMBERS.

Fox, Samson, Messrs. The Leeds Forge Co., Leeds	(E)	Dec. 1887
Halley, David, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark	(E)	Feb. 1887
Macoll, H., 2, Borough Road Terrace, Sunderland	(S)	Nov. 1884
Pascoe, J. R., Tyrmont, Woodford, Essex	(S)	Dec. 1889
Spence, W. G., Messrs. Gourlay, Bros., & Co., Engineers and Shipbuilders, Dundee	(E)	Nov. 1884

LIFE ASSOCIATE.

Eccles, Edward, G, Exchange Buildings, King Street, Newcastle-on-Tyne	(S O)	Oct. 1887

MEMBERS.

A.

Aberg, Henning, Stora Warfoet, Stockholm, Sweden	(E)	Oct. 1888
Abey, Henry, 41, Milton Road, West Hartlepool	(E)	Jan. 1889
Adamson, Alex., c/o Messrs. Barrow Shipbuilding Co., Barrow-in-Furness	(S)	Nov. 1885
Ahlbom, C., 11, Sidney Grove, Arthur's Hill, Newcastle-on-Tyne	(E)	Nov. 1884
Aitchison, Jas., Hylton, Sunderland	(S)	Nov. 1884
Alchin, A. H., 89, Wood Lane, Shepherd's Bush, London	(E)	Jan. 1885

		ELECTED.
Allan, David T., c/o Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne	(E)	May 1889
Allan, Jas. McNeal, 5, Warwick Street, Heaton, Newcastle-on-Tyne	(E)	Dec. 1886
Allardes, Wm., Greenville Terrace, Bloomfield, Belfast	(E)	Nov. 1884
Anderson, J., Messrs. Wigham Richardson & Co., Neptune Works, Low Walker-on-Tyne		Nov. 1884
Andrew, D., 31, Westmorland Road, Newcastle-on-Tyne	(SUR)	Jan. 1885
Andrews, Allan, Woodstock Street, Kilmarnock	(E)	Dec. 1885
Andrews, Jas., Drawing Office, Messrs. Naval Construction and Armaments Co., Barrow-in-Furness	(E)	Nov. 1884
Anthony, Jas., 6, Northumberland Square, North Shields	(S)	Oct. 1886
Archbold, Joseph G., Messrs. E. Scott & Co., Close, Newcastle-on-Tyne	(E)	Jan. 1889
Armstrong, G. S., 37, Warwick Street, Heaton, Newcastle-on-Tyne	(E)	Nov. 1884
Armstrong, Robert B., 47, Cromwell Street, Newcastle-on-Tyne ...	(E)	Oct. 1887
Arnison, Geo., Jun., 5, Tavistock Place, Sunderland	(N A)	Nov. 1884
Ash, Mortimer W., c/o Messrs. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Feb. 1887
Austin, S. P., Wear Dockyard, Sunderland	(S)	Nov. 1884
Austin, W. K., Lloyd's Register of Shipping, Dock Office, West Hartlepool	(E)	Oct. 1888

B.

Bailey, James, 6, Ashfield Terrace, Ryton-on-Tyne	(E)	Nov. 1884
Baines, Geo. Henry, Messrs. Central Marine Engineering Co., West Hartlepool	(E)	Oct. 1888
Baird, Alex., 22, Horsford Road, Brixton Hill, London, S.W. ...	(E)	Nov. 1884
Barclay, James, Lloyd's Register of Shipping, Newcastle-on-Tyne...	(SUR)	Nov. 1888
Barley, C. J., Caterham Manor, Warlingham Station, Surrey	(E)	Graduate, Feb. 1885 Member, Dec. 1886
Barron, T. G., Fern Villas, Elwick Road, West Hartlepool ...	(E)	Oct. 1888
Bartliboi, Jehangir Framji, Bombay, British India (temporary address: 1, Olive Street, Sunderland)	(E)	Dec. 1888
Bate, Edward R., 5, Ferndale Road, Clapham, London	(E)	Jan. 1885
Batey, John Thomas, 30, Richmond Street, Newcastle-on-Tyne ...	(S)	Nov. 1885
Baxter, J., 9, Warwick Street, Heaton, Newcastle-on-Tyne ...	(E)	Nov. 1884
Baxter, W. J.	(E)	Oct. 1886
Beadon, D. C. *	(E)	Jan. 1885
Bell, James, 29, Croft Terrace, Jarrow-on-Tyne	(E)	Feb. 1887
Bell, William, Rosehill Terrace, Rosehill, Wallsend-on-Tyne ...	(E)	Nov. 1888
Bergstrôm, Gus., Poplar Grove, Hart Road, West Hartlepool ...	(N A)	Mar. 1886
Berkley, A. B., Grange Villa, Jarrow-on-Tyne	(E)	Mar. 1887
Bindesböll, S. C. W., 1, Tamworth Road, Newcastle-on-Tyne ...	(S)	Nov. 1884
Bittleston, W. H., 9, Crooms Hill, Greenwich, S.E....	(S)	May 1885
Black, Jas., Portobello Foundry, Sunderland	(E)	Jan. 1885
Black, J., Messrs. J. Merryweather & Co., West Hartlepool ...	(E)	Nov. 1888
Black, Wm., Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne	(E)	Jan. 1885
Blakston, J. W., 5, Douro Terrace, Monkwearmouth, Sunderland...	(S)	Jan. 1886

		ELECTED.
Blechynden, Alfred, 12, Cavendish Park, Barrow-in-Furness ...	(E)	Oct. 1885
Blenkinsop, John N.	(E)	Oct. 1885
Blumer, Wm., Riversley, Milburn Terrace, Sunderland	(S)	Dec. 1886
Boddy, John, Tyne Engine Works, Alexandra Docks, Newport, Mon.	(E)	Dec. 1888
Bond, C. P. W., 27, Leadenhall Street, London, E.C.	(E)	Nov. 1888
Bone, W. J., 61, Linskill Terrace, North Shields	(S)	Dec. 1884
Boolds, Jas. H., c/o Messrs. Raylton Dixon & Co., Middlesborough	(S)	Oct. 1886
Borowski, G., Government Dock Yard, Cherson's Depart., Nicolajew, Russia	(E)	Oct. 1885
Boyd, Wm., North House, Long Benton, Newcastle-on-Tyne ...	(E)	Nov. 1884
Bramwell, Balfour, 2, Beverley Terrace, Cullercoats	(E)	Graduate, Nov. 1886 Member, Nov. 1887
Brankston, R. T.	(E)	Nov. 1884
Bray, C. H., 6, Kent Street, Jarrow-on-Tyne	(E)	Mar. 1887
Bremberg, G., Messrs. Kockum's Mekaniska, Verkestad, Malmo, Sweden	(S)	Nov. 1884
Brock, John, 5, St. Mary's Place, Newcastle-on-Tyne	(E)	Nov. 1885
Brough, Robert, 9, Western Hill, Sunderland	(E)	Dec. 1885
Brown, Eugene	(E)	Feb. 1886
Brown, T. R., 34, Dock Street East, Sunderland ...	(E)	Graduate, May 1885 Member, Oct. 1886
Brown, William	(E)	April 1887
Brown, E. D., c/o Tees Conservancy Commissioners, Middlesborough	(E)	Nov. 1888
Browne, Sir B. C., Westacres, Benwell, near Newcastle-on-Tyne	(C E)	Jan. 1885
Buchanan, A., Michaelson Villa, Barrow-in-Furness	(S)	Nov. 1884
Buchanan, John H., Lloyd's Register of Shipping, West Hartlepool	(SUR)	Oct. 1888
Buchanan, Charles, 14, Humbledon View, Sunderland	(SUR)	April 1889
Buckland, H. B., Hamburg Chambers, Quayside, Newcastle-on-Tyne	(E)	Nov. 1885
Buglass, A. W.		Nov. 1884
Bulmer, John, 1, Graingerville North, Newcastle-on-Tyne ...	(E)	Mar. 1886
Burdon. J. G., 20, Archbold Terrace, Newcastle-on-Tyne	(E)	Nov. 1884
Burns, J., 3, Kaiser Terrace, West Hartlepool		Nov. 1884
Butterfield, George, 30, John Candlish Road, Millfield, Sunderland		Nov. 1884

C.

Cama, Nusserwanji Bomanji, 17, Girgaum Back Road, Bombay, British India	(E)	Dec. 1888
Campbell, James J., Messrs. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Oct. 1888
Cannell, Frank, Messrs. H. Parry & Son, Lisbon	(E & S)	Nov. 1887
Carr, J. W., 4, Grey Street, North Shields	(E)	Feb. 1885
Carrick, H., Holly House, Gateshead-on-Tyne	(E)	Nov. 1884
Carstons, Samuel, 37, Cardigan Terrace, Heaton, Newcastle-on-Tyne	(S)	Dec. 1887
Carter, G. J., Elswick Shipyard, Newcastle-on-Tyne	(S)	Dec. 1886
Carter, Thos., 7, Dundas Street, Monkwearmouth, Sunderland ...	(E)	Nov. 1884
Cay, Arthur, Westoe, South Shields	(E)	Nov. 1884
Chapman, Abel, Capt., Belle Vue, Low Fell, Gateshead-on-Tyne...	(E)	Nov. 1884

		ELECTED.
Chapman, Alfred C., 2, St. Nicholas' Buildings, Newcastle-on-Tyne	(E)	Oct. 1888
Chapman, Hedley, 147, Park Road, Newcastle-on-Tyne	(E)	Feb. 1886
Charlton, Henry, 1, Millfield Terrace, Gateshead-on-Tyne... ...	(E)	Nov. 1884
Charlton, R. B., Jun., Manors Railway Station Works, Newcastle-on-Tyne	(E)	Nov. 1884
Charlton, T., 25, Lincoln Street, Gateshead-on-Tyne	(E)	Nov. 1884
Christie, C. A., 4, Colbeck Terrace, Tynemouth	(E)	Nov. 1884
Christie, C. J. D., Neptune Works, Low Walker-on-Tyne	(S)	Nov. 1884
Christie, J. D., 4, Colbeck Terrace, Tynemouth	(S)	Nov. 1884
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, Thos., Rye Hill, Newcastle-on-Tyne	(E)	Nov. 1884
Clarke, William, Victoria Engine Works, Gateshead-on-Tyne ...	(E)	Oct. 1887
Cochrane, James, 25, Aduana, Cadiz, Spain	(E)	Nov. 1888
Connell, Charles, 2, Broomhill Drive, Partick, Glasgow	(S)	Nov. 1888
Conning, Alfred C., Dunston Iron & Steel Works, Gateshead-on-Tyne	(F M)	May 1885
Conradi, Carl	(E)	Nov. 1884
Cooper, William, Baltic Chambers, Quayside, Newcastle-on-Tyne	(E)	Feb. 1888
Coote, Arthur, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne	(S)	Nov. 1884
Cornforth, J., Messrs. Gladstone & Cornforth, Church Street, West Hartlepool	(E)	Oct. 1888
Cornish, H. P., c/o Messrs. Wigham Richardson & Co., Low Walker-on-Tyne	(E)	Oct. 1888
Cowan, M., 22, Clarendon Terrace, South Shields	(S)	Mar. 1889
Craggs, Ernest H., Messrs. R. Craggs & Sons, Middlesborough ...	(S)	Oct. 1888
Crawford, Jas., 9, Custom House Court, Quayside, Newcastle-on-Tyne	(SUR)	Nov. 1886
Crawford, John P., 1, St. Vincent Street, Sunderland	(E)	May 1889
Crawford, W. A. F., c/o Messrs. Rayne & Crawford, 31, Close, Newcastle-on-Tyne...	(E)	Nov. 1884
Cross, Wm., 4, Fenham Terrace, Newcastle-on-Tyne	(E)	Mar. 1886
Cruddas, W. D., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick, Newcastle-on-Tyne	(E)	Dec. 1884
Cuevel, John L., Kadyk, Amsterdam	(E)	Mar. 1886
Cummins, W. R., 40, Perth Road, Dundee	(E)	Nov. 1884
Curwen, Henry R., 16, De Grey Street, Newcastle-on-Tyne	(S)	Graduate, Feb. 1886 Member, Oct. 1887

D.

Dalrymple, Wm., 11, Queen's Terrace, Gateshead-on-Tyne ...	(E)	Dec. 1886
Danson, Thos. James, 3, St. Nicholas' Buildings, Newcastle ...	(E)	Oct. 1888
Darling, W. J., Lloyd's Surveyor, Leith	(S)	April 1887
Darney, John, Messrs. Short Bros., Pallion, Sunderland	(S)	Nov. 1884
Davie, Albert, c/o Messrs. W. Denny & Bros., Leven Shipyard, Dumbarton, N.B.	(E)	Graduate, Feb. 1886 Member, Oct. 1887
Davison, A. J., Rosedale, Wallwood Road, Leytonstone, Essex ...	(E)	Oct. 1888

		ELECTED.
Davison, John, 4, Dean Terrace West, Southwick, Sunderland	(E)	Nov. 1884
Davison, John W., The Crescent, Low Fell, Gateshead-on-Tyne	(E)	Nov. 1886
Dempsy, S., 112, Elswick Road, Newcastle-on-Tyne	(S)	Nov. 1884
Derby, J. W., 48, South Cumberland Street, Glasgow	(E)	Nov. 1884
Dick, Francis, Elmwood Terrace, Field Road, Forest Gate, London, E.	(E)	Nov. 1885
Dickinson, F. T., Park House, Sunderland	(E)	Graduate, May 1885 Member, Oct. 1886
Dickinson, James, Park House, Sunderland	(E)	Nov. 1884
Dickinson, John, Park House, Sunderland	(E)	Nov. 1884
Dickinson, W., Park House, Sunderland	(E)	Nov. 1884
Dickinson, R. E., Messrs. Palmer's Iron & Shipbuilding Co., Jarrow-on-Tyne	(E)	April 1889
Dixon-Brown, L. D., Unthank Hall, Haltwhistle	(S)	Nov. 1886
Dixon, Raylton, Cleveland Shipyard, Middlesborough	(S)	Feb. 1888
Dobson, William, Low Walker-on-Tyne	(S)	Nov. 1888
Donald, James, 48, St. Luke's Terrace, Pallion, Sunderland	(S)	Nov. 1884
Donovan, J. W., 4, Elizabeth Street, Newcastle Road, Sunderland	(E)	April 1885
Douglas, John F., Messrs. Wigham Richardson & Co., Low Walker-on-Tyne	(E)	Jan. 1888
Dowsen, Chas., 8, Croft Terrace, Jarrow-on-Tyne	(E)	Dec. 1885
Doxford, Charles D., Bainbridge Holme, Tunstall Road, Sunderland	(S)	Nov. 1884
Doxford, R. P., Pallion Engine Works, Sunderland	(E)	Nov. 1884
Doxford, W. T., Pallion Shipyard, Sunderland	(S)	Nov. 1884
Drakenberg, J. A., 5, Brahegatan, Stockholm, Sweden	(E)	Feb. 1886
Duckitt, Jno., 4, St. Nicholas' Buildings West, Newcastle-on-Tyne	(E)	Nov. 1884
Dudgeon, F. S., 112, Fenchurch Street, London, E.C.	(E)	Feb. 1885
Dunlop, William, 31, Hartington Street, Barrow-in-Furness	(E)	Mar. 1888
Dykes, James, 78, Dilston Road, Newcastle-on-Tyne	(E)	May 1885

E.

Eckmann, John, Sunderland Engine Works, South Docks, Sunderland	(E)	May 1886
Edmiston, Jas. B., Ivy Cottage, Highfield Road, Walton, Liverpool	(E)	Nov. 1886
Eiles, Robert, Messrs. Eiles & Dryden, 4, Quayside, Newcastle-on-Tyne	(E)	Apr. 1889
Elliott, Consitt, 4, Suffolk Street, Sunderland	(E)	May 1885
Eltringham, J., c/o Messrs. J. T. Eltringham & Co., South Shields	(E)	May 1889
Engelbach, Herbert R., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne	(E)	Nov. 1884
English, E. Harold, Messrs. Westgarth, English, & Co., Middlesbro'	(E)	Feb. 1889
Errington, Joseph R., 51, Dock Street East, Sunderland	(E)	Jan. 1888
Eshelby, William, 4, Lax Terrace, Stockton-on-Tees	(E)	Feb. 1888
Evers, G., Actiengesellschaft Wesu, Bremen, Germany	(S)	Nov. 1884

F.

Fairman, A. E., 23, St. Bede's Terrace, Sunderland	(N A)	Oct. 1886
Fairweather, C. W., Ernest Scott & Co., Close, Newcastle-on-Tyne	(E)	Dec. 1886
Farina, A. J., Oakwood House, Westmorland Road, Newcastle-on-Tyne	(E)	Nov. 1884
Faruffini, Capt. M. C., 6, Claremont Terrace, Newcastle-on-Tyne	(N A)	Dec. 1888
Feldtmann, H., Bergen, Norway	(E)	Jan. 1889

		ELECTED.
Firth, H. Branson, Messrs. T. Firth & Sons, Sheffield	(S M)	Oct. 1888
Fleming, Charles Edward, 71, Elswick Road, Newcastle-on-Tyne	(E)	Nov. 1884
Fletcher, James, 6, Radnor Terrace, Old Dumbarton Road, Glasgow	(E)	Dec. 1885
Fletcher, Robert, Walker Forge, Low Walker-on-Tyne	(F M)	Dec. 1886
Flohr, Justus, 32, Birkencellies, Stettin, Germany	(E)	Oct. 1886
Foley, Nelson, Villa Beatrice, Parco Griffeo, Naples, Italy	(E)	Nov. 1884
Forbes, John	(E)	Oct. 1885
Forster, C., 6, Ellison Place, Newcastle-on-Tyne	(S)	Nov. 1888
Foster, G. E., 23, Holly Street, Jarrow-on-Tyne	(E)	Jan. 1886
Foster, Henry, Newburn Steel Works, Newburn-on-Tyne	(E)	April 1885
Fothergill, J. R., 1, Bathgate Terrace, West Hartlepool	(E)	Mar. 1886
Fownes, Henry, Tyne Forge, Ouseburn, Newcastle-on-Tyne	(F M)	Nov. 1884
Franki, J. P., Messrs. Morts Dry Dock & Engineering Co., Sydney, N.S.W., Australia	(E)	Jan. 1886
Furneaux, J. B., Victoria Engine Works, Gateshead-on-Tyne	(E)	Nov. 1885
Furness, John, 11, Oakhurst Terrace, Benton, near Newcastle-on-Tyne	(E)	Nov. 1885
Furse, Fred., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	April 1887

G.

Gannaway, H. G., 17, Caroline Street, Jarrow-on-Tyne	(S)	Nov. 1884
Garratt, H. A., c/o Mrs. Henderson, Long Benton, Newcastle-on-Tyne	(E)	Graduate, Nov. 1884 Member, Nov. 1886
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
Geddes, Christopher, Messrs. Leeds Forge Co., Leeds	(E)	Oct. 1888
Gibson, H., 6, Dundas Street, Monkwearmouth, Sunderland	(S)	Nov. 1884
Gibson, W. F.		Nov. 1884
Gibson, W. H., 37, Tatham Street, Sunderland	(E)	Nov. 1884
Gilroy, Thomas R., Messrs. Laird Bros., Shipbuilders, Birkenhead	(E)	Nov. 1886
Gladstone, Arthur, Messrs. Gray & Gladstone, West Hartlepool Rolling Mills, West Hartlepool	(I & S M)	Oct. 1888
Glencross, Thos., 11, Ryehill, Newcastle-on-Tyne	(E)	Feb. 1885
Glover, Terrot, 6, Azalea Terrace, Sunderland	(E)	Mar. 1886
Gordon, William James, 74, Old Dumbarton Road, Glasgow	(E)	Oct. 1887
Graham, Edwin, Messrs. Osborne, Graham, & Co., Hylton, Sunderland	(S)	Nov. 1884
Graham, Joseph, 32, Brookland Road, Sunderland		Nov. 1884
Graham, T. S., 11, Brougham Street, Hartlepool	(E)	Nov. 1888
Graham, Wm.	(S)	Nov. 1884
Gravell, John, Custom House Court, Quay, Newcastle-on-Tyne	(SUR)	Nov. 1884
Gray, A., c/o Messrs. R. Stephenson & Co., South Street, Newcastle-on-Tyne	(E)	Nov. 1888
Gray, George, 13, Harold Street, Sunderland	(E)	Feb. 1888
Gray, Harry, 6, Grosvenor Place, Jesmond, Newcastle-on-Tyne	(E)	Dec. 1885
Gray, Matthew, Messrs. W. Gray & Co., West Hartlepool	(S)	Oct. 1888

		ELECTED.
Gray, William, Messrs. W. Gray & Co., West Hartlepool	(S & E)	Oct. 1888
Green, W. G., Messrs. Palmer's Iron and Shipbuilding Co., Jarrow-on-Tyne	(E)	Nov. 1884
Green, William, c/o Messrs. Barrow Shipbuilding Co., Barrow-in-Furness	(E)	Oct. 1885
Greener, G. W., 110, George's Road, Newcastle-on-Tyne	(E)	Nov. 1884
Grey, James		Nov. 1884
Grieves, Robert, 38, Linskill Terrace, North Shields	(S)	Graduate, Nov. 1884 Member, Dec. 1886
Gulston, A., Clayton Park Lodge, Jesmond, Newcastle-on-Tyne	(E)	Dec. 1884

H.

Hake, G. A., 29, Rothbury Terrace, Heaton, Newcastle-on-Tyne	(SUR)	Oct. 1888
Hall-Brown, E., 15, Moor Terrace, Hartlepool	(E)	Nov. 1888
Hall, Edward, Astellos del Navion, Bilbao, Spain	(S)	Nov. 1885
Hall, J. Percy, Mayfield Villa, Jarrow-on-Tyne	(E)	Oct. 1885
Hall, John W., Abden Shipyard, Kinghorn, N.B.	(S)	Oct. 1887
Hamilton, John, 81, Charlotte Street, Carlisle	(E)	Nov. 1886
Hamilton, J. H., 61, Lovaine Place, Newcastle-on-Tyne	(E)	Nov. 1888
Hamilton, R. R., Messrs. Maudslay, Sons, & Field, Lambeth, London	(E)	Nov. 1884
Hansen, F. T., Rose Cottage, Willington Quay-on-Tyne	(E)	Nov. 1884
Harding, J. C., 9, Alderson Street, West Hartlepool	(E)	Nov. 1884
Hardwick, T. Norman, 140, Ryehill, Newcastle-on-Tyne	(E)	Dec. 1888
Hardy, Arthur Francis, 20, Hartington Street, Barrow-in-Furness	(S)	Oct. 1887
Harkness, Richard, 9, Meldon Terrace, Heaton, Newcastle-on-Tyne	(S)	Nov. 1884
Harlow, F., 1, Clarence Crescent, Newcastle-on-Tyne		Nov. 1884
Harman, Bruce, 12, Annfield Terrace West, Partick, Glasgow	(E)	Oct. 1886
Harper, J. H., 1, Beaumont Street, North Shields	(E)	Jan. 1885
Harrold, Alexander, 19, Lawton Street, Newcastle-on-Tyne	(E)	Nov. 1884
Harrold, F., 14, Rowell Street, Hartlepool	(E)	Nov. 1888
Hartness, J., East Boldon, near Sunderland	(E)	Nov. 1884
Harvey, Alfred, Messrs. Darlington Forge Co., Darlington	(E)	Dec. 1888
Harvey, John W. L., Richmond Villa, Chertsey Road, Bristol	(E)	Feb. 1889
Haswell, Robert, 137, Albert Road, Middlesborough	(S)	Dec. 1888
Havelock, Michael, Commercial Chambers, Side, Newcastle-on-Tyne	(E)	Dec. 1887
Haver, Arthur H., 15, Howarth Street South, Hylton Road, Sunderland	(S)	Nov. 1884
Head, Archibald P., Coatham, Redcar, Yorkshire	(E)	Graduate, Nov. 1884 Member, Oct. 1887
Headlam, Robert, 5, Edward Street, Stockton-on-Tees	(E)	Nov. 1886
Heck, John H., Lloyd's Registry, Newport, Monmouthshire	(S)	Nov. 1885
Helyer, A. J., Germania Werft, Gaarden bei Kiel, Germany	(S)	Oct. 1887
Henderson, George, 54, Westmorland Road, Newcastle-on-Tyne	(E)	Nov 1884
Henderson, Robert, 4, Church Street, Hebburn-on-Tyne	(S)	Nov. 1884
Hepburn, Alex., Grosvenor Place, Jesmond, Newcastle-on-Tyne	(E)	Dec. 1885
Hepple, William, Slipway, North Shields	(E & S)	Oct. 1885
Hildrey, A. J., 11, Chester Street, Sunderland	(S)	Nov. 1884
Hill, Maxwell, Messrs. Palmer's Iron and Shipbuilding Co., Jarrow-on-Tyne	(S)	Nov. 1884

		ELECTED.
Hill, Maxwell, c/o Messrs. J. & G. Thompson, Clydebank, Glasgow	(S)	Nov. 1887
Hindhaugh, C. W., 59, Bedford Street, North Shields	(S)	Nov. 1884
Hindson, William, Bensham Lodge, Gateshead-on-Tyne	(E)	Nov. 1884
Hirst, Richard, 4, Cleveland Road, North Shields	(E)	Nov. 1885
Hök, Wilhelm, Deptford Shipyard, Sunderland	(S)	Oct. 1886
Holmes, John H., Portland Road, Newcastle-on-Tyne	(E)	Jan. 1888
Homji, A. C. N., 13, Trinity Street, Dhobie, Talao, India	(E)	Nov. 1884
Hooper, Ernest, 23, Whitehall Terrace, Sunderland	(E)	Nov. 1885
Hunter, George B., Messrs. C. S. Swan, Hunter, & Co., Wallsend-on-Tyne	(S)	Nov. 1884
Hunter, J. W., 9, Alice Street, Sunderland	(E)	May 1885
Hunter, Summers, Rosehill Terrace, Howdon-on-Tyne	(E)	Nov. 1885
Hutchinson, C. W., 52, Westmorland Road, Newcastle-on-Tyne	(E)	Nov. 1884
Hymers, Richard, 197, Norfolk Road, Byker, Newcastle-on-Tyne	(E)	Mar. 1887

I.

Inglis, John, Messrs. Ramage & Ferguson, Leith	(S)	April 1887
Inglis, John, Jun., Pointhouse Shipyard, Partick, Glasgow	(E)	Oct. 1886
Irwin, J. H., Sunderland Engine Works, South Docks, Sunderland	(E)	Nov. 1884
Irwin, Thomas F., 2, Tower Chambers, Old Churchyard, Liverpool	(C E & N A)	Mar. 1888

J.

Jackson, Vincent, 19, Regent Street, Hartlepool	(S)	April 1888
Jackson, A., 22, Ward Street, West Hartlepool	(E)	Nov. 1888
James, M. C., c/o Messrs. Robert Stephenson & Co., Ld., Engineers and Shipbuilders, Hebburn-on-Tyne	(S)	Nov. 1884
Jamieson, John, 25, Azalea Terrace South, Sunderland	(E)	Nov. 1885
Jobling, J. C., 1, Brandling Place West, Newcastle-on-Tyne	(E)	Nov. 1884
Jobling, W. J., Queen Street, Newcastle-on-Tyne	(E & S O)	Nov. 1884
Johnson, Johan, 14, St. Georges' Terrace, Sunderland	(S)	May 1885
Johnson, T. Allan, 10, Tankerman Terrace, Birmingham Road, Whitehaven	(S)	Nov. 1884
Johnstone, William, 7, Hamilton Terrace West, Partick, Glasgow, N.B.	(SUR)	Nov. 1884
Joicey, Jacob G., Forth Banks West Factory, Newcastle-on-Tyne	(E)	Jan. 1889
Jones, George, Messrs. W. Gray & Co., West Hartlepool	(S)	Oct. 1888
Jones, Morlais G., 1, Fern Bank, Chester Road, Old Trafford, Manchester	(E)	Nov. 1887
Jorgenson, F., Inspector to Austrian Lloyd's, Constantinople	(SUR)	Nov. 1888

K.

Kean, James, West Hartlepool Iron Works, West Hartlepool	(E)	Nov. 1884
Keene, H. R., 120, Park Road, Newcastle-on-Tyne	(E)	Graduate, May 1885 Member, April 1887
Kellner, T., K.K. Schiffbau Ingenieur Pola, Austria	(N A)	Oct. 1887
Key, Alexander	(SUR)	Nov. 1884
Kilvington, W., Northumberland Engine Works, Wallsend-on-Tyne	(E)	Nov. 1884
Kirkaldy, John, 40, West India Dock Road, London	(E)	Nov. 1885

L.

		ELECTED.
Laidley, R. W., Messrs. Mort & Co., 155, Fenchurch St., London, E.C.	(E)	April 1887
Laing, Arthur, Deptford Shipyard, Sunderland	(S)	Nov. 1884
Laing, Jas., Jun., Deptford Yard, Sunderland	(S)	Nov. 1884
Laing, John, Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Nov. 1884
Larkin, James, East Jarrow-on-Tyne	(E)	Nov. 1884
Leckie, Andrew, Cambridge Terrace, West Hartlepool	(SUR)	Oct. 1888
Leddicoat, Frederick, 5, Cromwell Terrace, Gateshead-on-Tyne	(E)	Oct. 1885
Lewis, Henry W., Llwynynhess, Abercanaid, near Merthyr, Glamorganshire, Wales	(E)	Nov. 1885
Lewis, R. A., Newburn Steel Works, Newburn-on-Tyne	(E)	Nov. 1884
Liddell, A. R., 110, Park Road, Newcastle-on-Tyne	(S)	Nov. 1884
Liddell, J., Messrs. Denny & Co., Engine Works, Dumbarton	(E)	Nov. 1884
Lindfors, H., P.O. Box, 758, Norwark Comm., U.S. America	(S)	Oct. 1886
Lindgors, Hugo, 16, Alexandersgatan, Helsingfors, Findland	(S)	May 1889
Littleboy, Chas. Wm., 12, Shaftesbury Street, Stockton-on-Tees	(S)	Oct. 1887
Livingston, Thos., Dunedin House, Jarrow-on-Tyne	(S)	Nov. 1884
Livingstone, John, 6, Simonside Terrace, Heaton, Newcastle-on-Tyne	(E)	Nov. 1884
Lohmeyer, H., 43, Crown Street, Newcastle-on-Tyne	(E)	Nov. 1884
Long, A. E., 124, Albert Road, Jarrow-on-Tyne	(S)	Nov. 1884
Lynn, J., St. Luke's Engine Works, Sunderland	(E)	Nov. 1884

M.

Macarthy, Harry, Ashfield House, Newcastle-on-Tyne	(E)	Nov. 1888
MacCoy, John, 55, Larkspur Terrace, Newcastle-on-Tyne	(E)	Feb. 1886
Mace, W., 253, Albert Road, Jarrow-on-Tyne	(E)	Jan. 1886
MacGregor, John, 51, Harrison Street, Barrow-in-Furness	(E)	Mar. 1888
MacHaffie, John, 38, South Hawk Street, Albany, New York, U.S. America	(E)	Dec. 1885
Macoll, D. C., 14, Connaught Terrace, Jarrow-on-Tyne	(S)	Nov. 1884
Manuel, G. W., Fern Bank, Catford Hill, London	(E)	Dec. 1885
Marlborough, Richard, 11, Brookland Road, Sunderland	(S)	Nov. 1884
Marr, James, 6, Ash Place, Sunderland	(S)	Nov. 1884
Marshall, F. C., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Nov. 1884
Marshall, Frank T., 38, Percy Gardens, Tynemouth	(E)	Graduate, Jan. 1885 Member, Oct. 1888
Marshall, R. J., 32, Mariners' Cottages, South Shields	(E)	Mar. 1887
Martens, D., 52, Kent Street, Jarrow-on-Tyne	(E)	Mar. 1887
Mastaglio, W. D., 15, Rosslyn Terrace, Sunderland	(E)	Nov. 1885
Mather, Charles, 6, Kenilworth Road, Newcastle-on-Tyne	(SUR)	Oct. 1888
Matthews, A., The Baths, Blyth	(E)	Nov. 1884
Matthews, Jas., Messrs. R. & W. Hawthorn, Leslie, & Co., Forth Banks, Newcastle-on-Tyne	(E)	Oct. 1886
Maughan, Wm., 15, Addison Road, Heaton, Newcastle-on-Tyne	(E)	Mar. 1887
McGlashan, Arch., 26, Milton Street, West Hartlepool	(S)	Nov. 1885

		ELECTED.
McIlvenna, J. G., Messrs. The Tyne Pontoon and Dry Docks Co., Wallsend-on-Tyne	(S)	Nov. 1884
McIntyre, John, 3, Abbotsford Terrace, Newcastle-on-Tyne ...	(S O)	Jan. 1885
McKay, Jno., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Nov. 1884
Menzies, Wm., The Side, Newcastle-on-Tyne	(E)	Nov. 1884
Messenger, Thomas, 2, Clarence Lawn, Dover, Kent	(E)	Mar. 1887
Metcalf, J. C., 4, Azalea Terrace North, Sunderland ...	(SUR)	Nov. 1884
Metcalfe, C. S., 5, Tunstall Terrace West, Sunderland	(E)	Nov. 1884
Micheli, Pietro, Jun., 5, Via Assarotti, Genoa	(E & N A)	Oct. 1888
Milburn, Christopher J., 87, Morley Street, Heaton, Newcastle-on-Tyne	(E)	Feb. 1888
Millar, Thos., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Low Walker-on-Tyne	(S)	Nov. 1884
Miller, Thomas B., 6, Vernon Terrace, Gateshead-on-Tyne	(E)	Graduate, Nov. 1886 Member, Oct. 1888
Mills, John, c/o Messrs. Greenock Steam Shipping Co., Greenock	(E)	Feb. 1888
Milne, W. J., 110, Park Road, Newcastle-on-Tyne	(S)	Nov. 1884
Milton, J. T., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Nov. 1886
Mitchell, Chas., Jesmond Towers, Newcastle-on-Tyne	(S)	Nov. 1884
Moffat, D., 36, Falconar Street, Newcastle-on-Tyne	(E)	Nov. 1884
Moffitt, George, 32, Mitchell Street, West Hartlepool	(E)	Oct. 1888
Moffitt, Robert, 13, Grace Terrace, Sunderland	(E)	Dec. 1885
Moody, Thomas V., Riding Mill, Northumberland	(E)	Dec. 1887
Morgan, W. H., 141, Denmark Street, Heaton, Newcastle-on-Tyne	(E)	Nov. 1884
Morison, D. B., 8, Albion Terrace, Hartlepool	(E)	Feb. 1885
Mörk, Peter, 3, Hawthorn Street, Newcastle-on-Tyne	(E)	Nov. 1884
Morrison, Robt., 5, Challoner Terrace, South Shields	(E)	Nov. 1886
Mountain, William Chas., Messrs. E. Scott & Co., Close, Newcastle-on-Tyne	(E)	Feb. 1889
Mowat, John, 3, Cooper Street, Monkwearmouth, Sunderland ...	(S)	Nov. 1884
Mudd, Thomas, Central Marine Engine Works, West Hartlepool	(E)	Mar. 1886
Muir, J. M., Messrs. Wigham Richardson & Co., Low Walker-on-Tyne		Nov. 1884
Muir, John, 10, Rium Terrace, Hart Road, West Hartlepool ...	(E)	Oct. 1888
Muir, Robert, 17, Westmorland Road, Newcastle-on-Tyne ...	(SUR)	Oct. 1886
Myles, David, 231, Elliot Street, Glasgow	(E)	Nov. 1884

N.

Nance, A. J., c/o Mr. Nance, 14, Stacey Road, Routh, Cardiff ...	(E)	April 1887
Napier, R. J., Lloyd's Register of Shipping, Newcastle-on-Tyne	(SUR)	Nov. 1888
Napier, W. E., c/o Messrs. Humphrey, Tennant, & Co., Deptford, London	(E)	Nov. 1884
Newitt, Leonard, c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne	(E)	Dec. 1887
Newton, Richard, Park Square, West Hartlepool	(E)	April 1889
Newton, W. A., 90, Broughton Road, South Shields	(E)	Graduate, May 1885 Member, Oct. 1886
Nichol, B. G., 49, Leazes Terrace, Newcastle-on-Tyne	(E)	Nov. 1884

		ELECTED.
Nichol, Thos., 50, Ripon Street, Monkwearmouth, Sunderland	(SUR)	Nov. 1884
Nicol, John M., 10, Linskill Place, North Shields	(E)	Nov. 1884
Nicolson, G. C., c/o Mr. Shearer, Victoria Jubilee School, Byker, Newcastle-on-Tyne	(E)	Graduate, Oct. 1885 Member, Oct. 1888
Nicolson, J. T., Engineering Department, University, Cambridge	(E)	Nov. 1884
Noble, Harry, Northern Machine Tool Works, Forth Road, Newcastle-on-Tyne	(E)	Nov. 1888
Norman, W. S., Messrs. Tyne Pontoon and Dry Docks Co., Wallsend-on-Tyne	(E)	Nov. 1884
Noton, F. R., 32, Azalea Terrace, Sunderland	(S)	Nov. 1884

O.

O'Neil, J. J., 2, Erith Terrace, Pallion, Sunderland	(E)	Nov. 1884
Orde, E. L., Orde House, Morpeth, Northumberland	(E)	Oct. 1887
Oxley, G., Station Road, Howdon-on-Tyne		Nov. 1884

P.

Pacey, John W., 64, Hotspur Street, Heaton, Newcastle-on-Tyne...	(E)	Feb. 1888
Panton, W. H., Stockton Forge, Stockton-on-Tees	(E)	Nov. 1887
Parkin, Rd., Chester-le-Street	(E)	Nov. 1884
Parsons, Hon. Charles A., Elvaston Hall, Ryton-on-Tyne	(E)	Dec. 1887
Parsons, P. B., St. George's Wharf, Deptford, London, S.E. ...	(E)	Nov. 1888
Patterson, Jas., The Green, Wallsend-on-Tyne	(E)	Nov. 1884
Pattison, Jos., Messrs. Wallsend Pontoon Co., Cardiff	(E)	Nov. 1884
Paulson, John, 26, Charles Street, Heaton, Newcastle-on-Tyne ...	(S)	Feb. 1886
Pearson, James John, 20, Gladstone Street, Newcastle-on-Tyne ...	(E)	Feb. 1886
Pease, J. F., Messrs. Darlington Forge Co., Darlington	(E)	Dec. 1888
Penny, A. W., 69, Percy Road, Whitley	(S)	Nov. 1884
Penney, R. H., 15, Azalea Terrace South, Sunderland	(S)	Nov. 1884
Pepper, W., The Groves, Yarm Road, Stockton-on-Tees	(E)	Nov. 1888
Perrett, J. Richard, 14, Eskdale Terrace, Jesmond, Newcastle-on-Tyne	(N A)	Oct. 1887
Petersen, John L., Bellerby Terrace, West Hartlepool	(E)	Oct. 1888
Petree, James, Messrs. Laird Bros., Birkenhead	(S)	Oct. 1885
Phillips, Walter, 3, West Grove Terrace, Greenwich, London ...	(E)	Oct. 1886
Phillipson, Roland, Tynemouth	(E)	Dec. 1884
Phorson, P., 86, Roker Avenue, Sunderland	(S)	Nov. 1884
Piaud, Leon, Bureau Veritas, 8, Place de la Bourse, Paris	(N A)	Nov. 1888
Pike, James J., 6, Corta Street, Peckham, London, S.E.	(E)	Dec. 1888
Pilcher, F. J., 3, City Buildings, Old Hall Street, Liverpool ...	(S)	April 1887
Pilling, J., 11, Rosslyn Terrace, Chester Road, Sunderland ...		Nov. 1884
Plotnicki, E. C., 102, West Percy Street, North Shields	(E)	Nov. 1886
Potts, John George	(E)	Nov. 1884
Potts, Robert, 11, Mount Pleasant, Deptford, Sunderland	(S)	Oct. 1888
Potts, T. T.	(E)	Jan. 1886
Prest, Stanley Faber, Chatsworth Terrace, Barrow-in-Furness ...	(E)	Mar. 1888
Price, F. D., 6, Osborne Villas, Jesmond, Newcastle-on-Tyne	(E & S)	Oct. 1888
Price, John, 6, Osborne Villas, Jesmond, Newcastle-on-Tyne ...	(S)	Nov. 1884

		ELECTED.
Prince, Alfred, Kent Villa, Jarrow-on-Tyne	(E)	Nov. 1884
Proud, Anthony, Tyne Docks, South Shields	(E)	Dec. 1888
Pryor, Benjamin, Experimental Tank, Royal Arsenal, Spezzia, Italy		Nov. 1885
Purdy, A. J., Drawing Office, Navy Yard, Washington, D.C., U.S. of America		Nov. 1884
Purves, David, Fern Dene, Green Lane, N. Dulwich, London, S.E.	(SUR)	Dec. 1885
Putnam, T., Darlington Forge, Darlington	(F M)	Nov. 1884
Putnam, William, Darlington Forge, Darlington	(F M)	Nov. 1884
R.		
Rae, John, 4, Grey Street, Glasgow, N.B.	(E)	April 1886
Ralston, G. O., 19, Fenham Road, Newcastle-on-Tyne	(E)	Oct. 1887
Ramage, J. T., The Hawthorns, Leith, N.B.	(E)	April 1887
Ramsay, C. W., Hornsborg, Lgungby, Sweden		Nov. 1884
Ramsay, W. G., 10, Stanhope Road, Tyne Dock, South Shields	(E)	Mar. 1887
Rankine, Jno., 26, Park Crescent, North Shields	(E)	Nov. 1884
Readhead, Jas., Beach View, South Shields	(S)	Nov. 1884
Readhead, John, Jun., 18, Thomas Street, South Shields	(E)	Mar. 1886
Readhead, R., Beach View, South Shields	(E)	Nov. 1884
Readhead, W. B., Beach View, South Shields	(S)	Nov. 1886
Reavell, W., 40, Guildford Road, Clapham, London, S.W.	(E)	Graduate, April 1885 Member, Oct. 1887
Reed, J. W., 96, Queen's Road, Bootle, Liverpool	(E)	Nov. 1884
Reed, T. A., Merchants' Exchange, Cardiff	(C E)	Mar. 1887
Rendel, H. W., 44, Lancaster Gate, London, W.	(S)	Nov. 1888
Rendel, L. J., 61, Westmorland Road, Newcastle-on-Tyne	(E)	Mar. 1887
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
Reynolds, Charles H., Sir W. G. Armstrong, Mitchell, & Co., Low Walker-on-Tyne	(S)	Mar. 1889
Reynolds, Edward, Messrs. Vickers, Sons, & Co., Sheffield	(E)	Jan. 1888
Reynolds, W. G., 7, St. Thomas' Square, Newcastle-on-Tyne	(E)	Oct. 1886
Richardson, J. Wigham, Neptune Works, Low Walker-on-Tyne	(S)	Nov. 1884
Richardson, Thos., M.P., Hartlepool Engine Works, West Hartlepool	(E)	Oct. 1888
Richardson, Wm., Hartlepool Engine Works, West Hartlepool	(E)	Oct. 1888
Richardson, T., Jun., Hartlepool Engine Works, Hartlepool	(E)	April 1888
Rickaby, A. A., Bloomfield Engine Works, Sunderland	(E)	
Ridley, J. C., Swalwell Steel Works, Newcastle-on-Tyne	(E)	Nov. 1884
Ridley, J. H., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Nov. 1884
Rimmington, R. F., 6, Cliff Terrace, Hartlepool	(E)	Nov. 1888
Ritson, M., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C.	(E)	Nov. 1884
Robinson, B. A., 5, The Knoll, Sunderland	(E)	Nov. 1884
Robinson, Frederick F., 26, Wilkinson Street, Albert Square, Lambeth, London, S.W.	(E)	Dec. 1888
Robinson, William, 6, Choppington Street, Newcastle-on-Tyne	(E)	Graduate, May 1885 Member, April 1888

		ELECTED.
Robinson, William, 9, Waterville Road, North Shields	(E)	April 1889
Robson, Arthur, Messrs. J. Blumer & Co., Sunderland	(S)	Dec. 1886
Robson, John H., Grainger Hotel, Newcastle-on-Tyne	(E)	Nov. 1885
Robson, J. M., c/o W. Whyte, 8, Lombard Street, Newcastle-on-Tyne	(E)	Nov. 1884
Robson, M., 19, Zion Terrace, Newcastle Road, Sunderland	(S)	Nov. 1884
Rodgerson, William John, 7, Wycliffe Terrace, Gateshead-on-Tyne	(E)	Dec. 1888
Roger, Robert, Stockton-on-Tees	(E)	Nov. 1888
Rogers, Herbert M., Lloyd's Registry, Newcastle-on-Tyne	(SUR)	April 1889
Ropner, Robert, Jun., Preston Hall, Stockton-on-Tees	(S)	Feb. 1886
Rowan, Jas., 231, Elliott Street, Glasgow	(E)	Nov. 1886
Rowe, John A., 11, Spring Terrace, North Shields	(SUR)	Oct. 1888
Rowell, G. W., 22, Durham Street, Newcastle-on-Tyne	(E)	Feb. 1885
Rowell, H.		Nov. 1884
Rusden, L., 11, Mistletoe Road, Jesmond, Newcastle-on-Tyne	(E)	Nov. 1884
Rutherford, G., c/o Messrs. Wallsend Slipway Co., Engine Works, Cardiff	(S)	Oct. 1886
Rutherford, T. A., Messrs. J. & G. Thompson, Clydebank, Glasgow	(S)	Nov. 1884
Ryder, C. L., Lloyd's Register of Shipping, Cardiff	(E)	Oct. 1886
S.		
Salmon, P. R., St. Bede's Park, Sunderland	(SUR)	Nov. 1884
Sanderson, J., 31, Park Road, Jarrow-on-Tyne	(S)	Nov. 1884
Sandison, M., Elswick Shipyard, Newcastle-on-Tyne	(E)	Dec. 1884
Sawyers, John, Messrs. Thos. Wilson, Sons, & Co., Hull	(E)	Oct. 1886
Schaeffer, A. G., 4, Benton Terrace, Newcastle-on-Tyne	(E)	Nov. 1884
Scorer, G. S., Messrs. T. & W. Smith, North Shields	(S)	Jan. 1885
Scotson, Alf., Messrs. Blyth Shipbuilding Co., Blyth	(S)	Feb. 1887
Scotson, Wm., 78, Stafford Street, Wednesbury	(E)	Nov. 1884
Scott, Ernest, Close Engine Works, Newcastle-on-Tyne	(E)	Nov. 1884
Scott, H., 47, Mainsforth Terrace, Sunderland	(E)	Graduate, May 1886 Member, April 1888
Scott, Joseph R., 9, Queen Street, Newcastle-on-Tyne	(E)	Oct. 1887
Scott, Wm., 198, Portland Road, Newcastle-on-Tyne		Nov. 1884
Seabury, Edward, 40, West India Road, Limehouse, London, E.	(E)	Mar. 1886
Sells, C., c/o Messrs. Gio Ansaldo, Sampierdarena, Genoa, Italy	(E)	Oct. 1887
Shand, H., 41, Grosvenor Place, West Jesmond, Newcastle-on-Tyne	(E)	Nov. 1884
Sharp, A. E., Albert Terrace, Jarrow-on-Tyne	(E)	Nov. 1884
Sharpe, H. R., 11, Zingari Terrace, Upton Park, London	(E)	Nov. 1888
Shaw, Jas., 1, St. Edmund's Road, Gateshead-on-Tyne	(E)	Jan. 1885
Sheppard, W. O.	(E)	Mar. 1887
Shevill, W. H., 5, Avenue Terrace, Sunderland		Nov. 1884
Shilston, Thomas, 14, Wentworth Place, Newcastle-on-Tyne	(SUR)	Nov. 1885
Short, J. Y., 49, West Sunniside, Sunderland	(S)	Nov. 1884
Short, Jos., 49, West Sunniside, Sunderland	(S)	Nov. 1884
Shotten, John W., 13, Meldon Terrace, Heaton, Newcastle-on-Tyne	(SUR)	Nov. 1886
Sinclair, R., c/o J. R. C. Sinclair, Esq., 2, West Quay, Greenock	(E)	Nov. 1884
Sinton, John K., 7, Grasmere Terrace, Gateshead-on-Tyne	(E)	Nov. 1885
Sisson, Wm., Gloucester	(E & N A)	Oct. 1888

		ELECTED.
Sisterson, G. R., Locomotive Department, London and South Western Railway, Nine Elms, London, S.W.	(E)	Nov. 1884
Sivewright, G. W., 5, Radcliffe Terrace, Hartlepool	(S)	Nov. 1886
Sjögren, H., Kockum's Mekaniska, Verkstad, Malmo, Sweden	(S)	Nov. 1884
Smith, C. Hubert, Board of Trade Offices, North Shields	(SUR)	May 1889
Smith, C. E., 89, Scarborough Street, West Hartlepool	(E)	Nov. 1888
Smith, Charles Mayfield, 29, Mitchell Street, West Hartlepool	(S)	April 1888
Smith, Eustace, 5, Queen Street, Newcastle-on-Tyne	(S)	Nov. 1884
Smith, J.		Nov. 1884
Smith, R. J., 2, West Lawn, Sunderland	(E)	Nov. 1884
Smith, Reginald Thomas, 38, Belitha Villas, Battersea, London	(E)	April 1888
Smith, Thomas, Steam Crane Works, Old Foundry, Rodley, near Leeds	(E)	Oct. 1888
Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle-on-Tyne	(E)	April 1885
Smith, Wm., 51, Dock Street East, Sunderland	(E)	Nov. 1884
Soliani, Nabor, Connitato Pei Designa delle Navi Ministero dilla Marina, Roma, Italy	(S)	Jan. 1885
Soulsby, J. C., 4, Bute Crescent, Cardiff	(SUR)	Nov. 1886
Sowter, Isaac G., 867, East Congress Street, Detroit, Michigan, United States of America		Jan. 1889
Spear, John, Messrs. T. Wilson & Sons, Hull	(E)	Oct. 1887
Spearman, Richard, 118, York Street, Jarrow-on-Tyne	(E)	Feb. 1889
Spence, James C., Messrs. Tyne Boiler Works Co., Low Walker-on-Tyne	(E)	Dec. 1888
Spencer, J. W., Newburn Steel Works, Newburn-on-Tyne	(E)	Feb. 1885
Spencer, R. E. E., Palazzo Canevara, Spezzia, Italy	(E)	Nov. 1884
Spiers, James		Nov. 1884
Stafford, William, Dunston-on-Tyne	(E)	Nov. 1885
Stephenson, C., 5, West View, Wallsend-on-Tyne	(S)	Nov. 1884
Stevenson, R.	(E)	Graduate, Mar. 1886 Member, Oct. 1886
Stevenson, Wm., c/o Messrs. Victor Coates & Co., Princess Docks, Belfast	(E)	Nov. 1884
Stewart, H., 18, Brookland Road, Hylton Road, Sunderland	(E)	Nov. 1888
Stirling, Andrew, Jun., 3, Greenvale Terrace, Dumbarton	(E)	Feb. 1888
Stirzaker, J. C., 86, Brighton Grove, Newcastle-on-Tyne	(E)	Nov. 1884
Stoddart, J. E., Lloyd's Registry of Shipping, Dock Office, West Hartlepool	(SUR)	Oct. 1888
Stokoe, Thomas, 4, Lower Archer Street, West Hartlepool	(S)	Dec. 1885
Stone, Wm., 13, Rosslyn Terrace, Sunderland		Nov. 1884
Stubbings, James, Cornhill, Sunderland	(E)	Nov. 1884
Summers, James, 114, Grange Road West, Middlesbrough	(E)	Mar. 1889
Surtees, R., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Nov 1884
Sutton, James, 84, Westmorland Road, Newcastle-on-Tyne	(S)	Jan. 1885
Sutton, Jos., 84, Westmorland Road, Newcastle-on-Tyne	(E)	Graduate, Mar. 1886 Member, Oct. 1886

		ELECTED.
Swan, A. S., Grove House, Gosforth, Newcastle-on-Tyne	(S)	Nov. 1888
Swan, H. F., North Jesmond, Newcastle-on-Tyne	(S)	Nov. 1884
Swan, Thomas, 152, Ellison Street, Jarrow-on-Tyne		Nov. 1884
Swinburne, T. M., Bewick Road, Gateshead-on-Tyne	(E)	Jan. 1885
Swinburne, M. W., 117, Park Road, Newcastle-on-Tyne	(E)	Nov. 1884
Swinney, W., 10, Wentworth Terrace, Westoe Lane, South Shields	(E)	Dec. 1888
Sydserff, Thomas, B., Jun., c/o Messrs. W. B. Thomson & Co., Lilybank Foundry, Dundee	(E)	Oct. 1888

T.

Tate, Chas. H., 7, Side, Newcastle-on-Tyne	(N A)	Nov. 1884
Tatham, Stanley, Messrs. Hawks, Crawshay, & Sons, Gateshead-on-Tyne	(E)	Feb. 1887
Taylor, Alexander, Mercantile Chambers, Quayside, Newcastle-on-Tyne	(E)	Nov. 1884
Taylor, C. W., Beach View, South Shields	(E)	April 1885
Taylor, J. E., Lloyd's Register of Shipping, Bute Crescent, Cardiff	(SUR)	Nov. 1884
Taylor, Tom Henry, Messrs. The Wallsend Slipway Co., Wallsend-on-Tyne	(E)	Oct. 1885
Thompson, C. E., Messrs. J. L. Thompson & Sons, Sunderland	(S)	Nov. 1884
Thompson, Charles, 9, Dean Street, Newcastle-on-Tyne	(E)	Feb. 1887
Thompson, Jas., 11, Elmwood Street, Sunderland	(E)	Dec. 1886
Thompson, John, Post Office Chambers, Newcastle-on-Tyne	(E)	Nov. 1884
Thompson, J. L., Jun., North Sands Shipyard, Sunderland	(S)	Nov. 1884
Thompson, Robert, North Sands Shipyard, Sunderland	(S)	Nov. 1884
Thompson, R. C., Bridge Dockyard, Sunderland	(S)	Nov. 1884
Thorn, W. H., 5, Waterville Terrace, North Shields	(E)	Nov. 1884
Tinwell, George, General Gordon Terrace, Sunderland	(E)	Jan. 1889
Todd, Surtees, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne	(S)	Nov. 1884
Todd, Thomas, 20, Billiter Street, London, E.C.	(E)	Nov. 1885
Tone, John M. F., 50, Clayton Park Square, Newcastle-on-Tyne	(E)	Graduate, April 1885 Member, Oct. 1887
Toomer, C. R.	(E)	Graduate, May 1885 Member, Feb. 1887
Towers, Edward, Jun., 4, Latimer Street, Tynemouth	(E)	Graduate Nov. 1886 Member, Oct. 1888
Trewent, F. J., 9, Northumberland Terrace, Tynemouth	(S)	Dec. 1884
Tritton, S. B., Assistant Locomotive Superintendent, Eastern Bengal State Railway, Kanchrapara, Bengal, India	(E)	Nov. 1884
Tulip, George, 48, Blenheim Street, Newcastle-on-Tyne	(E)	Dec. 1888
Turnbull, T. W. H.	(E)	Nov. 1884
Turner, Henry John, 11, Tindal Street, Westgate Road, Newcastle-on-Tyne	(E)	Feb. 1888
Turner, S. J., 86, Addison Road, Heaton, Newcastle-on-Tyne	(E)	Mar. 1887
Tweddell, R. H., 14, Delahay Street, Westminster, London, S.W.	(E)	Jan. 1885
Tweedy, J., Neptune Works, Low Walker-on-Tyne	(E)	Nov. 1884
Tyzack, George, Dean Street, South Shields	(E)	April 1888

U.

		ELECTED.
Ullstrom, Otto, Messrs. Raylton Dixon & Co., Cleveland Dockyard, Middlesbro', or 110, Grange Road East, Middlesbro'	(S)	Nov. 1884
Ulm, John, Marine Casino, Pola, Austria	(E)	Nov. 1885

V.

Vianson, N. E., *vià* Galeazzo Alessi 6 into 1, Genoa, Italy	(E)	Dec. 1885
Vick, R. W., Messrs. E. Withy & Co., West Hartlepool	(S)	Nov. 1888

W.

Wailes, E. F., 35, Close, or 13, Tankerville Terrace, Newcastle-on-Tyne	(SUR)	Nov. 1884
Wailes, T. W., Mount Stuart Dry Docks, Cardiff	(E & S)	Oct. 1887
Walker, Archibald, 147, Constitution Street, Leith, N.B.	(E)	April 1887
Wallau, J., Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne...	(E)	Nov. 1884
Walliker, J. F., 6, Lovaine Terrace, North Shields	(E)	Nov. 1885
Walton, F. W., 24, Lord Street, Barrow-in-Furness...	(S)	Nov. 1885
Walton, J. G., 26, Fenchurch Street, London, E.C.	(E)	Nov. 1884
Warburton, J., 16, Elmwood Street, Sunderland		Nov. 1884
Wardale, Henry, 52, Bewick Road, Gateshead-on-Tyne	(E)	Feb. 1888
Warren, Wm., Southwick Engine Works, Sunderland	(E)	Nov. 1884
Warren, G. R., Lloyd's Register of Shipping, Constantinople ...	(SUR)	Nov. 1888
Watson, Ralph J., Willington House, Willington Quay-on-Tyne	(E)	Graduate, Jan. 1886 Member, Oct. 1888
Watt, Adam, 11, Salem Hill, Sunderland		Nov. 1884
Watt, Robert B., Messrs. Raylton Dixon & Co., Middlesborough ...	(S)	April 1888
Watts, Philip, Elswick Shipyard, Newcastle-on-Tyne	(S)	Nov. 1885
Waugh, G. W., 30, Greame Street, Alexandra Park, Manchester ...	(E)	May 1885
Weatherall, J., 48, Hotspur Street, Heaton, Newcastle-on-Tyne	(E)	Graduate, Oct. 1885 Member, Oct. 1887
Weighton, R. L., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Nov. 1884
Weir, John, Engine Department, Messrs. A. Stephens & Sons, Linthouse, Glasgow	(E)	Nov. 1884
West, Henry H., 14, Castle Street, Liverpool	(E & N A)	Oct. 1886
Westgarth, Tom, Messrs. Westgarth, English, & Co., Middlesborough	(E)	Oct. 1886
Westmacott, P. G. B., Elswick Engine Works, Newcastle-on-Tyne	(E)	Nov. 1884
White, C., 13, Mosley Street, Newcastle-on-Tyne	(E)	Nov. 1884
White, R. S., Fairfield Works, Govan, Glasgow	(S)	Nov. 1884
Whitehead, Francis, c/o Messrs. Blyth Dry Dock Co., Blyth ...	(E)	May 1889
Whyte, Wm., B, Lombard Street, Newcastle-on-Tyne	(E)	Nov. 1884
Widdas, T. D., 99, Belgrave Road, Aigburth Road, Liverpool	(SUR)	April 1885
Wiles, John W., 10, Chillingham Road, Heaton, Newcastle-on-Tyne	(S)	Nov. 1886
Wilkie, J., 9, Croft Avenue, Sunderland	(E)	Nov. 1884
Willcox, F. W., 45, Sunniside West, Sunderland	(E)	Nov. 1884
Williams, J., 3, Azalea Terrace, Sunderland	(SUR)	Nov. 1884
Wilson, James, 100, Brougham Terrace, West Hartlepool	(E)	Feb. 1886

		ELECTED.
Wilson, J. T., 34, Kent Street, Jarrow-on-Tyne	(E)	Graduate, April 1885 Member, Feb. 1886
Wilson, Robert, 19, Victoria Street, Newcastle-on-Tyne	(S)	Oct. 1887
Wilson, R. D., 17, Hawthorn Street, Newcastle-on-Tyne	(E)	Nov. 1886
Wilson, T., Messrs. General Steam Navigation Co., Deptford, London, S.E.	(E)	Nov. 1884
Wilson, William	(S)	Oct. 1885
Winstanley, P. D., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick, Newcastle-on-Tyne	(E)	Nov. 1884
Withy, H., Middleton Shipyard, West Hartlepool	(S)	Nov. 1884
Worsdell, Wilson, North-Eastern Locomotive Works, Gateshead-on-Tyne	(E)	Dec. 1888
Wotherspoon R., Board of Trade Offices, West Hartlepool	(E)	April 1889
Wright, R., 25, Westmorland Road, Newcastle-on-Tyne		Nov. 1884

Y.

Young, J. D., 18, Derby Street, Sunderland	(E)	Oct. 1888
Younger, R., Elmire House, Heaton, Newcastle-on-Tyne	(E)	Nov. 1884

Z.

Zeltz, A., Actien Gesellschaft Vulkan, Bredow bei Stettin, Germany	(E)	Nov. 1884

ASSOCIATES.

A.

Allden, William R., Akenside Villa, Newcastle-on-Tyne	(A)	Dec. 1886
Armstrong, S., 14, Victoria Place, Hartlepool	(A)	Nov. 1888

B.

Barklam, George, Tipton, Staffordshire		April 1888
Barwick, J. S., Ashbrook Grange, Sunderland	(S O)	Nov. 1884
Bell, John Henry, 24, Park Place West, Sunderland	(I & S M)	Oct. 1887
Boyd, Robert, Messrs. Hannay, Boyd, & Co., Quay, Newcastle-on-Tyne	(S O)	Nov. 1884
Branfoot, W. J., Messrs. Tyzack & Branfoot, John Street, Sunderland	(S O)	Dec. 1887
Briggs, R. S., Moorlands, Sunderland	(S O)	Dec. 1886
Browne, John L., Thornhill Gardens, Sunderland	(S O)	Dec. 1886
Brunton, John, 3, Prior's Terrace, Tynemouth	(S O)	Oct. 1886
Byers, Wm. Lumsdon, 51, West Sunniside, Sunderland	(S O)	Oct. 1888

C.

Carr, Ralph, Thornleight, Clayton Park Road, Newcastle-on-Tyne	(A & S O)	Nov. 1886
Charlton, W. A., St. Nicholas' Buildings, Newcastle-on-Tyne	(A)	Mar. 1888
Common, Francis James, 5, Elms West, Sunderland	(I & S M)	Oct. 1887
Coull, John, 43, Stanley Street West, North Shields	(S O)	Oct. 1886
Coverdale, R. H., Messrs. J. Coverdale & Sons, Steamship Owners, West Hartlepool	(S O)	Nov. 1888

		ELECTED.
Crowther, Joseph, Dispensary Lane, Newcastle-on-Tyne	(I M)	Jan. 1889
Culliford, J. H. W., Sunderland	(S O)	Nov. 1884
D.		
Dodds, Charles Henry, General Manager, River Wear Commission, 16, Thornhill Terrace, Sunderland		Oct. 1887
Dodds, John B., 13, Dean Street, Newcastle-on-Tyne		Oct. 1888
Dodds, A. P., 13, Dean Street, Newcastle-on-Tyne	(A)	Jan. 1889
Dunford, T. G., Messrs. Elliott, Lowrey, & Dunford, Lombard Street, Quay, Newcastle-on-Tyne	(S O)	Nov. 1884
F.		
Furness, Christopher, Victoria Terrace, West Hartlepool	(S O)	Oct. 1888
G.		
Garnett, William, Principal, The Durham College of Science, Newcastle-on-Tyne		Jan. 1889
Gjemre, Lauritz, Maritime Buildings, King Street, Newcastle-on-Tyne	(S O)	Mar. 1886
Greenwell, Thos. G., Sunderland	(S O)	Dec. 1886
H.		
Harland, George, 1, Westoe Crescent, South Shields	(A)	Dec. 1888
Hedley, John H., 10, Esplanade West, Sunderland	(S)	Dec. 1886
Heslop, Richard O., Akenside Hill, Newcastle-on-Tyne ...	(I & S M)	Oct. 1885
Hogg, George J. H., N.E.C. Insurance Association, West Hartlepool	(S O)	Oct. 1888
Hollis, H. E., 3, St. George's Terrace, Jesmond, Newcastle-on-Tyne	(I & S M)	Feb. 1885
Hudson, Ralph M., Jun., 8, The Cedars, Sunderland	(S O)	Dec. 1886
Hunting, Charles, Jesmond Dene, Newcastle-on-Tyne	(S O)	April 1886
I.		
Iley, D. W., 1, Elmwood Street, Sunderland	(I & S M)	Nov. 1888
J.		
Jenkins, William, Consett Hall, Durhamshire	(I & S M)	Nov. 1887
Jobson, W. J., c/o Messrs. Robert Stephenson & Co., South Street, Newcastle-on-Tyne	(A)	May 1889
K.		
Kerr, James, 18, Azalea Terrace South, Sunderland	(A)	Jan. 1888
L.		
Loveridge, W. H., Mainsforth Terrace, West Hartlepool ...	(I & S M)	Oct. 1888
M.		
Macarthy, George E., 9, Dean Street, Newcastle-on-Tyne	(S O)	Oct. 1887
Matthiessen, P. H., 12, Lombard Street, Newcastle-on-Tyne ...	(A)	Oct. 1888
Maughan, William, Westmorland Road, Newcastle-on-Tyne ...	(A)	Feb. 1887
Mawson, Rowland, Bank Chambers, Quay, Newcastle-on-Tyne ...	(S O)	Jan. 1889
McNabb, Thos., Cail's Buildings, Quayside, Newcastle-on-Tyne ...	(S O)	Nov. 1886
Metcalf, Thomas, Sea View Gardens, Roker, Sunderland ...	(SUR)	Jan. 1888
Milburn, J. D., Queen Street, Newcastle-on-Tyne	(S O)	Nov. 1884

		ELECTED.
Miller, T. R., c/o Messrs. Lamplough & Co., 72, Cornhill, London	(A & S O)	Nov. 1884
Mudd, John, Castletown Rolling Mills, near Sunderland	(I & S M)	Nov. 1884
Mulherion, G. F., 144, Albert Road, Jarrow-on-Tyne	(A)	Nov. 1884

N.

Newby, S., Messrs. Thomson & Newby, 13, Bridge Street, Sunderland	(I & S M)	Nov. 1884

O.

O'Hagan, James, St. Nazaire-sur-Loire, France		Oct. 1888
Osbourne, Jas., Hylton, Sunderland	(S)	Jan. 1885

P.

Panton, Hugh, 38, Fawcett Street, Sunderland	(I & S M)	Nov. 1887
Patterson, John, 28, Belgrave Terrace, Newcastle-on-Tyne	(A)	Feb. 1885
Patterson, Thos., 6, Argyle Square, Sunderland	(S)	Jan. 1885
Pattison, W. J., Messrs. Hunting & Pattison, Exchange Buildings, Quayside, Newcastle-on-Tyne	(S O)	April 1886
Perry, Edwin, 23, Side, Newcastle-on-Tyne	(A)	Nov. 1885
Phalp, Oliver, Captain, Almora, Richmond Road, Cardiff	(SUR)	Feb. 1889
Pinkney, Thomas, Creswell Villa, Sunderland	(S O)	Dec. 1886
Pinkney, T. W., John Street, Sunderland	(S O)	Feb. 1888

R.

Ramsay, J. W., Newburn Steel Works, Newburn-on-Tyne	(A)	Feb. 1885
Reichwald, A., Lombard Street, Newcastle-on-Tyne	(A)	Nov. 1884
Reid, Andrew, Printer, Akenside Hill, Newcastle-on-Tyne		Nov. 1884
Renwick, G., Messrs. Fisher, Renwick, & Co., Queen Street, Newcastle-on-Tyne	(S O)	Nov. 1884
Roberts, G., Baltic Chambers, Quayside, Newcastle-on-Tyne	(S O)	Nov. 1884
Robson, Frederick, 46, Dean Street, Newcastle-on-Tyne		Oct. 1887
Robson, Thos., 28, North Bridge Street, Sunderland	(S O)	Nov. 1884

S.

Sanderson, John, 9, The Elms, Sunderland	(S O)	Dec. 1886
Scholefield, A., 17, Sandhill, Newcastle-on-Tyne	(S O)	Nov. 1884
Scott, W. H., Messrs. Scott Brothers, Dean St., Newcastle-on-Tyne	(S O)	Nov. 1884
Seaman, C. J., 19, Willington Street, Stockton-on-Tees	(A)	Jan. 1889
Smith, George, c/o Messrs. Hawthorn, Leslie, & Co., St. Peter's Works, Newcastle-on-Tyne	(A)	Feb. 1889
Snowdon, W. F., Salter's Road, Gosforth, Newcastle-on-Tyne	(E A)	Dec. 1886
Squance, J. W., Marine Superintendent, 13, The Avenue Sunderland		April 1888
Stephens, D., Messrs. Stephens, Mawson, & Co., Bank Chambers, Quay, Newcastle-on-Tyne	(S O)	Nov. 1884
Swan, Isaac J., Grove House, Gosforth, Newcastle-on-Tyne	(S O)	Feb. 1888

T.

Taylor, John W., Thornhill Tower, Sunderland	(S O)	Dec. 1886
Temperley, C., 9, Gracechurch Street, London	(S O)	Nov. 1885

		ELECTED.
Thompson, V. T., Baltic Chambers, Sunderland	(S O)	Dec. 1886
Towers, Edward, 4, Latimer Street, Tynemouth	(A)	Oct. 1888
Tweedy, George, Gresham House, Bishopsgate Street, London	(S O)	Mar. 1889

V.

Varley, John, 257, High Park Road, Leeds	(I & S M)	Mar. 1887

W.

Wait, James, Maritime Buildings, King Street, Newcastle-on-Tyne	(S O)	Nov. 1884
Wallace, Wm., 27, South Scarborough Street, West Hartlepool	(A)	Oct. 1888
Ward, Joseph, Messrs. Wallsend Slipway Co., Wallsend-on-Tyne	(A)	Nov. 1886
Welford, Richard, Gosforth, Newcastle-on-Tyne	(S O)	April 1888
Woods, James Jabez, Messrs. Herskind & Woods, West Hartlepool	(S O)	Oct. 1888

Y.

Yeoman, F., Messrs. Murrell & Yeoman, West Hartlepool	(S O)	Nov. 1888
Young, William M., Guildhall Chambers, Newcastle-on-Tyne	(S O)	Mar. 1889
Younger, Robert, Messrs. Greenock Steamship Co., Limited, Greenock	(A)	Feb. 1889

GRADUATES.

A.

Adamson, Daniel, c/o Messrs. Joseph Adamson & Co., Hyde	Feb. 1888
Anderson, Robert	Nov. 1886

B.

Barnes, William, 3, High Ellison Street, Hebburn-on-Tyne	Feb. 1887
Blackett, Walter, 6, Windsor Crescent, Newcastle-on-Tyne	Nov. 1886
Boyd, William, Jun., North House, Long Benton, Newcastle-on-Tyne	Nov. 1887
Bryson, John J., 16, Chester Crescent, Newcastle-on-Tyne	Feb. 1889

C.

Common, F., 13, Tavistock Place, Sunderland	May 1885
Coull, Alex. B., 43, Stanley Street W., North Shields	Feb. 1887
Crosby, J., 1, Randolph Street, Sunderland	May 1885

D.

De Mattos, James Hilbert, c/o J. Dickinson, Esq., Palmer's Hill Engine Works, Sunderland	
Dixon, John R., Warden House, Tynemouth	Oct. 1887
Donkin, Samuel, 5, Dean Terrace, Southwick, Sunderland	Jan. 1888
Duckitt, J. Brentnall, 9, St. James' Street, Newcastle-on-Tyne	Oct. 1888

F.

Fairbairn, Jas., Hendon Valley Road, Sunderland	May 1885
Finch, Herbert K., 1, St. Peter's Terrace, Cambridge	Dec. 1888
Foley, Wm. C. le B., 12, Grove Street, Newcastle-on-Tyne	Nov. 1887

G.

	ELECTED.
Gaine, Roger L., 17, Park Place E., Sunderland	Dec. 1887

H.

Hamilton, James, 3, Victoria Square, Newcastle-on-Tyne	Oct. 1887
Head, Alston G., 3, Cambridge Road, West Hartlepool	
Henshall, Samuel, 9, Chester Road, Sunderland	May 1885
Holey, J. T., 19, Rosslyn Terrace, Sunderland	Jan. 1886
Hume, Alfred Ernest, 34, Burdon Terrace, Newcastle-on-Tyne	Oct. 1888

I.

Ingram, Herbert P., 30, Brougham Street, East Hartlepool	April 1888

L.

Liebert, Richard A. E., 214, Portland Road, Newcastle-on-Tyne	Dec. 1888

M.

Manford, Frank, 1, Osborne Terrace, Jesmond, Newcastle-on-Tyne	Mar. 1888
McRobie, Frank, 14, Westmorland Terrace, Newcastle-on-Tyne	Mar. 1889
Metcalf, Thos., 6, Dundas Street, Sunderland	May 1885

N.

Nicholson, John, Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne	Dec. 1886
Nicholson C., 9, Sussex Place, Southampton	Nov. 1888

R.

Reed, Joseph, 51, Fisher Street, Low Walker-on-Tyne	
Rickaby, Augustine, Bloomfield Engine Works, Monkwearmouth, Sunderland	Nov. 1885
Ritson, Stanley M., 18, St. Bede's Terrace, Sunderland	Nov. 1887
Roberts, T. C., Neptune Shipyard, Low Walker-on-Tyne	Oct. 1886
Ross, A. T. C.	Dec. 1886
Ross, Wm. Chisholm, 67, Falmouth Road, Heaton, Newcastle-on-Tyne	Dec. 1888
Rutherford, J. T., 80, Ryehill, Newcastle-on-Tyne	Jan. 1886

S.

Shaw, Thomas, West Boldon, near Sunderland	Dec. 1885
Skinner, Leslie, 22, Ravensbourne Terrace, South Shields	Dec. 1886
Speeding, Joseph C., Boker House, Sunderland	Dec. 1886
Stoddart, Swinton, 24, North Milburn Street, Sunderland	May 1885
Strang, T. R., Bath Lane, Newcastle-on-Tyne	Nov. 1888

T.

Taylor, M., Hawthorn Road, Gosforth, Newcastle-on-Tyne	Feb. 1889

W.

Westmacott, Alfred, Benwell Hill, Newcastle-on-Tyne	Dec. 1885
Wheeler, O., 4, Wilberforce Street, Wallsend-on-Tyne	Oct. 1886
White, Ernest T., 3, Belle Vue Terrace, Gateshead-on-Tyne	May 1889
Wortley, H., 311, Shields Road, Byker, Newcastle-on-Tyne	Jan. 1886

MEMOIR.

THE LATE MR. G. H. GARRETT.

Mr. G. H. Garrett was the son of a clergyman and a native of Tamworth. He began his professional career as a pupil under William Adams, Esq., the well-known locomotive engineer of the Great Eastern Railway Company, and afterwards, when that gentleman was elected locomotive superintendent of the London and South Western Railway Company, he was appointed his assistant. In that capacity he materially rendered great service in rearranging the works and placing them on their present efficient footing. A vacancy occurring at Messrs. Sterne's works, Glasgow, he was appointed manager, which appointment he held for about three years. After the death of Mr. Douglas, of Messrs. R. Stephenson & Co., Limited, Newcastle-upon-Tyne, in September, 1885, the deceased gentleman was appointed to direct the affairs of that well-known establishment, which appointment he held until his death. In this office he gave every satisfaction, and endeared himself both to the management and men by his ability, tact, and kindly disposition. His death, which took place on Sunday, March 10th, 1889, was painfully sudden, as he was in the full enjoyment of his usual health up to the Friday preceding that date.

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, AND MAY 13TH, 1889.

CONSTITUTION.

Name.

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

Objects.

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.

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

Honorary Members.

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

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.

Associates.

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.

Graduates.

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.

Life Members and Associates.

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.

Officers.

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

Election of Officers. (See Bye-Law No. 11.)

X.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Councilmen shall be elected annually. The retiring Vice-Presidents and Councilmen 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 and Councilmen shall not be eligible for re-election to the same offices until after a similar interval, 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.

Honorary Members' Privileges.

XI.—Honorary Members may attend all the General Meetings, they may read papers, take part in discussions, in voting, in moving and supporting resolutions, in presentation of notices of motion, or in requisitions for Special Meetings, and in the proposition of new members; they shall also receive copies of the Transactions.

Members' Privileges.

XII.—Members shall have all the privileges of the Institution as enumerated in the foregoing paragraph, and shall be eligible for office.

Associates' Privileges.

XIII.—Associates shall have all the privileges enumerated in paragraph XI. They shall be eligible for office as Councilmen.

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 winter seasons 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.

Revised at the Closing Business Meetings held on May 4th, 1887, *and May* 13*th,* 1889.

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 Balloting for Members.

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 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 June 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 June 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 unknown in the meeting shall only be able to claim the privilege in question on proving his membership for the current Session.

Arrears of Subscriptions.

9.—Any member whose subscription is one year in arrear shall be reported to the Council, who shall direct application to be made for it, according to Form E in the Appendix; and in the event of its continuing in arrear until the end of that

Session after such application, the Council shall have the power, after remonstrance by letter, according to the Form F in the Appendix, of declaring that the defaulter has ceased to be a member.

Power of Council to remove Name from List of members.

10.—The Council may refuse to continue to receive the subscriptions of any member who shall have wittingly acted in contravention of the Regulations of the Institution, or who shall, 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.

Election of 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. 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. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be, at least, two in excess of the number required in each section of the Council. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members, 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.

Any voting paper returning either more or less than one President, six Vice-Presidents, one Honorary Treasurer, and fifteen Councilmen, 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 Councilmen, 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 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 General Meeting, to be held in May, at which meeting general business shall be transacted. At the May General 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 person whose place they fill would have retired. Vacancies not filled up 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 shall be held in Newcastle. 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.

Notice of Meetings.

15.—Seven clear days' notice of every General Meeting, Ordinary or Special, specifying the nature of business to be transacted, shall be given to every member of the Institution.

Special General Meetings.

16.—A Special General Meeting may be convened at any time by the Council, and such meeting shall be convened by the Council whenever such is the declared wish of a General Meeting, or whenever a written requisition, signed by twenty members, specifying the object of the meeting, is left with the Secretary. If, for fourteen days after the delivery of such requisition, a meeting be not convened in accordance therewith, the requisitionists, or any twenty members of the Institution, may convene a Special Meeting in accordance with the requisition. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting.

Quorum.

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.

Chairman at Meetings.

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, a Councilman shall take the chair; or if no Councilman be present and willing to take the chair, the meeting shall elect a Chairman.

Decisions of General 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.

Questions of a Personal Nature in 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.

Transactions of Business 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.

Dissolving a General Meeting.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be 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 transacted at any Council Meeting, unless the circular gives six clear days' notice, and states the business.

Discussions of a Personal Character.

All discussions of a personal character in the Council shall be considered and treated as being strictly confidential.

Regulation of Proceedings.

26.—The Council may regulate its own procedure, and delegate any of its powers and discretions to any one or more of its number.

Chairman and Quorum.

The President shall, *ex-officio,* be chairman of all Council Meetings, and in his absence one of the Past-Presidents or one of the Vice-Presidents shall take the chair; or in the absence of these, one of the Councilmen shall be elected to take the chair. Five members of Council, including the Chairman, shall form a quorum.

Sub-Committees.

In the appointment of Sub-Committees, the Council shall determine the number which shall form a quorum in each case, and shall appoint a Chairman. These regulations shall not affect the Finance Committee.

Sub-Committees.

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.

Invitation of Strangers.

29.—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.

Secretary and Treasurer's Duties.

30.—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 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.

Finance Committee.

31.—The following Sub-Committees shall be appointed annually by the Council:—(1) A Finance Committee, to consist of seven persons, viz., one Past-President or Vice-President, who shall be Chairman; five Councilmen, 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. (2) A Reading Committee, to consist of six members of Council.

Payment of Accounts.

Reading Committee.

TRANSACTIONS.

Papers to be submitted to Council.

32.—All papers shall be forwarded to the Secretary at least five clear weeks before the proposed date of reading. The Secretary shall submit them for approval to the Council, and on their general approval they shall be handed to the Reading Sub-Committee, three of whom at least, shall read the paper through.

Reading Committee.

The Reading Committee shall be at liberty to strike out any parts which, in their opinion, ought not to be read. They may also make any suggestions to the author as to points which might with advantage be inserted or altered.

Printing Transactions.

33.—The papers read, and the discussions on them, or such portions of them as the Council shall select, shall be printed for distribution among the members, each of whom shall receive a copy. These Transactions shall be edited by the Secretary, in accordance with instructions of the Council, who shall have 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.

34.—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.

35.—Proofs of the reports of discussions shall be sent for correction to the members who have taken part in the discussion, but must be returned to the Secretary within seven days of the date on which they were sent, otherwise they will be deemed correct, and will be printed off.

Liberty to Print Explanatory Notes.

36.—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 shall bear the date on which they shall have been received by the Secretary.

Institution not responsible for statements.

37.—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.

38.—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 41.

Transactions not supplied to Members in Arrears.

39.—The Transactions shall not be supplied free to members whose subscriptions are more than one year in arrear.

Members not to receive Transactions till after First Payment.

40.—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.

41.—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.

42.—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.

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

ALTERATIONS TO CONSTITUTION AND BYE-LAWS.

44.—Alteration in or addition to the Constitution and Bye-Laws may be made only by resolution of the members at the May General Meeting, 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 May General Meeting 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 May General Meeting.

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.

For Library and Reading Room Bye-Laws, see page 98.

APPENDIX.

FORM A. (BYE-LAW 1.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned [Members or Associates], propose and recommend that he shall become [a Member, Associate, or Graduate] thereof. We know him to be [a Principal, &c., or engaged in, &c.,] and eligible for the proposed membership.

FROM PERSONAL KNOWLEDGE.

Signed____________________ } Four [Members or Associates.]

____

____

____

Dated this day of 18

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 twenty-four years of age, and being desirous of becoming a of the said Institute, we, the undersigned [Members or Associates], recommend him, from *personal knowledge,* as a person eligible for the proposed Change of membership, because—

(Here specify distinctly the Qualifications of the Candidate according to the spirit of the Rules of the Institution.)

Signed____________________ } Three [Members or Associates.]

____

____

Dated this day of 18

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.

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,
Secretary.

FORM G. (BYE-LAW 10.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that they feel it their duty to advise you to withdraw from the Institution, or otherwise they will be obliged to act in accordance with Bye-Law 9 (or 10, as the case may be.)

I am, Sir,
Yours faithfully,
Secretary.

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.)*

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————
} 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, and NOT 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.

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

Councilmen.—**Fifteen Names** only to be returned, including the ten who remain in office.

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} Ten Councilmen 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 Councilmen 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 Councilmen, 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 44.)

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.

Signature..

Address..

....

....*Secretary.*

NORTH-EAST COAST INSTITUTION
OF
ENGINEERS AND SHIPBUILDERS.

FIFTH SESSION, 1888-89.

PROCEEDINGS.

ANNUAL GENERAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, OCTOBER 3RD, 1888.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the closing business meeting of the last session, held in Newcastle-upon-Tyne, on May 9th, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. T. Milton and M. Sandison to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Aberg, Henning, 8, Union Street, East Hartlepool.
Austin, W. K., Lloyd's Register of Shipping, Dock Office, West Hartlepool.
Baines, George Henry, Messrs. Central Marine Engineering Co., West Hartlepool.
Barron, T. G., Fern Villas, Elwick Road, West Hartlepool.
Campbell, James J., Messrs. Hawthorn, Leslie, & Co., St. Peter's.
Chapman, Alfred C., 2, St. Nicholas' Buildings, Newcastle.
Cornforth, J., Messrs. Gladstone & Cornforth, Church Street, West Hartlepool.
Craggs, Ernest H., Messrs. R. Craggs & Sons, Middlesbro'.
Danson, Thomas James, 3, St. Nicholas' Buildings, Newcastle.
Firth, H. Branson, Messrs. T. Firth & Sons, Sheffield.
Geddes, Christopher, Messrs. Leeds Forge Co., Leeds.
Gladstone, Arthur, Messrs. Gray & Gladstone, West Hartlepool Rolling Mills, West Hartlepool.

Gray, Matthew, Messrs. W. Gray & Co., West Hartlepool.
Gray, William, Messrs. W. Gray & Co., West Hartlepool.
Jones, George, Messrs. W. Gray & Co., West Hartlepool.
Leckie, Andrew, Cambridge Terrace, West Hartlepool.
Micheli, Pietro, Jun., 5, Via Assarotti, Genoa.
Moffitt, George, 32, Mitchell Street, West Hartlepool.
Muir, John, Brougham Terrace, West Hartlepool.
Petersen, John L., Bellerby Terrace, West Hartlepool.
Richardson, Thos., M.P., Hartlepool Engine Works, West Hartlepool.
Richardson, William, Hartlepool Engine Works, West Hartlepool.
Rowe, John A., 11, Spring Terrace, North Shields.
Sydserff, Thomas B., Jun., Messrs. Naval Construction and Armaments Co., Barrow-in-Furness.
Sisson, William, Falmouth Dock Ironworks, Falmouth.
Stoddart, J. E., Lloyd's Register of Shipping, Dock Office, West Hartlepool.

GRADUATES RAISED TO MEMBERS.

Burton, Christopher D., 34, Edith Street, Jarrow-on-Tyne.
Gayner, Robert H., Jun., Beech Holm, Sunderland.
Marshall, Frank T., 38, Percy Gardens, Tynemouth.
Miller, Thomas B., 6, Vernon Terrace, Gateshead.
Nicolson, G. C., Messrs. Hawthorn, Leslie, & Co., St. Peter's.
Watson, Ralph J., Willington House, Willington Quay.

ASSOCIATES.

Byers, Wm. Lumsdon, 51, West Sunniside, Sunderland.
Dodds, John B., 13, Dean Street, Newcastle-on-Tyne.
Furness, Christopher, Victoria Terrace, West Hartlepool.
Hogg, George J. H., N.E.C. Insurance Association, West Hartlepool.
Loveridge, W. H., Mainsforth Terrace, West Hartlepool.
Matthiessen, P. H., 12, Lombard Street, Newcastle-on-Tyne.
O'Hagan, James, St. Nazaire-sur-Loire, France.
Wallace, William, 27, South Scarbro' Street, West Hartlepool.
Woods, James Jabez, Messrs. Herskind & Woods, West Hartlepool.

GRADUATES.

Duckitt, J. Brentnall (15), 4, Selborne Terrace, Gateshead.
Hume, Alfred Ernest (18), 34, Burdon Terrace, Newcastle-on-Tyne.

The PRESIDENT in declaring the results of the ballot desired to call attention to the great influx of members from the Hartlepools, and intimated that the thanks of the Institution were due to some of the members who had certainly been most successful in working the interests of the Institution in that district.

The SECRETARY submitted the Council's Report and the Treasurer's Financial Statement for the last year as follows :—

COUNCIL REPORT.

(Fourth Session.)

The Council has to report that the finances of the Institution are, on the whole, in a satisfactory condition. The attention of members is however respectfully called to the arrears of subscription which, for the year just closed, amount to £51 2s. 6d., while a further sum of £18 5s. 6d. still remains unpaid for the year 1886-7. It is very gratifying to find that the demand for the published copies of the Transactions of the Institution has not decreased, the sales from stock for the past year having amounted to £47 2s. 3d.

The session has been a very busy one. The following nine papers upon subjects of present interest and practical utility have been read and discussed, viz.:—

1.—"**Notes on Steamship Speed Calculations.**" By **Mr. G. N. Arnison, Jun.**
2.—"**The Influence of Coal Consumption on the Commercial Efficiency and the Design of Cargo Steamers.**" By Mr. Robert Thompson.
3.—"**Improvements in the Construction of Large Stern Frames, Rudders, and Keels.**" By Mr. E. F. Wailes.
4.—"**The Compound Steam Turbine and its Theory as applied to the Working of Dynamo-Electric Machines.**" By the Hon. C. A. Parsons.
5.—"**The Combustion of Coal and some Evaporative Experiments with Natural and Forced Draught.**" By Mr. W. G. Spence
6.—"**The Results of some Experiments on an Improved Boiler Joint.**" By **Mr. James Patterson.**
7.—"**Slide Valve Gears.**" By Mr. J. T. Milton.
8.—"**Stockless Anchors and Fittings.**" By Mr. G. W. Sivewright.
9.—"**Pontoon and Floating Docks.**" By Mr. Alex. Taylor.

Many matters of importance have engaged the attention of the Council. Of these may be mentioned the desirability for a better representation of shipbuilders and engineers on Lloyd's Register Committee. The Council of the Institution has undertaken to co-operate with the Institution of Naval Architects and the Institution of Engineers and Shipbuilders in Scotland, and has appointed F. C. Marshall, Esq. (President), and John Price, Esq., to represent this Institution upon the combined deputation to wait upon Lloyd's Committee to discuss the subject in all its bearings.

The Committee appointed to confer with the Council of the Durham College of Physical Science upon the establishment of a Chair of Naval Architecture and Marine Engineering in the College is still continuing its labours. The attention of the members of this Institution is once more called to the chief question now before the Committee, viz.:—the raising of the necessary funds for the endowment of the Chair.

The Committees appointed (1) to endeavour to frame a General Rule for the Horse-power of Marine Engines and Boilers, and (2) to obtain Statistics of the Comparative Progress of British and Foreign Shipping during the last twenty-five years, have submitted their Reports to the Council, both of which the Council has thought fit to adopt. These Reports have now been printed, and are appended to Volume IV. of the Transactions of the Institution.

In order to place the finances of the Institution upon a more satisfactory basis, the proposed advance in the subscriptions of members (under Class II.) and of graduates, and the desirability of having suitable Offices and a Reference Library for the use of the members, have engaged the attention of the Council, and a sub-committee was appointed to consider and report thereon. The whole question was brought before the members at the Closing Business Meeting of the session, when it was agreed that the subscriptions should be raised as recommended, viz.:—that the Members previously paying half-a-guinea shall pay one guinea per annum, and that the subscriptions of Graduates shall be raised to half-a-guinea per annum. It was, therefore, agreed to alter Articles V. and VII. of the Constitution in accordance with the resolution passed.

The matter of suitable Offices and a Reference Library is at present engaging the attention of the Council.

During the Session 1 Life Member, 1 Life Associate, 60 Ordinary Members, 18 Associates, and 16 Graduates have been enrolled, and 11 Graduates have been raised to the rank of Members. The Institution has lost by resignations, gentlemen leaving the district, and from other causes, 68 Members, 7 Associates, and 20 Graduates.

As the British Association will visit Newcastle-upon-Tyne next summer, the following four gentlemen have been appointed to represent this Institution upon the Local General Committee, viz., F. C. Marshall, Esq., President; W. Boyd, Esq., and W. Theodore Doxford, Esq., Past-Presidents; and H. F. Swan, Esq., Vice-President.

In response to an invitation received from the members resident in the Hartlepools, together with the Mayors of Hartlepool and West Hartlepool, and other influential gentlemen, the Council has arranged that the Institution will visit and hold a General Meeting in West Hartlepool on Saturday, October 20th. Due notice of this has been given to the members, and it is hoped they will do their utmost to make the meeting a success.

NORTH-EAST COAST INSTITUTION OF

STATEMENT OF RECEIPTS AND PAYMENTS

Receipts.

	£	s.	d.	£	s.	d.	£	s.	d.
To Balance from last Account—									
At Bankers				89	10	9			
In hand				16	17	0			
							106	7	9
„ Balance from Naval Architects' Guarantee Fund							14	11	8
„ Subscriptions received for Session 1887-8—									
149 Members at £2 2s.	£312	18	0						
69 Associates „ £1 1s.	72	9	0						
351 Members „ 10s. 6d.	184	5	6						
57 Graduates „ 5s. 0d.	14	5	0						
626				583	17	6			
For Session 1886-7 (arrears)—									
4 Members at £2 2s.	£8	8	0						
4 Associates „ £1 1s.	4	4	0						
14 Members „ 10s. 6d.	7	7	0						
1 Graduate „ 5s. 0d.	0	5	0						
23				20	4	0			
				604	1	6			
Arrears previously struck off as not recoverable				2	12	6			
							606	14	0
For Session 1888-9 (in advance)—									
2 Members at £2 2s.							4	4	0
„ Life Member—Samson Fox				21	0	0			
„ Life Associate—Edward Eccles				10	10	0			
							31	10	0
„ Transactions Sold from Stock per Secretary				47	2	3			
„ Printed Copies of Papers—									
Per H. Gannaway				0	15	0			
„ W. T. Doxford				1	9	6			
„ R. Thompson				2	5	0			
„ Jas. Patterson				1	0	0			
„ E. F. Wailes				3	6	8			
„ Hawthorn, Leslie, & Co.				8	5	0			
„ Hon. C. A. Parsons				2	2	0			
„ J. T. Milton				0	17	6			
„ A. Taylor				3	6	0			
„ G. W. Sivewright				1	5	0			
							71	13	11
							£835	1	4

ENGINEERS AND SHIPBUILDERS.

FOR SESSION ENDING 31ST MAY, 1888.

Payments.

	£	s.	d.	£	s.	d.
By Andrew Reid—						
Balance from Session 1886-7	38	17	3			
Transactions 1887-8	462	16	3			
				501	13	6
„ General Stationery	31	16	3			
„ Reporting	21	10	0			
„ Advertising	23	15	4			
„ Rents	6	4	0			
„ Secretary's Salary	120	0	0			
„ Secretary's Expenses and Postages	94	10	9			
„ Insurance	0	5	0			
„ Sundry Donations to Hall Keepers	2	10	0			
„ Rent for Measured Mile Posts and Painting	8	13	2			
„ Auditor's Fee	1	11	6			
				310	16	0
„ Balance—						
At Bankers	20	1	1			
In hand	2	10	9			
				22	11	10
				£835	1	4

NORTH-EAST COAST INSTITUTION OF
STATEMENT OF RECEIPTS AND PAYMENTS

Receipts.

		£ s. d.	£ s. d.
To Balance from last Account—			
At Bankers		89 10 9	
In hand		16 17 0	
			106 7 9
„ Balance from Naval Architects' Guarantee Fund			14 11 8
„ Subscriptions received for Session 1887-8—			
149 Members at £2 2s.	£312 18 0		
69 Associates „ £1 1s.	72 9 0		
351 Members „ 10s. 6d.	184 5 6		
57 Graduates „ 5s. 0d.	14 5 0		
626		583 17 6	
For Session 1886-7 (arrears)—			
4 Members at £2 2s.	£8 8 0		
4 Associates „ £1 1s.	4 4 0		
14 Members „ 10s. 6d.	7 7 0		
1 Graduate „ 5s. 0d.	0 5 0		
23		20 4 0	
		604 1 6	
Arrears previously struck off as not recoverable		2 12 6	
			606 14 0
For Session 1888-9 (in advance)—			
2 Members at £2 2s.			4 4 0
„ Life Member—Samson Fox		21 0 0	
„ Life Associate—Edward Eccles		10 10 0	
			31 10 0
„ Transactions Sold from Stock per Secretary		47 2 3	
„ Printed Copies of Papers—			
Per H. Gannaway		0 15 0	
„ W. T. Doxford		1 9 6	
„ R. Thompson		2 5 0	
„ Jas. Patterson		1 0 0	
„ E. F. Wailes		3 6 8	
„ Hawthorn, Leslie, & Co.		8 5 0	
„ Hon. C. A. Parsons		2 2 0	
„ J. T. Milton		0 17 6	
„ A. Taylor		3 6 0	
„ G. W. Sivewright		1 5 0	
			71 13 11
			£835 1 4

ENGINEERS AND SHIPBUILDERS.

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„ Auditor's Fee	1	11	6			
				310	16	0
„ Balance—						
At Bankers	20	1	1			
In hand	2	10	9			
				22	11	10
				£835	1	4

The PRESIDENT moved the adoption of the Council's Report of the proceedings of the Institution and Financial Statement for the last session. The Council had begun by stating that on the whole the finances of the Institution were in a satisfactory state. If a gradually decreasing balance at the bank was a satisfactory condition, well, theirs was so; but he would have them observe that the balance was extremely small—much smaller than last year. This was no doubt to be accounted for to some extent by the arrears, which were hereby mentioned as amounting to £51 2s. 6d. for the last year, and £18 5s. 6d. remaining for the year before; but if these arrears could be paid up, the funds of the Institution would enable the Council to be a little more free in undertaking work for the advancement of the objects of the Institution and the benefit of its members. He had no doubt that a considerable amount of these arrears arose from the very depressed state of trade during the past two years, which also accounted for the fact that a certain number of resignations had been tendered. Naturally they very much regretted that any one should see it necessary to leave the Institution because of the increase in the amount of subscription which it had been found desirable to make in order to maintain a sound financial position; but the number of resignations was not by any means so large as was feared, and it was very satisfactory to find that the increase was larger than the decrease. He might say, however, with regard to this matter, that even of the number of those resignations a large proportion had arisen from gentlemen leaving the district partly owing to the depression of trade and from other causes. He was sure they all regretted this, as some of those who had gone were gentlemen with whom they were all acquainted more or less, and who had been of great service to the Institution. He thought it very desirable that they as members of the Institution should use every means to induce those who had resigned on account of the increased subscriptions to return to their membership at the very earliest possible date.

He might say that the total number of members up to the present was 653, including those who had been elected that night.

They would observe that the Council had decided on having the Institution represented in a combined deputation to wait upon Lloyd's Committee. He presumed that the greater part of the members were aware of the meaning of this intended deputation; it was therefore unnecessary for him to say anything beyond what they would find alluded to in the address he was about to give.

With regard to the Chair of Naval Architecture, this matter had been before them for a considerable time. Professor Garnett was there that

THE BALANCE SHEET.—31ST MAY, 1888.

Liabilities.	£ s. d.
Subscriptions for Session 1888–9, Paid in Advance ...	4 4 0
Surplus as per Revenue Account	248 14 6
	£252 18 6

Assets.	£ s. d.	£ s. d.	£ s. d.
Sundry Debtors— For copies of Transactions sold			8 16 6
Subscriptions in Arrear, viz.:—			
Arrears from last Session ...	£41 17 6		
Subscriptions payable for Session 1887–8, as per Revenue Account	637 2 0	678 19 6	
Less—Subscriptions paid as per Cash Account	604 1 6		
Subscriptions paid in advance during 1886–7 ...	2 2 0		
Arrears for Session 1886-7 written off	3 8 0	609 11 6	69 8 0
Stock of Transactions, viz.:—			
1 copy Volume 1, bound 167 copies ,, ,, unbound	.. ...	25 0 0	
21 ,, ,, 2, bound 82 ,, ,, ,, unbound	... ...	54 0 0	
12 ,, ,, 3, bound 57 ,, ,, ,, unbound	... ...	36 0 0	
15 ,, ,, 4, bound 45 ,, ,, ,, unbound	.. ...	31 10 0	146 10 0
Office Furniture			5 12 2
Cash—At Bankers		20 1 1	
In hand		2 10 9	22 11 10
			£252 18 6

Audited and Certified,
R. W. SISSON. F.C.A

Newcastle-upon-Tyne, 14th September, 1888.

PRESIDENT'S INAUGURAL ADDRESS.

DELIVERED OCTOBER 3RD, 1888.

GENTLEMEN,—It has been your pleasure to elect me to the post of President of our Institution. It is an honour of which any engineer would be proud; to me it is one of the highest value. My career is known to most of you, having been passed in your midst, begun at the age of fourteen in the same workshops with which I am still connected, those of Robert and William Hawthorn of this city. I have gone in and out amongst you with scarcely an interruption for nearly forty-four years, and some of the workmen to whom as a boy I have held the candle are still amongst us. It has pleased you to falsify the proverb regarding the giving of honour to a prophet in his own country.

You have conferred on me the highest honour it is in the power of the Institution to bestow, and I enter on the duties of the office relying on my own firm determination and the cordial co-operation of all our members, and especially my colleagues in the Council, to continue and still further advance the interests and usefulness of our Institution during my year of office.

The report you have just heard read calls for a few remarks at the present juncture. The papers of the past session, and we may express our satisfaction in saying it, were all of great professional value and interest; and, it is not too much to say, worthy of any Institution in the world. The papers of our Institution are now sought for and read in our own and other countries as records of engineering and shipbuilding experience of the first importance. As many as forty-six volumes of our past Transactions have been sold during the year, many of them to Germany, America, and other parts of the world, and the volume of the last session is equal to any previous in quality.

I will not comment on these valuable papers further than to say in regard to one of them that its importance demands it should be only the first of a series, I mean that on the "Combustion of Coal under Natural and Forced Draught;" the experiments recorded have only touched the outside edge of the advantages open to us in the application of the principle of forced draught, and it is of importance it should be still further experimentally investigated. This Institution has no funds for this work, but, in co-operation with the Council of the Mining Institute, assisted by the coal trade of this district, experiments might be carried on to such a complete extent as to settle the vexed questions of Welsh *versus* North Country and other bituminous coals in regard to their value for marine purposes—under properly defined modes of working—whether under natural or forced draught.

The papers already promised for this session are also of much interest.

This is the centenary year of marine engineering. Exactly 100 years ago the first vessel driven by a steam engine was put to work. The President of such an Institution as ours might be pardoned if he inflicted upon its members a "Historical Address" recording the marvellous growth of marine engineering and shipbuilding, had the work not already been recently done so gracefully and well by the Earl of Ravensworth in his admirable address to the Institute of Naval Architects, at its recent meetings in Glasgow, and in the paper on "The First Century of the Marine Engine," read by Professor Dyer of Glasgow University at the same meetings.

In addressing you this evening, I shall endeavour to avoid discoursing on "Nothing," and even, if I can, to shun the "Next to Nothing," because of the transcendent ability which has recently been so powerfully directed to those apparently negative and unsubstantial subjects, and I feel I must content myself to follow, at an almost infinite distance, the great minds who can find in such intangible subjects matter from which to develop the splendid intellectual efforts to which some of us may have listened from the lips of the late Lord Iddesleigh and Sir Frederick Bramwell.

My purpose this evening is to talk with you, to the best of my ability, of OUR DAILY WORK and what it requires of us.

At the beginning of this our Institution year, it is gratifying to be able to congratulate ourselves and all associated with us, whether professionally, commercially, or mechanically, that we are, in the order of providence, being lifted out of the condition lamented over—though in hopeful, almost prophetic tones—by my distinguished predecessor in the two valuable addresses delivered during his term of office. I mean the condition of having "*got no work to do*."

Notably on this North-East Coast this is so. If only capital and labour will agree to work each for the interest of the other, and not only for its own, *apart* from the other, we may confidently look for a winter in which we shall have "no complaining in our streets," but work, wages, comfort and plenty for all.

What a marvellous change have a few months wrought! Not many months ago our yards were conspicuous for their resemblance to a blighted forest—a wilderness of bare poles around which the grass grew luxuriantly, and the cattle might almost have rejoiced in the abundance of food—the owners thereof travelling to the ends of the earth and struggling night and day that they might proselytise the man who was known to have "an order to place," all willing to sacrifice a large part of their "working charges," many willing to let them all go—and some, alas, more than all—rather than let go the unhappy man who has it on his conscience that he bought in the cheapest market and brought about a condition in the nett cost balance so terribly disastrous to the successful competitor. Now, all this is changed, and our daily work requires of us that we, in all politeness, request the erewhile object of our quest to be good enough to wait our convenience, and give the price with reasonable profit which we now demand. As a happy shipbuilder recently said, the difficulty now is not to get buyers into the office but to keep them out. Marvellous change! It is no part of my "work" here in discharging this duty to descant on the causes which have brought it about, the folly of overbuilding—or, if you will pardon the suggestion, of overtrading in affording facilities, unsound and unreal, for overbuilding—a glutted market, with depreciation, loss and ruin following in its wake, and in consequence a cessation of building, a continuous death-rate or shrinkage of tonnage, abundance of money and a deficient harvest, the upspring of new trades, improved and therefore cheapened production, improved machinery and reduced consumption of the fuel necessary for propulsion, improved means of working cargo—all have contributed to bring about the present demand and to afford us an abundance of our daily work. The lessons of the past five or six years, let us hope, will not soon be forgotten, but the remembrance of them form part of our daily work and contemplation.

Let us consider the nature of the work in which most of the members of this Institution are engaged. It may be generally described as Engineering, or the art of Constructing and using Engines or Machines. With many of us our engineering is directed to engines of destruction—and we cannot contemplate the magnificent establishment at Elswick, with its 14,000 workmen and its marvellous achievements in the invention and manufacture of ordnance of all descriptions, without a feeling of pride and satisfaction that the development and outcome of the genius of LORD ARMSTRONG and those associated with him have led to such results—but with probably the majority it is devoted to the more peaceful purpose of ministering to the wants of our fellow-creatures by providing transport either by land or sea for themselves or the commodities necessary for their sustenance and comfort, and generally to supply the demands made by a constantly advancing knowledge and civilisation for the more complete realisation of the highest ideal in regard to expedition, safety and certainty, combined with commercial success. In the building of ships, machinery for their propulsion, guidance, lighting, loading and discharging, and their expeditious working and in the manufacture of locomotives, bridges, hydraulic and steam cranes and other appliances for reducing labour and in the manufacture of the various materials used therein we most of us find our daily work.

Now, such being the case, what does it demand of us? In endeavouring to answer this, I presume that I have now the honour of addressing members of this Institution, all of whom are imbued with the principles set forth in our constitution as its object—namely, the promotion of the advancement of the science of Engineering and Shipbuilding—and therefore I shall venture to take you over the ground of our personal and individual relations to our work from the time we begin such association to our present daily work and all it demands of us in the way of *personal application*, *observation*, *study* and *conduct*.

First, I would say, it demands of us FITNESS. We have associated with us about 70 graduates—young men devoting themselves as apprentices to engineering or shipbuilding—and doubtless there are others in whom we are interested anxious to enter on such a career.

To those of us belonging to the generation now passing away, such fitness as we possess for the positions we occupy has come to us as the result of long and frequently dearly bought experience. New requirements had to be met, of which we had little or no previous knowledge—either of the facts bearing upon them or of the principles which might have guided us in carrying out the work involved. With many of us it has often been a groping of our way, or, may be, taking a leap in the dark: the occasion demanding immediate action has found us unprepared and unfitted for the work of the day. To the rising men of to-day no excuse such as might be made for some of us can now be made. No young man need now leave school without such a training as will enable him to take immediate advantage, on the best terms, of the facilities afforded in all our towns for continuing his education and obtaining such a thorough knowledge of science as will, if combined with the daily training of the workshop, fit him for any position of practical usefulness in our professions. The encouragement given by the Government of this country in its Science and Art Department, working through such institutions as those at Elswick, Bath Lane, and elsewhere in this city, the stimulus afforded by Whitworth and other Scholarships, the personal interest taken by noblemen such as LORD ARMSTRONG, manufacturers, and others, all contribute to make the fitness for work a more facile task for the man of the future.

As to the best way in which this may be brought about in practice, I venture to endorse the opinion of LORD ARMSTRONG, expressed in his recent paper on "Technical Education," and would repeat his words that "A man's success in life depends incomparably more upon his capacities for useful action than upon his acquirements in knowledge; and the education of the young should therefore be directed to the development of faculties rather than to the acquisition of knowledge, which may be deferred to more mature age." On a boy's leaving school, say at 14 or 15 years of age, and having evinced a preference for mechanical pursuits, let him at once be placed in contact with *work that is to be done*, so that the faculty of *seeing*, *doing*, and *making something* may be cultivated—that is, his eyes, hands, and intellectual faculties may be exercised from day to day. With a view to this, I prefer to start a youth on such work as pattern-making, joinering, moulding, forging, or smithing in engine works, or smithing, joinering, or model-making in a shipyard. The adapting and combining parts will come afterwards, naturally and easily—such as erecting of machinery and the building up of the various parts of ships which really depend, in all well managed works, more upon mechanical arrangement and accuracy than on individual power or faculty.

The individual, if wisely directed, while so engaged during work hours, will have been keeping up his studies during his leisure hours and, considering the short hours now worked, these are many. If you ask what should be the subjects of his study, I would say, Mathematics, Applied Mechanics, Heat, Electricity, Chemistry, Metallurgy, Graphics, Drawing, and, with these, on no account to neglect the study and exercise of modern languages—French, German, and Italian—for which purpose friendly association and conversation with persons of those nationalities will be found most valuable.

If it be desired to pursue further the higher branches of our profession by study in our colleges, for the reason before stated I prefer that this should be done *after* rather than before the apprenticeship in the workshop is over; then the mind is ready to receive and readily apply, because it perceives the practical bearing of the subjects, principles and laws expounded in the class-room or laboratory.

In all this time nothing is so important as the cultivation of habits of observation. The differences in men largely consist in seeing and not seeing what is going on around them. "Eyes and No Eyes" is an old children's story that might be read with profit by many of us who are only after all "children of a larger growth." Nine-tenths of our troubles, mistakes and inefficiency in office and workshop arise from the neglect of this faculty. That which we fail to observe is useless, or may be worse than useless, to us, whilst the observing of it would remove a difficulty, correct an error, restore efficiency, or open up as well as clear the way to new fields of action.

In the cultivation of the eye, the science of Graphics, or the representation of forces, results of experiments, calculations, or processes of reasoning or working, by means of diagrams, making such results visible to the eye, is perhaps one of the most important applications of Mathematics of recent years.

Similarly, I consider the power of sketching by hand the ideas, designs, and details of designs that constantly present themselves to the mind of the engineer or shipbuilder who has the spirit of his profession is one of the greatest powers he can possess. The late Robert Hawthorn and his brother William had this faculty largely developed. The mode adopted by these brothers in their earliest works was as follows (pumping and winding engines for collieries being in their early history, their chief work):—On ordinary foolscap sheets the work to be done was calculated and the size of boilers required, diameters of cylinders and length of stroke stated. The parts were sketched by hand alongside the calculations in sufficient detail to enable the millwright or pattern-maker to lay them down full size and to make the pattern for the founder. Copies of every part were hand-sketched on sheets of foolscap for the smith's and other shops. Every detail requiring explanation to the workman was thus sketched and afterwards the sheets were stitched together, forming to this day interesting records of how these, in their day, giants of engineering did their work, it is needless to say, in much less time than the modern draughtsman could do. I mention this principally to commend the practice to our younger members and to show what many are slow to believe and therefore seldom act upon in our offices, that to be able to sketch out freely on paper the design present to the mind is to have more than half completed the drawing to be laid down afterwards for purposes of detail, manufacture and record. Time is of the essence of every contract and of all places it is of greatest value in the drawing office; one day saved there is worth months afterwards and a profit to boot.

I think I may mention here a scheme which is being promoted by the Engineer-in-Chief of the Royal Navy—MR. RICHARD SENNETT—and which cannot fail to have great attractions for those of our young men who avail themselves of our colleges to enable them to pass an examination in science, or such branches of it as constitute the usual engineering course, viz., the selection of a number of engineers so qualified—about ten in each year—for appointment as Probationary Assistant Engineers (to rank as Sub-Lieutenants) in the Royal Navy. For such appointments, the applicants must have served a regular apprenticeship of not less than three years in an engineering establishment and passed through the regular course at a recognised college for education.

It appears to me this scheme is one of great promise for the future of all young engineers who care to qualify themselves for such appointments in the service of their country and it should provide for the Royal Navy a class of well-educated, practical men, accustomed to work and well acquainted with the construction of the machinery of which they are to take charge. It further opens up employment for many amongst us who, having mechanical tastes, have a difficulty in finding, at the end of their apprenticeships, situations suitable to their station in life in other respects. The regulations for these appointments will, I understand, be published shortly.

Next to observation by the eye, I would remind you of the importance of close and earnest reading of the scientific journals of the day. Nothing has struck me more when visiting other countries than the high value and importance attached by the Ministers and heads of government departments, as well as more subordinate officials, to the records and drawings published from week to week in *Engineering*, *The Engineer*, and other of our weekly journals, and this leads me to remark by the way to how few of us are the journals of other countries—in many cases most valuable journals—intelligible, or in a language we understand.

The man thus fitted becomes a "workman," whether with his brain, his hands, or both, and as such has the knowledge and capacity of personal responsibility for his work and to his fellows, whether the work be that of design, execution, or direction, by himself or in co-operation with others.

In the fulfilling of any of these functions the workman must have an accurate knowledge of the materials best fitted for his work, their proportions, strength and durability, and their adaptability and fitness for the purpose he has to accomplish. In this respect we have now great advantages over our predecessors. For instance, in our shipbuilding the substitution of steel for iron has brought with it the practice of continuous testing to secure uniformity of quality, so that now no steel or iron can be used unless its tensile and bending tests reach an accepted standard of strength. It has led also to the much more careful distribution of material, adjustment of riveting to strength of materials, and, to some extent, the proportioning of scantlings to the requirements of the relative strains. This latter question is still one of those requiring the careful attention, as part of his daily work, of the naval architect, inasmuch as arbitrary bodies like the Board of Trade and Lloyd's Committee, constituted as they are, afford little or no guarantee that the *best possible* is being done in this direction.

Much still is demanded of the naval architect with regard to the best form of vessel and the most sure method of ascertaining it for a given speed. Whether this is to be best done by the "experimental tank" or by the more slow and empirical method of calculation and progressive trials of similar ships is still by many considered open to question. I believe I am correct in saying that the experience of the British Admiralty in the establishment and use of the experimental tank goes to prove it to be of the utmost importance and value. The question of such a tank in this district and the more important one of the establishment of a Chair of Naval Architecture will form part of the work to be done by your College of Science Committee during the current session. The growing importance of our district as a shipbuilding centre demands that this subject should ever be kept before the minds of the members of this Institution and earnest steps taken to establish such a centre of instruction as will enable us to go on in progress, scientific and practical.

Many of us cannot forget the day when the building of a war vessel —by which I mean a vessel requiring the highest description of workmanship—was a rare event in this locality and the construction of the machinery of such a vessel was a work with which we were not to be trusted. Marine engineers located in these parts were only deemed capable of making machinery for a collier or "ocean tramp," whilst all work for war vessels must be delegated to our brother engineers on the

Thames. This state of things exists no longer. Vessels of the highest class for war purposes are constructed in our midst and it is only right and just to say that the most important advances in high-class machinery for such vessels and the production of the highest power on the least weight of material—so enabling the naval architect to design vessels of a speed and power previously unattainable—have had their earliest and fullest development up to the present time in the engineering establishments of Tyneside.

The same progress may be noted in other descriptions of vessels for commercial purposes. The development from the Screw Collier to the highest class of merchant and war vessels—combined as it is with the magnificent works of Jarrow—is due to the enterprise and energy of Sir Charles Mark Palmer and Mr. John Price (General Manager of the Company), one of the Council of this Institution, and those associated with them. The construction of the "oil ship," as it is now called has been made—most successfully in every respect—the speciality of another of our Vice-Presidents, Mr. Henry F. Swan. For Atlantic liners and first-class passenger vessels of high speed and best accommodation, the world has been accustomed hitherto to look to the Clyde, and perhaps justly so. A friendly rivalry now, however, exists between the two sides of the island. Many vessels of sixteen and seventeen knots have recently been delivered in this district, of unexceptionable finish and completeness, and now one of large dimensions, with a speed of eighteen knots, is being built, which as a passenger vessel will be equal to anything afloat.

To maintain our position and continue our progress it is essential that the men coming after us should be afforded all the advantages possessed by those of other districts in facilities for scientific training of the first order—hence my appeal for a Chair of Naval Architecture in our College of Science as a work of continuous effort until it is obtained. The College is now an established fact amongst us—thanks to the indomitable energy and perseverance of its Council and its Principal, Dr. Garnett. It has now a "local habitation and a name" and we would do well to make it the success which its Council deserves at the hands of our Institution and of the North-East district.

Before leaving this part of our daily work I would mention again—because of its, in my opinion, great importance—the subject of light engines and boilers combined with forced draught. A war vessel—the "Elisabeta"—built at Elswick and engined by the company with which I am connected, has just completed her trials. The vessel is 222 feet long, 33·5 feet beam and 11·5 feet draught. The engines are twin-screw, having cylinders 26, 40 and 57 inches diameter, with a 24-inch stroke and four *navy-type* boilers, having 6,650 square feet of heating surface and 214 square feet of grate surface. The displacement is 1,263 tons. Her speed on the measured mile trials, extending nearly four hours, was 18 knots with open stokeholds and 18½ knots with closed stokeholds. The indicated horses-power was approximately 5,000, and the total weight of the machinery and water was under 250 tons. Thus with a triple expansion engine, with navy-type boilers (*not* locomotive), strong cast steel framing, no working part loaded to any more severe strain than in an ordinary merchant engine, we have one indicated horse-power for 112 lbs. or 20 indicated horses-power per ton of weight. Engines with boilers of locomotive-type have given as high as 24 indicated horses-power per ton, but this machinery is the lightest yet fitted to any vessel, war or merchant, having boilers of the usual freely accessible navy-type, and it is of such a substantial character and design that any voyage may be undertaken without hesitation or fear of mishaps other than is incidental to the machinery of any other vessel.

It may be interesting and useful to compare the magnificent performances of two vessels recently added to our Royal Navy, with one of which we are immediately associated, H.M.S. "Victoria" and H.M.S. "Sanspareil," the machinery of which vessels was supplied by Messrs. Humphrys, Tennant, & Co., of London, with the performances of the Cunard liner "Etruria," of similar power, and the Elswick cruiser above mentioned. The contract power of the "Victoria" and the "Sanspareil" was originally intended to be 12,000 horses, but on their trials, conducted by Mr. Robert Humphrys—perhaps under the stimulus of a handsome premium—they attained a maximum power of 14,500 horses, on a weight of 1,100 tons, the heating surface of the boilers being [illegible] square feet and the grate surface 690 square feet. In relation of weight to power the comparison therefore will stand as follows:—

	I.H.P.		Weight of Machinery, including Water. Tons.		I.H.P. per Ton.
[illegible] Machinery for Merchant [illegible]	2,000	..	400	...	5·0
[illegible]	14,700	...	1,800	...	8·166
[illegible]	14,500	...	1,100	...	13·1
[illegible]	5,000	...	250	...	20·0
[illegible]		..	--	...	24·0

[illegible] the machinery of our war vessels, large and [illegible] is a subject of great interest to an increasing number of the members of this Institution at the present moment, and as it is naturally suggested by the above paragraph, I venture to digress a little from the special subject before me. Newspaper correspondents have great responsibilities and there is no class of men to which we are more indebted. They influence us in every aspect of our life, individually and nationally. One of these gentlemen remarked, in conversation with a friend of mine interested in torpedo work, not long ago, "I suppose you would like a war to break out with somebody, or somewhere; it would be a harvest for you?" "No," my friend replied, "I would *not* like a war, but I do, and would, like a good scare. Cannot you help in that?" Now, the stories of newspaper correspondents go very far often in raising and helping on a scare, notwithstanding the stories are, or may be based only on rumour, or possibly want of knowledge.

The conclusion to which we must come, if we are to accept all we have read lately, is that our fleet is almost worthless, and the vessels, and especially their machinery, absolutely untrustworthy; and that this particularly applies to the more recently constructed vessels, high-speed protected cruisers, torpedo gunboats, torpedo boat chasers and torpedo boats. The machinery of these classes of vessels being that which has for many years formed the leading part of my daily work, I have taken some trouble to find out if the stories were true, how and where the engines and boilers failed when put to the stress and strain of actual work, and I will ask you to pardon my departing from the ordinary form of an address while we look at this subject.

Largely due to the continued advocacy of LORD ARMSTRONG and those associated with him (notably Mr. W. H. White, formerly of Elswick, now Director of Naval Construction to the Admiralty), vessels of the high-speed cruiser class, with light machinery of great power, have become the accepted type of the larger proportion of war vessels for our own navy as well as for the navies of other countries, and in these vessels three great changes, incidental to their requirements, have been going on concurrently, viz.:—

1.—Forced Draught;
2.—Triple Expansion, with its attendant higher pressure of steam;
3.—High Speed of Piston and of Revolution.

These have rendered possible the attainment of great powers with small weight of machinery.

The changes and progress have, however, been so rapid in this, as in all kinds of marine engineering and in all descriptions of vessels, that many matters of minor detail, now found to be essential, have only been arrived at by experience in working—such matters, for instance, as the best system of lubrication, packings for pistons, piston and other quick moving rods, modes of adjustment, etc. There is a great tendency to credit a system with failure in consequence of a necessary attention to adjustment or a defect in detail which does not in the slightest degree affect the principle on which the system is based. It was unreasonable to expect that a considerable number of ships should be rapidly commissioned, with engine room complements to a large extent strange to the ships, a large proportion of the stokers freshly entered and untrained to sea-going duties, without the machinery requiring adjustment in its bearings, glands, etc., to make them fit for continuous steaming. Yet any stoppage for adjustment of any of the many hundreds of bearings has sometimes been reported as a serious detriment to the efficiency of the ship.

It cannot be too clearly understood, and should go forth from an Institution composed as this is of practical engineers, that incidents of this nature are inevitable to any and every kind of machinery or set of engines. It is only by continuous working, voyage after voyage, that our Atlantic liners have secured that immunity from accident or stoppage in mid-ocean for which these triumphs of engineering and naval skill are so justly celebrated.

So far as can be judged from the information published, which appears pretty full and complete, such defects as have occurred have arisen in the ships newly commissioned and were of the character mentioned, such as are always expected in new ships; and further, they were in no way attributable to the adoption of the principles either of forced draught working, high-speed, or light engines. This remark applies also to the various classes of *Ships* in the Royal Navy employed in the recent manœuvres. Reports have been published derogatory to some ships because they did not fulfil functions for which they were never intended and to which they could never in the nature of things attain, as, for instance, the discomforts of a small ship in a seaway being incomparably greater than in a larger ship. Yet this is complained of by one of our newspaper friends and the ship written down as an unseaworthy type of vessel.

In regard to defects in boilers, it is quite possible, indeed most probable, that, to meet the demands of the officer in charge of the vessel, the blowing fans may have been injudiciously used to effect rapid variations in the pressure and power of the boilers, which would severely strain them, and that through imperfect firing from want of experience, the grates have not been properly covered with fuel, when, with a considerable air-pressure maintained in the boiler room, the air rushing into the furnaces would be injurious to the tube ends and cause leakage, but this must not be attributed to the system, but to the neglect of a proper use of it.

Every new system that has been introduced into marine engineering has been attended by certain inconveniences at first until the people in charge had been "trained" to its proper management; we all remember the difficulties experienced in the introduction of higher pressures in the Simple Expansion Engine, the outcry against Surface Condensation and notably against the Compound Engine, even by Engineers of the highest eminence.

Whatever difficulties or defects may have occurred during the recent manœuvres are of a very minor character, such as must necessarily occur under the conditions, and there cannot be a shadow of a doubt they are such as will be eliminated in the ordinary course of working and with a little experience. The principles are right and details will soon be accommodated to the new conditions.

So much depends on the "human factor" in all questions of this nature that it is very doubtful if the present system of running warships at their most economical rate, which is very slow, when on their passages from port to port is at all a wise one. Clearly what is wanted is that the engineer officers of all grades should be made as efficient as possible and the most advantageous course to this end, even from an economic point of view, seeing that frequent manœuvres are very costly to the country, would be that all our warships should make their passages at full speed so as to accustom the engine room and boiler room staffs to all the exigencies and requirements of working their engines and boilers at full power and speed.

Considering the number of ships engaged in the recent manœuvres the mishaps were very few indeed and the performances reflect great credit upon their designers and the officers in charge and should give every confidence in the principles that have been applied to the development of warships' machinery, both in the British and Foreign navies, viz., high speed of revolutions, lightness of construction, and forced draught, which alone have rendered high speed in ships of moderate size possible. In connection with this question I would remark, regarding Admiralty contractors' trials, that much has been said as to their uselessness and unreliability. I cannot concur in such an opinion. They are of the utmost value in ascertaining maximum results for purposes of comparison of both ships and machinery, but they are much misunderstood and sometimes misapplied by officers in command. For instance, we read that H.M.S. "Mercury" made a passage of 300 miles in 17 hours, or nearly 18 knots per hour. Now this was never intended. It is true that in her trials she made 18$\frac{3}{4}$ knots. The captain, knowing this, did his best to realise it when on service-duty and she did her work well without mishap up to 18 knots, but her real sea-going speed is 16 knots and to that she should have been kept. Contractors' trials, as required by the Admiralty, are *emergency* trials under forced draught pressure of two inches of water, but the full power at sea for continuous running is considered to be that due to an air-pressure of a quarter to half inch of water [that is, in most ships, about double the funnel draught] and at this rate there can be no question the engines and boilers of our warships could be as safely worked at their sea-going full power as any merchant vessel for as long a time as their coal supply lasted.

I fear, gentlemen, you will think I have departed altogether from the text on which my remarks were to have been made; not so, however. My course in this matter is very like that we pursue in our own homes and by our own firesides. We should not then talk "shop" and we apologise to those nearest and dearest to us for doing so, but the friend of our daily work comes in and we go back to the shop, yes, as naturally as the sunflower to the sun; we cannot help it and it generally happens that it is our own shop and our daily work in it. Thus you see the naturalness of the large digression I have made, I trust not altogether unacceptably to you.

Fitness demands EXERCISE or WORK. "The first necessity of man is to live and his first duty is to work," said Lord Salisbury on a recent occasion, and work demands FIDELITY.

In engineering and shipbuilding, fidelity, or faithfulness, embraces everything and everybody with whom we have to do. A great writer has said "The best security for the fidelity of men is to make interest coincide with duty." This is by no means the highest motive to duty, but, in the present state of society and man's imperfection, it is probably strictly true and indicates the direction in which it is our wisdom to go.

The interests of our client, the shipowner, we should make our own. I do not mean in the way of *financial* facilities, but that we should make ourselves acquainted with his wants and the necessities of his trade, so that our work when completed may faithfully meet his intentions and give him the satisfaction he has the right to expect for the money he invests in paying us for our work.

He finds, as he cannot see to all details himself, that it is necessary to appoint a representative or inspector and in addition he has the inspectors of the Board of Trade, of Lloyd's Register, or the Bureau Veritas.

This all has the appearance of suspicion and a low appreciation of the fidelity of the shipbuilder or engineer. It is not so, however, in any bad sense. The owner's inspector is merely the representative of himself and is a most useful auxiliary to the contractor in making sure of the wishes of his client and relieving himself of certain responsibility. The inspector should be, and generally is, an engineer and naval architect in the fullest sense of these words. He has generally to advise his "owner" on the form, construction, and outfit of the hull, and also the power required and the details of the machinery.

For this duty it is clear he must be fully equipped scientifically, practically and commercially, if he would secure and retain the confidence of his client the shipowner and the respect due to his office from the shipbuilder. The working of the vessels, from the standpoint of greatest interest to this Institution, is in his hands. Many of our members, we are glad to say, hold such positions with credit to their profession, and I take this opportunity of asking them to favour us with papers giving the results of the working out of the many problems in relation to engineering and naval architecture which come before them in the discharge of their important duties. The manufacturing engineer and shipbuilder have little opportunity of observing the effects of their joint efforts in the working of the vessel and her machinery. The inspecting engineer has always the results before him and if he chose could aid very much in the solution of many questions of interest to this Institution.

It is considered necessary to the security of the lives of passengers on board ship that the regulations of the Board of Trade should be faithfully complied with. This is most desirable and proper. The law is not made for the righteous, but for the sinner. Many of us are most anxious to do the very best in the interests of the public, but, unfortunately, are much hampered by the interpretation and hard rendering of regulations intended by the legislature to be elastic, and the want of harmony between the regulations of the Board of Trade and those of Lloyd's Committee on the same questions is a constant source of irritation and trouble.

The rules of these institutions are in most cases binding upon engineers and shipbuilders and in this age of progress and advancement it is necessary that they should possess sufficient elasticity to adapt themselves to circumstances which are continually changing. It is a well-known fact that if an adherence to these rules had been required in our war vessels we should now be without many of our swiftest and most efficient cruisers, which vessels have done and are doing their work well under all the ordinary conditions and exigencies common to other vessels and in all parts of the world. How is this unsatisfactory condition of things to be modified, if not altogether changed? In my opinion, what is wanted and what must sooner or later be done, is the appointment on the governing bodies of these institutions of the highest Technical talent to be found in the kingdom. If there were appointed annually on these bodies some of our leading engineers and shipbuilders their rules would, without doubt, give greater satisfaction and would certainly inspire more confidence than any rules can when they are formulated and devised by a few unchanging professional advisers, however competent they may be.

I make these remarks not in any spirit of antagonism to the gentlemen who now guide the destinies of those institutions (and to a great extent our own destinies also), who very rightly are highly respected and who do their work in as efficient and satisfactory a manner as is possible under the rigid system upon which those institutions are based.

Your Council has appointed a deputation to act along with one from the Institution of Engineers and Shipbuilders of Scotland and the Institution of Naval Architects of London in making a representation of our views to the Committee of Lloyd's Registry. Their views are on the lines I have indicated; let us hope the Committee will endeavour to meet them at the earliest date possible to the conditions of its constitution.

It was my intention to have proceeded to the consideration of our daily work in our workshops and yards; our associations and relations to each other; the utilisation of our machines and appliances to the greatest advantage in the production of work of the most perfect accuracy; but this address is already too long, and these branches of our daily work may well be made the subject of a paper for discussion.

We have spoken of our daily work and what it demands of us in relation to its material or professional aspect; but, gentlemen, there is another side to this question, that, namely, which relates us to our fellows engaged in the same or similar daily work. Those of us whose work is mostly done by the hand or by physical exertion are often wearied with the day's work and it may be they often long to be free from it and have what they deem to be the easier part of the work; but depend upon it the strain and stress are very fairly divided. He of the headwork is wearied and worried by what he considers the thoughtlessness, the selfishness, the stupidity and the wrong doing of those of his own class with whom he is in daily competition, or perhaps of those over whom he is placed to direct and from whom he expects devotion and service. And again, he of the hand work chafes under what he thinks to be the arbitrariness and heartlessness of those under whose direction he daily works. To him it is often the experience of "groaning under oppression" and he determines on a struggle to be free, to be better paid, to work shorter hours. He is quite right to do so if he likes; but either with the one or the other class the result is the same—vanity and vexation of spirit. On both sides, the welfare, happiness and good success depend on the exercise of the spirit of brotherhood and mutual regard, of charity in "hoping and bearing all things," of mutual forbearance and gentlemanly consideration of others as well as and not *only* of ourselves and our own shortlived interests. The progress and wellbeing of all, the greatest good of the greatest number—these are platitudes to which we are accustomed, but it is none the less true they must be our object and aim in life if we would meet all the demands of OUR DAILY WORK.

Mr. W. Boyd (Past-President) said, he had been deputed to ask them to join with him in a vote of thanks to their President for his address to them that evening, and he need not say that it gave him the very greatest pleasure to discharge that duty. He was quite sure that he spoke the feelings and opinions of all those who were present there that night in addressing himself to the importance and value of the address to which they had just listened. It was in some respects a very remarkable production, for although some of them perhaps might not agree with all the points touched upon in it, yet he was quite sure they would all agree in the breadth, and fearlessness, and boldness, with which his friend Mr. Marshall had touched upon many points of very great interest and very great difficulty to the profession to which they all belonged. The points to which he had alluded were so numerous that it was impossible to touch upon them all, and it was, of course, to a certain extent unusual to treat an address of this sort in the way in which one would discuss an ordinary paper. The matter had to be approached in a different way, and yet, at the same time, he thought it would be hardly suitable that they should separate that evening without some expression of satisfaction and pleasure at what they had just heard. There were two points in the address which attracted his attention more particularly, though, of course, there were very many others. He entirely wished to endorse the remarks made by Mr. Marshall with regard to what was called technical education. He thought that Mr. Marshall had certainly struck the right nail on the head in calling attention to the necessity or advisability of their lads coming into the workshop before endeavouring to train them afterwards to a greater extent in schools and colleges. The question seemed to resolve into this: What has been the complaint of the last few years, and what is the complaint to a certain extent to-day? It was want of employment for their unskilled labour. Skilled labour in all ordinary times can easily find employment; and he thought that the efforts of those who moved in this matter should be directed to endeavour to increase the number of boys who were taught a trade to increase the ranks of the skilled workmen, and thereby decrease the ranks of unskilled labour, and thereby remove as far as possible the causes which make destitution when trade is deficient. Now, this was best done by inducing all young lads who had the tendency, or anything drawing them in this direction, to go into the shops. The tendency, no doubt, was to make office men of them; but it appeared to him that the efforts of those interested in these matters should be directed more to making skilled mechanics of them, and giving them a scientific training at a later stage. Mr. Marshall, in a great many other very interesting questions, had alluded to the very remarkable results which had been obtained in the way of light engines in the twin-screw vessel "Elisabeta." It was purely a technical and scientific question, and he should be very pleased indeed if it could be made the subject of a discussion on some future evening during the session. It was alluded to, to a certain extent, he thought, at the close of the session before last, in May, 1887, when Mr. Hall read a paper on compound and triple expansion engines, and the extent to which it was possible to introduce these light engines into the mercantile marine was then very fully dealt with. He remembered on the last occasion Mr. Marshall was unhappily absent, and though he could not profess to remember the figures given that night, he (Mr. Boyd) ventured to take exception to some of the statements that were put forward then, and he ventured to express the opinion that it was dangerous to expect to carry this system of very light screw engines into the mercantile marine—at least it could only be carried to a very modified extent. Mr. Marshall had addressed himself that night to shipowners, and that had more particularly called his (Mr. Boyd's) attention to the question. It was true that by the introduction of assisted draught, with which their friend Mr. Fothergill had had very great experience, a very great improvement had been effected, and his own experience went to show that something like an increase of 20 per cent. in the power of any good set of engines could be derived with a very moderate and very safe employment of assisted draught, and that, consequently, the weight of engine per indicated horse-power would be reduced from something like 450 lbs. per indicated horse-power, as given in Mr. Hall's paper, down to something like 350 lbs. per indicated horse-power; but that was a long, long way from what was indicated by Mr. Marshall that night, and he thought they would be liable to be led astray if they got the impression that anything approaching the results obtained in the war vessels more particularly alluded to could be obtained in the ordinary practice of sea-going vessels, and therefore he would commend it to the consideration of the Council and to the Secretary whether an effort might not be made to obtain further discussion and elucidation of this very important subject some evening during the coming session. He had perhaps spoken too long, and perhaps beside the question, but from his own experience in the presidential chair he remembered that nothing was more unsatisfactory than to have one's efforts passed over with a very simple and very perfunctory vote of thanks, and he thought he should be in accordance with the feelings of Mr. Marshall in giving evidence that some of the thought and some of the care that he had expended in preparing the address delivered to them that night, had been thoroughly appreciated by those present. He begged to move a vote of thanks to Mr. Marshall; but before putting it, he was quite sure some other gentlemen would wish to speak to the same resolution.

Mr. H. F. **Swan** said he had been asked to second this vote of thanks to the President, and had great pleasure in rising to do so. He had had the pleasure of knowing Mr. Marshall for a very great number of years, and of being associated very closely with him in many of the successes that had been turned out of this river. He had had special opportunities of observing the great care and attention and the very high talent which Mr. Marshall had been enabled to bring to bear, especially in many of the war vessels that had been constructed on this river during the last twenty years. He well remembered the time mentioned in Mr. Marshall's paper when it was considered that the engineers on the Tyne were not fit to produce engines for a high-class vessel; and his late firm had very often, even for what they would now look upon as a very ordinary merchant vessel, to go to London to get machinery. However, as the French said, "Nous avons changé tout cela;" and to-day the boot would be on the other leg. It would just be as likely for southerners, or any other district in England, to come here with the greatest confidence to get their machinery; and he said, without fear of contradiction, that there was no man in this neighbourhood to whom was more due the great credit of this change than to their worthy President. He had therefore great pleasure in seconding the vote of thanks to him for the very able address which they had just heard.

Mr. **Doxford** (Past-President) had very great pleasure in rising to support the motion placed before them. He thought they would agree with him when he said that the address they had just heard helped to confirm them all in the opinion which they had formed at the time that they elected Mr. Marshall as their President. They then felt they were electing the right man in the right place, and after that night they would be sure of having done so. There were one or two points he wished to refer to. He (Mr. Doxford) would like to emphasise what Mr. Marshall had said in connection with the Chair of Naval Architecture at the College of Science and the experimental tank. Fortunately, circumstances were very much changed within the last few months, and they were more likely to be able to get over the great financial difficulty which last year and the year before was staring them in the face whenever they talked about the Chair of Naval Architecture and the experimental tank. Probably the times would continue to improve, so that during Mr. Marshall's presidency they might have the honour and pleasure of getting that Chair finally established, even if they were not able so soon to build the tank with all its accessories. Success in these matters would be of immense benefit to this district, and would help to establish the position of this Institution, Then there was the question of the Mining Institute and the forced draught experiments. That question was before them last year, but there were no definite steps taken. He hoped their President would find time to push the question with the Council of the Mining Institute, for much would depend upon his personal efforts. Mr. Boyd had referred to one subject in the address which he would also like to refer to, viz., the question of "indicated horse-power" in proportion to the weight of machinery. According to the figures given by the President, there was room for considerable reduction in the weight of machinery for ordinary vessels. Although not a practical engineer, he felt they would have to be very cautious what steps they took in that direction. In the figures given comparing the "Victoria" with "Etruria" it struck him that possibly the horse-power given of the former would be that developed on the run over the measured mile, whereas with the "Etruria" it would be the horse-power developed day after day across the Atlantic.

Now, if the horse-power were taken at which those on board the "Victoria" would feel justified in running at continuously for six or seven days, probably the apparent difference between that vessel and the "Etruria" would be very much modified. He (Mr. Doxford) agreed with Mr. Boyd that this subject was of so much importance that they should if possible have a paper during the present session upon it, so that the matter might be thoroughly discussed. He had very great pleasure in supporting the motion.

Sir B. C. **Browne** had very great pleasure in adding his word, whatever it was worth, of thanks for the satisfaction they had had in listening to the President's paper. Of course it was one that opened out a field of discussion, and the only point on which he (Sir Benjamin) could speak with special interest was that which related to the possible institution of the Chair of Naval Architecture and Engineering at the College of Physical Science. There was no doubt that in this matter—call it what they liked, "technical training" or anything else—they must always be working forward and further on and on. What was sufficient last year was not sufficient for the next year, and no doubt when they had a College like that it was most important that they should have a thorough grip on it, and to see that the most important industry in this district was represented. Of course in doing so it was very important that they should bear in mind the necessities of the College. He hoped in these days the College was going to have less trouble, on financial grounds, than in times past; but whether or not, in having a College they must have a well-defined scheme, and whatever was done they ought not to be a drag upon, but rather a help to the general work of the College. They must not think that if they gave 15s. to the College they were to get £1 out of it. What they were asked to do was not only for their special scientific requirements, but also to bear their part in doing the general work of the College itself. The College was open for the teaching of Naval Architecture and Engineering amongst other things, and therefore those who were to get the benefit should bear a general part in the cost of the fabric. He would like them to look at it in this light. He (Sir Benjamin) had been connected with the College for a considerable time, and was sure that by economy and by the attention of practical men a very great work might be done.

Prof. **Garnett**, being invited to address the meeting, said he supposed the honour had been given him of speaking in support of this resolution in order that he might say a word or two in connection with the work that had been done by their Committee towards the developing of the engineering side in the College of Science. Firstly, he thought he should not be betraying any confidence if he said that he had reason to believe that in the new scheme to which the President had alluded, with reference to the entrance of engineers into the Royal Navy, there would be a certain number—a small number—of colleges singled out at which attendance for a certain period would be accepted as evidence of a suitable college training, so that the candidate for the examination having to show that he had gone through an apprenticeship for a certain number of years at the works, and also through a college course, the certificate of the professors would be accepted as proof of the latter, and if the professorship was founded he had reason to believe that the College in Newcastle would be one of those few institutions. Then with reference to what they would get out of the College, supposing that this Institution were to undertake the whole of the responsibility of the engineering side. If they paid their 20s. to the College he hoped they would get 20s. out of the College from the engineering department alone; but there already existed departments of mathematics, chemistry, physics, geology, and other subjects, all of which were of advantage to the engineer, and if an engineering college had to be started *de novo* in the town it would be necessary to incur an additional expense for the teaching of these various subjects, and for providing the teaching staff with a laboratory and apparatus, all of which had been provided and were now in existence in the College of Science. It would be necessary, he was afraid, for the engineers to find, practically, the whole of the means required for the endowment of this Chair.

The PRESIDENT—How much?

Professor GARNETT—Of course that depended upon what was decided as a suitable fixed income for the professor. There would be his fees to supplement his fixed income; but he imagined to get a good man they ought possibly to provide a fixed income of something like £500 a year, and then the fees would go partly towards the payment of the professor, and supplement that sum. He thought that was about the position of affairs, for he might say that the present financial condition of the College was such that he had to go to one gentleman and tell him they were so dreadfully short of money that they would be obliged to him for the fire-bricks to build a boiler seat; and having got 3,000 fire-bricks for the boiler, he went to another to get the bricks for the shaft, and then begged a lightning conductor, or rather the copper wire and terminal to make one. Indeed he had to spend a great amount of his time in begging in that way, and scheming how to get 20s. worth of work done at the cost of 7s. 6d. He had great pleasure in supporting the resolution.

Mr. **Boyd**—Unless any gentleman wished to make any further remarks he now took it upon himself to put this resolution to the meeting, and ask them to carry it with acclamation.

The resolution was carried with acclamation.

The **President** acknowledged the very cordial manner in which they had thanked him for the address which it had been his privilege, in a very imperfect way, to deliver to them that night. He believed Mr. Boyd said on one occasion he could heartily sympathise with Mr. Doxford in the preparation of his address. He (the President) would also claim his sympathy, and add even for a very imperfect address. Mr. Boyd in his kindly criticism mentioned one or two things in connection with the address which he would like to say a word about. Regarding the question of weight in relation to power developed in merchant and other vessels, and taking it as recorded on page 22, they saw the difference was largely in favour of the "Etruria," which was a merchant vessel. He thought they might say that there was not such another vessel afloat for doing work. Her machinery was doing the best and most severe work going; and, therefore, taking it as a fair type of what could be done in the way indicated, the machinery of the "Etruria" was doing double the power on the ton of material of any ordinary merchant vessel, and this obtained simply by running her pistons faster—that was all; and here they had one of the severest works on any machinery afloat being done regularly, six to seven days continuously, without interruption or slightest hitch or difficulty. They never heard of the "Etruria" stopping until she got to port. He (the President) therefore thought it would be wrong of them stopping where they were, and Mr. Boyd would pardon him saying so. They were doing 4 horse-power, and the "Etruria" 8 horse-power per ton of material. Of course she was a larger vessel, and had a larger allowance for her machinery; but there was a considerable margin where they could advance. He did not say they would jump up to the "Elizabeta's" speed, it was quite impossible to maintain that for any length of time—300 or 400 miles on an emergency. These were emergency trials, and not meant to be regular trials. He pointed them out here as *the possible*, and he thought they were not worthy of their profession if they did not aim at the possible, and get the highest results they could. He was rather disappointed that none of the gentlemen who had spoken on this vote had mentioned the subject of the new project for the supply of engineers to the Royal Navy.

It seemed to him to be one of the most important steps taken by the Government in connection with the service. It would have the effect of removing what had always been a dificulty in the service, viz., the rank and status of engineers. By this scheme they would have elected from the colleges and workshops a large number of their best trained and educated pupils and apprentices who had equipped themselves for positions ranking equal to any other in the service. Ten would be required every year under present conditions, and more as time went on. He looked upon it as one of the greatest steps ever made in connection with the engineer officers of the Royal Navy, and he thought they ought to give it every encouragement possible. With reference to the colleges approved, he might say that Newcastle was one of the colleges the diploma of which would be accepted by the examiners. He thanked them heartily for the patience with which they had listened to his address, and the cordial way in which they had received it. He had again to express the hope they would not leave him in the position that Mr. Doxford indicated, viz., to do the work himself. He would do the best he could, but claimed and asked their hearty assistance to make the Institution a success during the current session.

After a reminder in regard to the arrangements for the forthcoming meeting at Hartlepool, and announcing that Mr. John Price, of Jarrow, would read a paper on "The Use of Machinery in Construction," the meeting terminated.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIFTH SESSION, 1888–89.

PROCEEDINGS.

SECOND GENERAL MEETING OF THE SESSION, HELD IN WEST HARTLEPOOL, ON SATURDAY, OCTOBER 20TH, 1888.

VISIT TO THE HARTLEPOOLS.

In response to the kind invitation given by the Members resident in the Hartlepools, their Worships the Mayors of Hartlepool and West Hartlepool, and other influential gentlemen, the Institution visited the Hartlepools on the afternoon of Saturday, October 20th, and inspected the various shipbuilding yards and engineering works in that neighbourhood.

For the convenience of the Members, a special train from Newcastle and Sunderland was timed to arrive at Hartlepool at 2·40 p.m. On arrival, the President, Council, and Members were met at the Hartlepool Railway Station by the following gentlemen, who formed the local Reception Committee:—

THE MAYOR OF WEST HARTLEPOOL (W. GRAY, Esq.)
THE MAYOR OF HARTLEPOOL (T. RICHARDSON, Jun., Esq.)
T. RICHARDSON, Esq., M.P.
G. H. BAINES, Esq., Central Marine Engine Works.
J. BLAND, Esq., General Superintendent, N.E. Railway Co.
A. GLADSTONE, Esq., West Hartlepool Iron and Steel Works.
M. GRAY, Esq., Messrs. W. Gray & Co., Shipbuilders.

R. Irvine, Esq., Messrs. Irvine & Co., Shipbuilders.
G. Jones, Esq., Manager, Messrs. W. Gray & Co.
A. Leckie, Esq., Surveyor, E.C. Insurance Association.
D. B. Morison, Esq., Manager, Messrs. Richardson & Sons.
T. Mudd, Esq., Manager, Central Marine Engine Works.
R. Murray, Esq., Engineer, N.E. Railway Co.
J. L. Petersen, Esq., Marine Surveyor.
W. Richardson, Esq., Messrs. Richardson & Sons.
G. W. Sivewright, Esq., Manager, Messrs. Withy & Co.
W. Thomlinson, Esq., Seaton Carew Iron Works.
H. Withy, Esq., Messrs. Withy & Co., Shipbuilders.
J. R. Fothergill, Esq., Member of Council, *Hon. Local Sec.*

The afternoon was spent in visiting the following works (for description of which see pages 61-68):—

Messrs. E. Withy & Co.'s Shipyard.
Messrs. T. Richardson & Sons' Engine Works.
The Central Marine Engine Works.
North-Eastern Railway Co.'s New Graving Dock.
Messrs. W. Gray & Co.'s Shipyards.
The West Hartlepool Iron and Steel Works.
The Seaton Carew Iron Works.

Other works were also thrown open for inspection.

At 5·30 p.m., by the kind permission of Colonel Cameron, the members and visitors—231 in number—were entertained to dinner by the local Reception Committee in the Armoury, West Hartlepool. William Gray, Esq., the Mayor of West Hartlepool, presided.

At 7·30 p.m. the second General Meeting of the session was held in the Central Hall, West Hartlepool. William Gray, Esq., Mayor of West Hartlepool, took the chair and welcomed the President, Council, and members of the Institution in the following address :—

W. Gray, Esq., the Mayor of West Hartlepool, said that in his official capacity as Mayor of that borough he had been asked to address a few words of welcome to the members of the North-East Coast Institution of Engineers and Shipbuilders on the occasion of their first visit to the Hartlepools. He believed that deeds were more expressive than words, and he was glad to hear that they had afforded a hearty welcome to them that day. If any words of his would add to that welcome, he would readily say them. They were pleased that the Institution had expressed satisfaction at what they had seen that day. They had seen the seats of some of the industries in the Hartlepools. Had time permitted, they could have shown them saw mills that turned out cut wood of all descriptions, cement works and paper-pulp works, which were about to be increased, and one of the greatest curiosities to be seen in any seaport in England, namely, a place for the reception and curing of eggs. This might seem to be a small matter; but it was not so small when they thought of the fact that within the last twelve months the Hartlepools had imported nearly 12,000 tons of eggs. A friend had devoted time, and calculated the number for that weight; he assumed each egg to weigh 2 ounces, being 8 eggs to the pound, which gave a total within the last twelve months of about 204,000,000 eggs. He merely mentioned that to show that they were not altogether confined in their industries to engineering and shipbuilding, but that they descended to more minute articles than ships and engines, and did not even despise eggs. It was unnecessary to detain them to say anything about the Hartlepools, as it had been dealt with at some length at the dinner. The speakers, however, could not go back beyond nineteen or twenty years, although Mr. Marshall spoke of what was thirty years ago. He could go back forty-four years; it was exactly forty-four years this month since he made his first appearance at old Hartlepool. It was just then emerging from the position of a fishing village to a place for the shipment of coal. The population of Hartlepool at that time was something like 6,000 inhabitants. West Hartlepool did not then exist. He saw the first sod turned over in commencing the formation of those magnificent docks they had seen that day; and during one man's lifetime he thought a very great deal had been done in that town. In the mother town of Hartlepool there were now some 17,000 inhabitants, whilst at West Hartlepool there were 38,000. In the various establishments that they had visited that day wages were paid weekly to the extent of some £11,000 or £12,000, and from figures of such magnitude they would see what a very large number of families were dependent upon their industries. He did not desire to weary them with more statistics; he knew they were very anxious to proceed to the more immediate business of the meeting. His duty was therefore completed by giving them a very hearty welcome on this their first visit to Hartlepool. As that meeting had been so successful, he thought similar meetings should be held—say bi-annually—on the Tyne, Sunderland, Hartlepools, and the Tees. If they came every year to the Hartlepools, he could assure them of a hearty welcome. As a new member of the Institution, he could not say much; but as a member of Lloyd's Committee he could say that institutes of that kind were looked upon very favourably. They brought out the talents of young men, and improved the building of ships and engines, a result which Lloyd's could not fail to take a deep interest in, and they rejoiced exceedingly at the establishment and success of such institutions. They must not forget either, that there are other ports in addition to the North-East Coast which they had to compete with; and if they could strengthen their position by means of such institutes, it would enable them to hold their own against any part of the world. He would now give place to the President of the Institution, who would conduct the business for the remainder of the evening.

The President, F. C. Marshall, Esq., then took the chair.

The President said he was sure he expressed the sentiment of every member of their Institution when he said they sincerely thanked the Mayor of West Hartlepool, the Mayor of Hartlepool, and the Reception Committee for the very cordial and most hospitable manner in which they had invited them, and the handsome way in which they had been treated since they arrived in Hartlepool. They had in every way enjoyed their hospitality to the full, and it had been no scant hospitality. He believed they had all enjoyed an extremely good dinner, and so far as the reception of the Institution as such was concerned, they were all extremely gratified by the kind remarks which the Mayor of West Hartlepool had been good enough to express. The enthusiasm and genuine kindness and consideration with which the Institution had been received was most gratifying. They had had not only the hospitality of their good friends, but they had had that intellectual and professional feast which was afforded them during the course of the afternoon by the inspection of the several works which had been thrown open to them in no stinted measure. He spoke as President of the Institution. He was sure that they would pardon him, being the medium of the sentiments of those members from the more northern part of the Institution's operations, when he said it had been to everyone of them an occasion of the very greatest interest and of pleasant stimulus. Some of them in the north had thought that, seeing the Tyne was the birthplace of engineering almost, of locomotive engineering especially, and to a large extent of the development of the more recent phases of marine engineering, they had a feeling that they were *par excellence* in the front rank of marine engineering. He was not quite sure that everyone of them had that proud feeling that night, personally, he must say the sense of satisfaction with which he had hitherto regarded his professional association with Tyneside was to-night much qualified and tempered; and he certainly felt proud that the Institution, over which he had the honour to preside, had a more extended range of influence, and embraced within its title of North-East Coast Institution of Engineers and Shipbuilders the districts of the Hartlepools and Tees, possessing works of the magnificent character to-day witnessed, for they had no establishments on the North-East Coast more complete or more admirably fitted for the efficient production of marine engines and ships than the two establishments they had had the honour of visiting that afternoon. They would presently have an opportunity of hearing from Mr. Price, a member of their Council, some of the advantages of machinery against hand labour. They had had the principle most marvellously exemplified before their eyes that day, the class of machinery witnessed, the work being done, the quantity as well as the quality of the work being all that possibly could be desired in marine engineering works. They had not seen the same amount of labour-saving appliances in the building of vessels at the yards they had been privileged to visit that afternoon, but he was sure they would all go home, as their Past-President had said, it might be sadder—well, perhaps not sadder, but certainly they would go home more thoughtful and wiser men, and he did not know but what the tool makers of England would soon receive very large orders. The members of the Institution had largely availed themselves of the invitation, and had enjoyed themselves immensely, both intellectually and physically, and he would again thank the local Committee most sincerely for their great kindness and hospitality. The suggestion of the Mayor of West Hartlepool regarding a bi-annual visit of this nature to the various towns he had indicated would receive the most cordial consideration of the Council of the Institution, and probably they would again, in a short period, avail themselves of the invitation the Mayor of this borough had been good enough to offer them. Again thanking the Committee for their reception, they would now proceed to business. He would therefore call upon the Secretary to read the minutes of their last meeting.

The SECRETARY read the minutes of the Annual Meeting, held in Newcastle-upon-Tyne, on October 3rd, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Sir B. C. Browne and Mr. H. F. Swan to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Buchanan, John H., Lloyd's Register of Shipping, West Hartlepool.
Cornish, H. P., c/o Messrs. Wigham Richardson & Co., Low Walker.
Davison, A. J., Rosedale, Wallwood Road, Leytonstone, Essex.
Hake, G. A., 129, Park Road, Newcastle-on-Tyne.
Mather, Charles, 3, Choppington Street, Newcastle-on-Tyne.
Potts, Robert, 11, Mount Pleasant, Deptford, Sunderland.
Price, F. D., 6, Osborne Villas, Jesmond, Newcastle-on-Tyne.
Smith, Thomas, Steam Crane Works, Old Foundry, Rodley, near Leeds.
Towers, Edward, jun., 4, Latimer Street, Tynemouth. (Late Graduate.)
Young, J. D., 3, Broughton Street, Tynemouth.

ASSOCIATE.

Towers, Edward, 4, Latimer Street, Tynemouth.

Mr. John Price then read the following paper "On the Use of Machinery in Construction":—

Mr. Price prefaced his paper by observing that the object of the paper was not to show up machinery as against hand labour, but the advantages of machinery in conjunction with hand labour. He thought it was wise to make that preliminary observation.

ON THE USE OF MACHINERY IN CONSTRUCTION.

BY JOHN PRICE, ESQ., M.I.C.E., M.I.N.A., MEMBER OF COUNCIL.

[READ BEFORE THE INSTITUTION, OCTOBER 20TH, 1888.]

THE use of Machinery in Construction has three main objects in view—accuracy in execution, facility in production or repetition, and cheapening of cost.

The demand for machinery in construction arises generally from these considerations, and it is in relation to the last of these that I purpose treating the subject, and without further reference to other causes for the employment of machinery than admitting that they exist.

Exactness and exhaustless energy in machine tools are too largely used to need any advocacy from me, and the importance of cheapened production needs hardly more, and it is less as a general principle that I call attention to it now, than as a resource available to the engineer and shipbuilder in the competition he has to meet from one or two directions.

In competing with foreign countries in constructive works, the machine tool is the English manufacturers' main resource, and may be taken as embodying his experience and as marking his progress. So soon as the English machine tool maker ceases to be fully employed on new tools for home use, so soon may the English manufacturer retire from the front rank in constructive skill, as to the three essentials which lie at the foundation of his business ; and which in turn are the foundations of scientific progress.

There are other directions in which competition is to be met by the employment of the machine tool, but it is more directly interesting to us now to look at a result of machine labour in the effect it has had upon hand labour, and the effect it may yet have.

Skilled and unskilled labour constitute undoubted bases of national wealth, hence it is desirable to make the purchasing power of so much of this wealth as may be used, as great as possible.

The higher skilled labour becomes, the finer the quality of the wealth it represents, and the greater the useful area it may be made to cover, and it is equally true that machinery in unskilled hands is an efficient means of producing skill. Hand labour and machine labour are growing more inter-dependent day by day, and cannot be entirely divorced, though occasionally serious differences arise between them. Capital, which weds them, is interested in preserving their relationship, and settling its conditions. Had capital been indifferent to these relations during the past fifteen years, English manufacturers and English workmen would ere this have exclaimed "Ichabod" over many a factory, and many a home.

It is impossible in the brief survey of a short paper to deal fully with the question of the relative position of capital and labour (*i.e.*, machine labour and hand labour) to the nation's present position in skilled construction. I can, however, offer some evidence as to the steady and silent evolution of the above propositions over the past fifteen to seventeen years.

Taking 1871-3 as a starting period, there has been a steady rise over the period from that date to the present month in the cost of hand labour of almost all kinds.

In the various branches employed in marine engineering, I find this to be equal to a permanent average increase, including day labourers, of over 21 per cent., ranging over the more highly skilled branches from 38 per cent. paid to pattern makers; to over 29 per cent. to fitters; and 27 per cent. paid to smiths.

Within the same period there have been two large enhancements of the cost of the marine engine and its boilers, the first in passing from the injection condenser types to the surface condenser type, and amounting to probably an increased cost of 20 per cent., the second in passing from the latter type to the triple expansion type, amounting to a probable total increased cost of 35 per cent., including the first enhancement; and yet, notwithstanding the increased cost of labour and the enhanced cost of the engines and boilers in passing from lower to higher and more costly types, the use of machine tools in our and kindred trades has brought down the total cost to-day to less than the total cost in 1865 or 1871, notwithstanding that labour has increased 21 per cent.

Indeed, taking two equally busy periods, namely, 1873 and 1882, I find the total cost of the compound engine per N.H.P. over 24 per cent. less in the latter period than in the former; the cost per N.H.P. for hand labour being reduced—principally by employing machine tools—by as much as 35 per cent.

The effect of the permanent increased cost of hand labour and its constant increase is shown in the increased percentage which it bears to the total cost of every engine, whether of the compound or triple expansion types, notwithstanding the larger use in the higher types of more costly material.

Taking the following years as representing periods in which the different types of engines were made, I find the percentage cost of hand labour in the total cost of the engines and boilers was in—

1871	from 25 to 27	per cent.
1882	„ 28 to 29	„
1885	„ 30 to 31	„

The variations between the percentages given for each period arises from differences in size of engines, or in specifications.

There is thus a steady and constant increase in the cost of hand labour. The rises and falls to which it is liable are not equal, the fall never reaches the average lowness that prevailed before the rise. The cost of materials on the contrary tends downwards through the agency of cheaper processes and machine labour, and it is only manual labour that does not accommodate itself entirely to the periodical demand for cheapness, but hedges itself in with its skill and with its combinations, and proves at times inaccessible to reasonable approaches.

So long, however, as skilled labour is equal to the demands made upon it, it remains to the manufacturer to make it go as far as possible in alliance with the machine tool.

I will show how this has been effected already in the following manner. The average artizan in the whole of the classes in an engine works as a producer of horse-power was equivalent in 1873 to 2·0, but by the extended use of machinery his equivalent was reduced in 1882 to less than 1·0; he thus was made only half as important as before.

Carrying this inquiry into the principal classes of skilled men, I find in the following periods the fall in importance of hand labour to be as indicated by the figures placed against them, namely :—

A Fitter in 1873	stood in relation to	machine labour as	1:1 on common engines
„ 1882	do.	do.	1:2·31 on compound engines
A Boilermaker in 1873	do.	do.	1:1·0 on low pressure boilers
„ 1882	do.	do.	1:2·19 on 80 lbs. to 90 lbs. high pressure boilers.

The true reading of these figures is, of course, that the sphere of the machine tool is becoming wider and wider. This will be enforced if I quote some figures which I gave in evidence before the Depression of

Trades Royal Commission in 1886, namely, that in 1873 to produce 2,260 N.H.P., my Company employed an average of 1,022 men, and that in 1882 to produce 5,868 N.H.P. they employed only 1,351 men. In the two periods the N.H.P. varied as 1·5 : 3·7, while the hands varied only as 2·0 : 2·6.

These relations will extend the more the machine tool and the details of the work are brought into suitable relations to each other. The gist of the whole matter lies in that truth. The tool must always follow the work, but in an important sense it must be equally held, that, to secure economic working, the design must be made in view of the machine tool which is to operate upon it.

In iron shipbuilding, the adaptation of the structure to the machine tool is an essential step to the extended application of machinery to construction.

Iron and steel ships illustrate very well the conservatism that pervades English life. In structure, the iron vessel followed as far as could be the wooden vessel it replaced, being formed of vertical transverse frames and longitudinal strakes. The steel ship continues this system, only lengthening the individual plates. Regard for economic construction was overlooked at the outset, and was finally shut out, and now it will require no mean effort to obtain wide acceptance of a system professing to combine needful strength with a reasonable distribution of the material, and an effective command over the cost of production by a larger use of the machine tool.

There is a wide field in this department for the revision of the details of the structure, and the adaptation of the machine tool.

The relative growth of machine labour in this department is not so easy to indicate as in engineering construction, but it is not difficult to show the cost that hand labour has put on over the last seventeen years.

The time wages for all the classes of men employed in the shipyard have acquired a permanent average increase of 25 per cent., ascending from 11 per cent. to drillers, to 32 per cent. to smiths and carpenters, and to 38 per cent. to platers.

The piece-work earnings of the members of the Boilermakers' Society have put on a permanent average increase of 22 per cent. over the same period.

There are some curious illustrations amongst the individual piece-work averages; the first is in that of the drillers' average, which has actually fallen over the last seventeen years, and if it were removed from the general average, the latter, instead of a permanent average of 25 per cent., would become an average of 32 per cent. It is curious to observe how the drillers' skill—the lowest employed in shipbuilding—has gone back in value as machinery has extended and produced more accurate work. On the other hand the riveters' average has increased by 46 per cent., again illustrating the effect of improved machinery and consequently more accurate work upon the riveters' list of rates. The caulkers average has risen 22 per cent. from the same cause.

In all the progress made by the manufacturer in supplying the market with a better and cheaper article—better and cheaper in spite of many of the conditions under which he has had to fulfil his customers' wishes—hand labour has run him a close race.

I have before me the cost per ton of deadweight of a vessel built in 1865, and carrying 1,700 tons—a large ship in those days. It is £10 13s. 11d. per ton, of which 30·64 per cent. was for hand labour. I have another built in 1873, and carrying 2,477 tons deadweight, the total cost per ton of which was £10 2s. 5d., of which 24 per cent. was for hand labour. Since the last date the percentage of labour in the total cost per ton of deadweight for the hull has been for the following years as follows :—

1882	34 per cent.
1884	34 „
1886	34 „
1887	34½ „

These averages are mostly taken upon large vessels ; in smaller vessels they rise to 36 and 38 per cent. You therefore find that the cost of hand labour upon the hulls of vessels, has reached the proportions of its cost upon engines, and indeed has exceeded it !

There is no fundamental reason for objecting to the enhanced cost of skilled, or any kind of labour, in itself. It has a perfect right to fetch its own price in its own market, and if in doing so no social or economic law is transgressed, and the community is bettered by it, we have reason to encourage rather than to discourage it. And it must not for a moment be assumed that I am discussing this except as an economic question affecting constructive work, and through that our respective industries, just as we may discuss the use of coal—itself a perfectly harmless and useful article.

Hitherto much of the application of machine tools has been involuntary by the manufacturer. He has been driven to adopt it further and further by inflexible circumstances, which gave him only the unbending alternative of doing it, or of, bit by bit, seeing his capital slip out of his hands; and while this process has been going on—along with a partial voluntary adoption of the machine tool where it could be done cheaply and easily—there has been a counteracting force at work in the upward progress of hand labour cost.

Looking through the figures given above, a thoughtful student would conclude that the two forces of machine labour and hand labour had been working over the past ten or twelve years with a knowledge of each other's purpose—the one to raise the cost of production, and the other to reduce it. No such intelligent action has, I am afraid, occurred. Capital has only spasmodically rushed in to rescue the trade that was being driven from its home, or was being reduced to slender proportions by a pursuit of the maximum wage.

Two considerations now demand that for the future the systematic application of the machine tool be made a cardinal principle of constructive work. These considerations are:—

Firstly.—The necessity of controlling the cost of production and of cheapening it constantly. Competition with foreign manufacturers is fast leaving to the British manufacturer only his always advanced experience, which, up to the present in constructive work, remains supreme all round. This, as I have already said, must be embodied in the machine tool. The foreign workman is equal to our own so far as mere manipulative skill goes, and although the physical and racial differences give our workmen an immense advantage, this is, as a matter of fact, already almost counterbalanced by the help of the machine tool alone, as it exists in the foreigner's hands, and it is actually found to-day to be *entirely* counterbalanced by the machine tool *and* cheaper living, and lower wages, abroad.

Apart from foreign competition, however, it is essential to be able to control the cost and lessen it when needful to meet the regularly recurring periods of depression in trade, when he who can sell cheapest not only sells what he produces, but he also keeps the little trade, there may be then, at home.

Secondly.—The necessity there is now of working the hugest constructive work, as well as the smallest, strictly on the arithmetic of commerce. We sell the largest cargo vessels with their machinery as well as the smallest on a price per ton of deadweight. This single ton is so small a unit, any error regarding it, being multiplied hundreds, or thousands of times, becomes a formidable matter. This applies both to estimating and carrying on the work. But this method of basing a price on a unit of the whole thing to be sold, is common to all constructive work, and is essential to commerce. We are, however, only now realising what this means in shipbuilding and engineering—how the disturbances and disputes in the labour market, and with labour fritter away the small modern margins of profit. A condition of things which only the most perfect system of costing, and an extended application of the docile, untiring, and perfectly reliable machine tool can avert from becoming disastrous. It has become necessary, therefore, to mechanically control as much of the cost of our structures as it is possible to do, and the great agent in aiding us is the machine tool.

DISCUSSION.

The **President**, in inviting discussion, said he only hoped a large number of gentlemen would express their sentiments on this valuable and important paper. They would pardon him if he laid down the rule, as their time was necessarily very short, that no member should speak longer than ten minutes on the subject.

Mr. T. **Richardson**, Jun., Mayor of Hartlepool, said he had been asked to open the discussion, which was a somewhat difficult task considering his own experience confirmed generally all that Mr. Price had said, especially with regard to the labour required now to produce a certain amount of work with what was required eight or nine years ago, as at the Hartlepool Engine Works their output had doubled during that period, yet the number of men employed remained about the same although the individual wage was higher. They had long taken an interest in the question of cheap production, and had found it to result from a judicious application of machine tools, as well as systematic methods of arranging the work to be done, so as to reduce to a minimum the unskilled labour, as well as the heavier class of skilled labour, such as chipping and filing, which was fast disappearing from a modern workshop. This was due, to a considerable extent, to the resources of machine tool makers, who appeared to be able to satisfy every requirement. He could not say that at Hartlepool they had ever suffered from foreign competition, as the competition they looked for was from the Tyne and Wear. He quite agreed with Mr. Price that it was most difficult to reduce the cost of production, as they knew from experience the labour part of it was always very impatient to participate in advance in the good times, which he hoped were now upon them.

Mr. A. Coote said he would like to say a few words, as he thought it would be unsatisfactory if some of the Tyne gentlemen did not speak on this occasion, as they ought to put forward their best efforts if only to show their appreciation of the kindness with which they had been received by their Hartlepool friends. He had not very much to say himself regarding this paper, but thought it brought out most forcibly the versatility of the talents of their friend Mr. Price, who had on previous occasions enlightened them on various subjects bearing more directly on both shipbuilding and engineering subjects, and who, in the present paper, had treated them to what he thought might be termed an essay on political economy. Without much more study than he had been able to give to this paper he was hardly able to go fully into the subject; but looking at the statement made regarding the wages paid now with what they were some seventeen years ago, he did not think that it was a matter of much surprise to note the rise in their particular industry, as he thought it was a fact that throughout all industries in most parts of the world increase of wages had taken place. What was a matter of greater surprise was that this increase should take place during a period when they were increasing their machine tools' power to an enormous extent. Undoubtedly, this increase of machine tools' power tended to the production of a greater quantity of work; and had the paper been read a year or less ago they would have judged it from an entirely different point of view than they did that evening. A year ago they would have been inclined to say that the production of these tools was bringing their industry to almost a standstill, and that by over-production a serious depression had been brought about. Fortunately, to-night, matters were different, and they could congratulate themselves on a distinct improvement which somewhat upset any previous views that might have been formed. Now it seemed as if they might multiply these machine tools and increase to almost any extent the output, and the world still appeared large enough for all. This paper then was one for encouragement to the extent that if they elected to go on multiplying their appliances for turning out both ships and engines, even to the extent of the large figures mentioned by Mr. Parker, the world seemed at present to need them all; and he trusted the young men that had joined this Institution, and were there in such large numbers that night, would all feel that they had a hopeful future before them, and that there was room for all.

Mr. C. W. Hutchinson said, that the study of machine tools had been almost a constant one with him in common with other engineers for many years past; and he thought that on the question they had before them that night it might strike them, as they reflected upon the points alluded to, that there was far more improvement in the machinery operations connected with the engines and the machine part of marine engineering than there was in the hull part. There was a very great deal of labour—unskilled labour—carried on for which there was really no reason, and as the advancement of education was leading people to look to something higher than mere "fisty-cuffing" work for a living, he thought it was time there was a little sharper looking round in shipbuilding works for a revision of their hand labour. Time after time they would see two or three men carrying a plate or some other thing up the slip gangways with danger to themselves and others while there seemed no good reason why it should not be done by mechanical aid. While he was saying that, most of them would say, "We do not do that in our yard;" and yet in every shipyard it was done. When they compared the hull with the shop work they would see there was a very great lack of mechanical arrangement. The shop work he had been accustomed to had not that immediate reference to ship engineering that the shop work of many of them had; but he had been surprised at the extent to which machine development had been carried out in shops well arranged and perfected, so much so that hand labour was reduced to the very minimum. When a man came to them for employment they said, "What is your trade?" "Oh, well, I don't know; I will do anything." And the man who would do anything was the very man who could get nothing to do; and if they had no regular trade they generally wanted employment as gatekeeper or storekeeper. And the man who could do nothing technical turned up in shipyards where there was employment in the roughest forms of manual labour. He thought he had perhaps touched upon a point which needed some development.

Mr. B. G. NICHOL thought the most striking part of the paper was that wherein it was shown that the value of hand labour had very materially increased along with the development and extension in the application of machine tools in shipbuilding and engineering operations. In his prefatory remarks, Mr. Price appeared to think that the extended application of machinery was not antagonistic to hand labour; but he (Mr. Nichol) feared when they examined the matter more closely they could not fail to see that the development of machinery was antagonistic at least to some classes of hand labour. It was doubtless within the knowledge of the audience that if the whole population of the globe were hand-loom weavers they could not produce in one year the cotton and woollen fabrics turned out by the Lancashire mills in one week. Again, after having seen the magnificent planing machines in the factories visited to-day, and the work done by them, it appeared to be quite clear that much less hand labour must be required than when, as was the case from twenty-five to thirty years ago, these immense surfaces were all levelled and fitted by hand work, and therefore a considerable proportion of the hand labour required, in proportion to the work done, must have been diverted into other channels. The meaning of all this, as far as he could judge, was that the development and extended use of machinery was steadily diminishing the demand for unskilled and semi-skilled labour, leaving only the higher and more intelligent classes of workmen, who certainly deserved a high rate of wage; and the logical issue of this appeared to be the entire abolition of unskilled and semi-skilled labour, or rather the setting of it free to be absorbed in other than mechanical pursuits, and that those remaining in their yards and shops would be called on to exercise administrative and directive functions, requiring cultivated intelligence, thus like Nature in its operations, demanding no more physical energy than necessary to accomplish the operations in view.

Mr. J. R. **Fothergill** said, an important feature of this paper appeared to him to be not so much a question of capital and labour as might be inferred from some of the remarks, as a question of the skill of the labourer and the application of special machinery to the power of producing. If they could produce cheap they created a market by the demand for the articles so produced. If the power of production be limited, the cost of the article must naturally be dearer, and the demand less. The magnificent engines and the steamers they had that day seen would certainly never have been required but for the fact that the power of producing enabled them to be built at remunerative prices in competition with the sailing ship, otherwise the sailing ship would have taken their place, the steamer being too costly. By applying special machinery to special purposes they produced cheap, and created a demand; and in that way they brought more labour into the market. and found occupation for that labour. He remembered at one of the meetings of the Institute of Mechanical Engineers it was very forcibly pointed out in reference to some Australian contracts for bridges of special design, that it was very largely due to the application of special machinery to the purpose that America had secured those contracts. There was one part of Mr. Price's paper which appeared to him to require some explanation. He (Mr. Price) stated "That in 1873 to produce 2,260 nominal horse-power my Company employed an average of 1,022 men, and that in 1882 to produce 5,868 nominal horse-power they employed only 1,351 men." Nothing was said as to the time. He (Mr. Fothergill) thought it was very important to know the time these men were occupied, and whether they worked ordinary day's work or piece work.

Mr. **Price**—These were two exceptionally busy periods, and the conditions under which the men worked was as he declared.

Mr. **Fothergill**, continuing, said, large tools were a great source of economy, and materially increased the producing power. No doubt they had particularly noted several very large tools in the shops they had that day visited. Large overhead travelling cranes for lifting machinery and heavy weights from one part of the shop to another were, in the erection of large engines, a very great saving both in time and labour; but what he more particularly wished to emphasise was the application of special tools to special purposes, which undoubtedly constituted the most economical feature in the power of production. In the early days of railways it was with all seriousness pointed out before the Parliamentary Committee that if railways were made no horses would be required in the country. They had all lived to see the absurdity of that statement, and yet the same argument in some form or other was always being brought forward. It was a great mistake to argue that they should limit their power of production. It was impossible to do so; they must of necessity improve and develop their producing power, which cheapened the cost of manufacture, thereby creating a demand and making a market.

Sir B. C. **Browne** said that the first point that struck him in Mr. Price's paper as interesting and instructive was where he spoke of "the iron and steel ship as illustrating very broadly the slow conservatism that pervades English life." He (Sir Benjamin) looked upon this, as they did upon everything, in the way it affected them personally. If it illustrated the "conservatism of English life" it showed that English conservatism was about the strongest force in the world, for he did not see any other enlightened nation strike out a ship which much differed from those they built in this country. Another point he wished to touch upon was, perhaps not quite so encouraging to them, and perhaps differed from the spirit and tone taken up that evening. Of course he would ask them all to remember this, though he did claim to be an engineer, for many years he had had to give attention to a great many things besides, he did not devote his whole time to engineering. Well, Mr. Price said that "the tool must always follow the work," and also to "secure economic working the design must be made in view of the tool which is to operate upon it," but by adapting the design to the machinery for producing it too persistently they would get into a groove which would lead to stagnation of ideas and tend to stop improvement. Just look at the great strides of marine engineering in the course of the last eighteen years. They had had the compound engine introduced and superseded by the triple expansion engine, but if they looked at the locomotive engines they had hardly gone on at all in that line. The locomotive engine of thirty years ago was in design pretty nearly as good as the locomotive now, a certain amount of steel had been introduced and a better class of material, but little if any difference in design. He attributed that to this fact—of railway companies making their own engines. The locomotive superintendent laid out his works entirely with a view to building engines of his own design, and his own inspectors reported on the work. He dared say they would all find great satisfaction if they were the inspectors of their own work, but that was not the way to improve. Of course he quite admitted there was the compound locomotive, but then he did not think any of them could mention twenty compound locomotives being put in hand except by the man who was the original inventor of that particular compound engine, and who had to work it all himself. When once a railway laid down plant and works it went on specific lines, adding to its stock, and working only for itself, but he asked them how many shipbuilders could afford to own all the ships they built? He would admit it was very gratifying to go into these works they had visited that day and see how they could turn out double the work and only employ one-third more workmen, but where was this to end? Would it not be better to turn out nine ships with a good profit rather than turn out eighteen ships with little or no profit? Mr. Price had not carried his paper far enough. Ships might be a great deal cheaper, but how about the builders' profits? Workmen had more wages than they used to have, and he congratulated them heartily on their employers giving more than they used to do twenty years ago. He had been talking to a trades unionist, and rather pleading to him that he really thought employers and their capital should be considered in some degree. He asked him if he had the *Daily Chronicle* to look at the local share list. He pointed to a number of northern industries put in a row, and what they paid as percentage on the capital. He (Sir Benjamin) said "please to strike out the *Consett Spanish Ore Company*, calculate the average dividend of the whole number, and including *Elswick* they did not, up to the end of June, pay 4 per cent. on the average." These concerns were not paying as well as an ordinary railway, and if they took a number of works that existed in any given district so many years ago, they would see what a great deal more mortality there was in such works. They talked a deal about Mr. Gray's works and Mr. Richardson's works, but the first things when he came into Hartlepool he had pointed out to him were two or three closed works, close to the railway station, ruins practically speaking. If people would go on cutting down prices and increasing their output some one must incur the risk of going down. The smallest men went first, and no one else was helped upwards or improved. At the present moment there was a better demand, but they knew that as night followed day so bad times followed good times, and if they spent all their profits in increasing their works, what advantage would they have when the good times were over?

Mr. B. MARTELL (by invitation) said he had not intended saying anything on this paper, had it not been for a reference by Mr. Price with regard to the construction of ships. As to the engines, he would leave that to the engineers. Sir Benjamin Browne had said there were a few very beautiful paragraphs and sentences, and such like, in this paper, and he must say he endorsed that. There was nothing so easy as to criticise and condemn. He would like to read this remark, and to hear Mr. Price's explanation in regard to it. As he (Mr. Martell) understood him, they should endeavour, if they possibly could, to utilise machinery to a much greater extent than they did at the present time, and that shipbuilders, to begin with, were so stupid they had constructed a ship in such a ridiculous manner that it was impossible to utilise machinery as it ought to be used:—"Iron and steel ships illustrate very well the conservatism that pervades English life. In structure the iron vessel followed as far as could be the wooden vessel it replaced, being formed of vertical transverse frames and longitudinal strakes. The steel ship continues the system, only lengthening the individual plates. Regard for economic construction was overlooked at the outset, and was finally shut out, and now it will require no mean effort to obtain wide acceptance of a system professing to combine all needful strength with a reasonable distribution of the material, and an effective command over the cost of production by a larger use of the machine tool."* He (Mr. Martell) wanted to know what that meant? The old builders of wooden vessels constructed them with vertical frames and longitudinal planking, and when iron shipbuilding came in, before boilermakers took up the trade, the wooden shipbuilders naturally began to build iron vessels in the way they understood, and applying their material in the way they considered most conducive to meet the various strains, as proved by experience to be necessary, in the millions of tons built and number of years over which this system of construction had extended. The principle had, he thought, been a very satisfactory one, and not so very stupid after all. It had been a very

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* Page 46.

reasonable system, and the only deviation he had known since Mr. Scott Russell's system forty years ago was by a shipbuilder in the North of England, who produced to them the model of a ship by which outside plates were to be dispensed with altogether, and the vessel formed with vertical troughs having the flanges riveted together, so that the vessel would have vertical seams extending from the keel to the gunwale—perhaps one hundred in number, according to her length. It was the only system he had known proposed against the *stupid* system that had prevailed for so many years ; except the longitudinal system of construction, which was adopted by the Government it might almost be said regardless of expense. But no one had brought this system into practical shape for mercantile vessels; and when it was said, further over in the paper, that "in all the progress made by the manufacturers in supplying the market with a better and cheaper article—better and cheaper in spite of many of the conditions under which he has had to fulfil his customers' wishes," etc.—he (Mr. Martell) thought this remark alluded in a manner to those rules which have been fixed by the Society which he had the honour to represent. If he was right in his conjecture his reply was, these rules were never intended to be repressive. They consulted shipbuilders as to what they thought proper, and had their views before framing them; and he could only say if some general system of construction could be brought out, and machine tools used to a greater extent and ships built as strongly, he for one would be most happy to do all in his humble power to have their rules based on this, and if such rules were proposed and put forward for the consideration of Lloyd's Register Committee, he was sure they would give such proposals their best attention. He considered Mr. Price's paper to be both interesting and instructive.

Mr. BAINES, as one of the youngest members of the Institution, except the gentlemen elected that night, thought he might be excepted from the rule of coming upon the platform, as he only wished to put a question and make a suggestion. He would, however, express his thanks, and he was sure the thanks of other members of the Institution in the same position as he was himself, connected with the commercial side of the profession, for the very suggestive paper Mr. Price had put before them. His question was, whether the words "total cost" in the following extract meant "net cost" or gross cost, inclusive of "charges:"—"Taking the following years as representing periods in which the different types of engines were made, I find the percentage cost of hand labour in the total cost of the engines and boilers was in—

1871	from 25 to 27 per cent.
1882	„ 28 to 29 „
1885	„ 30 to 31 „

The variations between the percentages given for each period arises from differences in size of engines, or in specifications." He thought that would lead many of them to go into details, and he would suggest that the various marine engineers might contribute to this Institution (it might be done anonymously if preferred) the result of their own observations on the relative progress of the value of hand and machine labour. This Institution would then be of considerable benefit to them all. He also asked if "hand labour" was exclusively hand labour, or hand labour in conjunction with machine tools? For instance, were the wages of labourers assisting at a hydraulic riveter termed hand or machine labour in the paper? If Mr. Price would just amplify that point he thought it would be a great benefit to them. It would be interesting if he would also refer to the question of engineering and shipbuilding in the United States at the present time in connection with the use of machines. The difference in the wages paid in this country and the United States was so very great that the Americans were not now their competitors. Without trenching upon the question now agitating the American people he would just give one or two figures from a card sent to him in connection with the present Presidential election, in which the wages of Englishmen and Americans in the same trade were compared. He had turned that of the latter into shillings:—

	England.	America.
Shipbuilders and Boilermakers ...	30s. ...	56s.
Machinists	27s. ...	57s.
Coppersmiths	28s. ...	60s.
Platers	32s.-34s.	72s.
Drillers	26s. ...	48s.
Riveters	34s. ...	75s.
Pattern Makers	34s. ...	96s.

(N.B.—These English wages represent the lowest rates prior to the advances in 1888.)

They knew the marvellous development in America of machine tools, and yet their manufacturers with that advantage were unable to compete with this old country. He said, long may they continue in this way of working, and allow us to supply the markets of the New World and our Colonies with British ships and engines.

Mr. Price, in reply to the discussion, said he would begin with Mr. Baines's question about the cost, it was the total net cost, inclusive, of course, of all charges, but containing no allowance or amount charged for interest on money out of pocket. He (Mr. Price) had not very much to reply to, but the next gentleman whose remarks he had to refer to were those very good-natured remarks of his friend Mr. Martell. He asked what these observations in his paper really meant? Did not the fact that he came up there and spoke so eloquently against them show quite well he knew what he (Mr. Price) meant? He might say they constituted a review of the past. He wished clearly to be understood to be making no invidious observations upon the present; but as to how far he was correct in the words Mr. Martell read he left the meeting to determine as to whether he (Mr. Price) was not correct in saying that it would be a struggle of no mean character to secure acceptance of a system combining all needful strength, with a more reasonable distribution of material, and better command over the cost of production by the extensive use of the machine tool. There had been very many deeply discussed, hardly contested questions, with Lloyd's Registry, and he took the liberty to say that every one of those questions had been settled in the affirmative on behalf of those who raised them. He did not care in what direction they went, whether they turned in the direction of the plating of vessels, or any other question raised as to the construction of vessels, all were settled in favour of the enlightened views of those who moved them, and, but for the fact that their friend (Mr. Martell) represented the enlightenment of the present day, he need hardly remind them that Lloyd's Society would not have been in existence to-day. He said that with all respect, but it was with all respect, too, to the historical period through which they had passed in the last twenty-five years. If Mr. Martell would attend one of their immediate meetings he would have the opportunity of discussing a paper to be submitted on a new system of construction with a view to simplify it and modify a great deal of the cost in the construction of ships, and until that evening he (Mr. Price) would reserve any further remarks he had to make with regard to any other observations, and not occupy the time of the meeting. The first speaker told them they knew no other competition except the competition of the district. Why, he knew of companies that previously built in Hartlepool that now built in Flensburg, and other Continental towns, and important firms there, built largely of the vessels for foreign countries; and he need not remind them that some of the largest and finest foreign fleets had ceased to be built in the Clyde, they were all built abroad, and it was a notorious fact that, the French and the Germans at least, were building the great bulk of their fleets; and naturally it was the endeavour of every nation to build their own vessels: it goes without saying, if they were to attain a position as constructors, they would have to take such means as would enable them to do so. Mr. Coote made some very appropriate observations. It struck him that the same advance of wages did not take place all over the world, as notwithstanding their improvement the Belgians were still working at starvation prices, and no man could stand upon this platform, and say, the cost charges of shipbuilders in the Clyde would bear such figures as he had quoted that night. It was notorious that on the east coast the wages were very much higher than elsewhere, and it was also notorious that the production was cheaper on the west coast than elsewhere. That was owing entirely to the extraordinary efforts made in past years to the application of machinery to constructive works. It appeared to him an anachronism to say that if machines cheapened work it would at the same time produce so largely there would not be anything to build, as he thought Mr. Coote said it might have been their position some twelve months ago. He thought they only existed that day from the fact of being able to produce so cheaply during the depressed period. It was quite true that if they produced things that were not wanted then trade would leave them and they would spend their money in vain. But, speaking of the overwhelming demand for tonnage, they had successive waves of depression, and, again of ascension of trade into more healthful conditions, and why they continued to enjoy the greater part of the building for the whole world was because they had been in the van of constructive work.

The **President** said the Secretary would gladly receive written remarks on any of the points raised in this paper, or papers if they liked, and they would be, in the ordinary course, if approved by the Council, included in the Proceedings. Any member who had anything more to say on the subject should not hesitate to address the Secretary. He moved that they tender their very best thanks to Mr. Price for the very able paper he had read. He should like to have made some remarks upon the subject from his own point of view, but there was not time, and he would probably have an opportunity on another occasion. Allow him to call their attention to a notice at the close of the programme, that their next meeting would be held in Sunderland on Friday, November 23rd, when a paper would be read on a new system of shipbuilding. Another most important duty rested upon them. They owed their presence there very largely to the efforts of one of their members of Council, to whom, he thought, it would be ungracious before parting not to accord a very sincere and cordial vote of thanks—he meant their friend Mr. Fothergill. It was at Mr. Fothergill's suggestion to the Council that this meeting was held; it was his effort—he believed without any great effort—that had induced their co-members to give them the cordial invitation which had been so largely accepted and so much enjoyed; it was through his efforts a very large accession had been made to the membership of this

Institution of their Hartlepool friends, and he was sure they would agree with him in according a most hearty vote of thanks to Mr. Fothergill for the valuable services rendered to the Institution in the several directions he had indicated.

The votes being given by acclamation, the PRESIDENT, on behalf of the Institution, thanked Mr. Price for his valuable paper, and, addressing Mr. Fothergill, said, he had very great pleasure in conveying to him the thanks of the members present for his valuable services in the interests of the Institution.

The meeting then closed.

COMMUNICATION RECEIVED FROM MR. J. SUTTON ON MR. PRICE'S PAPER.

October 25th, 1888.

TO THE SECRETARY OF THE INSTITUTION.

SIR,—There is one part of Mr. Price's paper upon which I should like to make a few remarks. (Page 46.) "In structure, the iron vessel followed as far as could be the wooden vessel it replaced," etc.

That is true only to a certain extent. I remember very well the late Mr. Miller, a shipbuilder of Liverpool, telling me more than twenty years ago, that he once built an iron ship without any transverse frames, simply with a certain number of transverse bulkheads and the shell plating, and I think he said a turtle-back deck. This certainly was a very wide departure from the old system of wood shipbuilding, but as I have never heard of any similar vessel being built, I can only assume that that system was found not to answer.

The late Mr. J. Scott Russell, in building the "Great Eastern," introduced the system of longitudinal frames and inner bottom plating, and I believe also in the designs for several other ships.

The Admiralty have for many years carried out the system of longitudinal frames with transverse bracket frames of very light material distributed so as to give the greatest amount of strength with the least possible weight, to carry the heavy armour of our battle ships, with the additional safety of an inner bottom, therefore, I think it can hardly be said that we are still following the same lines as that of wooden vessels.

While being fully alive to the fact that there is still plenty of room for improvement in the distribution of material used in the construction of our modern ships, many of which we see constantly taking place since the introduction of mild steel, such as the flanging of plates, etc., by which we get a great saving of weight of material and labour, a good example of which we had the pleasure of seeing carried out to a large extent in the framing of a tank bottom ship, building by Messrs. E. Withy and Co., at Hartlepool, on the visit of the Institution to that place on the 20th ult. Therefore it can hardly be said (as Mr. Price does) that "it will require no mean effort to obtain wide acceptance of a system professing to combine needful strength with a reasonable distribution of the material, and an effective command over the cost of production by a larger use of the machine tool."

JAMES SUTTON.

VISIT TO THE HARTLEPOOLS,

OCTOBER 20TH, 1888.

SHORT DESCRIPTION OF THE SHIPYARDS, ENGINEERING WORKS, AND DOCKS.

SEE MAP (FRONTISPIECE).

THERE are two Hartlepools designated by the Railway Company—East and West Hartlepool, but whose correct designations are Hartlepool, and West Hartlepool.

The ancient town of Hartlepool stands upon a rocky promontory forming the N.W. boundary of the bay, and viewed from Middleton, a village situated between the Hartlepools, presents a most interesting picture of English coast life.

From the year 1840 to 1847, Victoria Dock, situated at Hartlepool, and lying to the east side of the Old Harbour, was the only dock the port had; but as trade increased, and West Hartlepool sprang into existence, due to the energy and enterprise of Ralph Ward Jackson, Esq., its founder, he in 1845 commenced the West Hartlepool Docks, which communicate direct with the sea by the West Harbour, situated about a mile to the south of the Old Harbour. The West Dock, or Coal Dock, was opened in 1847, the Jackson Dock in 1851, and the Swainson Dock in 1856. The New Docks were commenced by the North-Eastern Railway Company (who had acquired the dock property) in 1872, and opened in 1880. They extend in one continuous line from the Lock, or Tidal Basin, at West Hartlepool, to the N.W. end of the Old Harbour, thus joining the docks of the two towns into one system. In addition to these docks there are extensive Timber Ponds, the Hartlepools for years being one of the largest timber ports in the kingdom.

The docks are well supplied with warehouse accommodation, especially the Central Dock, the warehouse being 307 feet in length and 107 feet in breadth. It is six stories in height above ground, the first being 18 feet high and the rest 9 feet, and there are extensive cellars.

On the north side of the Old Harbour there is a fine Fish Market, consisting of a covered-in quay about 600 feet in length, alongside of which fishing boats can get at any time of the tide. The fish is sold by auction as soon as landed, packed and wheeled direct into railway trucks which run alongside the quay, forming a level floor, and thus, without delay, despatched to all parts of the kingdom. In the height of the herring season 100 trucks per day have been despatched.

On the south side of the North Basin there is a well arranged Foreign Animals' Wharf. The cattle pass direct from the ships to the slaughterers' hands, and the carcases direct into trucks for the London and other markets.

The dock gates, swing bridges, warehouse appliances, cranes, etc., in connection with the New Docks are worked by hydraulic machinery, supplied by Messrs. Sir W. G. Armstrong, Mitchell, & Co., of Elswick, Newcastle-on-Tyne.

In the north corner of the Central Dock the North-Eastern Railway Company have constructed a very fine Graving Dock for public use. Dimensions:—Length, 550 feet; breadth of entrance, 50 feet; depth of sill, 19 feet; height of sill above dock bottom, 3 feet.

Alongside this dock the Company propose making a second dock of the same dimensions.

Conveniently situated, and belonging to the Railway Company, there are four sets of shear-legs and a 25-ton steam travelling crane.

SHEAR-LEGS.

	Tons.
Victoria Dock, capable of lifting	80
North Basin, " "	80
Union Dock, " "	80
Jackson Dock, " "	40

PARTICULARS OF DOCKS.

Docks.	Area.	Width of Entrances.
	Acres.	Feet.
Victoria	19	42
Coal	8	42
Jackson	13	50 and 60
Swainson	9	50
Timber	3½	50
Union	8	50 and 60
Central	13	60
North Basin or Lock	3	60
South Basin or Lock ...	2½	60
Old Harbour	20	......
West Harbour	44	......
Timber Ponds	57	25 and 35
Total area . .	200	

The North-Eastern Railway Company, so ably represented in this district by Mr. J. Bland, General Superintendent, and Mr. R. Murray, the Engineer, deserve great praise for completing a system of docks which offer every facility for the discharging and loading of steamers and ready despatch of cargoes to any part of the kingdom.

WM. GRAY & CO.'S SHIPBUILDING YARDS, WEST HARTLEPOOL,

Cover an area of about fifteen acres. There are six Building Berths and two Graving Docks. (See Plate I.)

Three of the Building Berths on the north side of the yard launch into the Jackson Dock, the remainder on the south side of the yard launch into the Swainson Dock. Vessels of about 380 feet can be built here. The yard is completely fitted with modern shipbuilding machinery, all the frames and beams being riveted by hydraulic riveters. An hydraulic bending machine, recently added, bends all the keel plates and other plates cold. All the donkey boilers and iron and steel masts are manufactured in the yard, also the sails, blocks, joinery and cabinet work required in the completion and outfit of vessels. There is also a commodious fitting shop well supplied with modern machinery. The North-Eastern Railway Company's lines run into the yard, and the whole of the shops, sheds, and graving docks are lighted with electric lamps.

The central shipyard is situated at the Central Dock, adjoining a large Graving Dock 560 feet long, and the works of the Central Marine Engine Company. (See Plate II.)

The site of this establishment covers an area of five acres, and there are three building berths, 500 feet long. Operations for the laying out of this yard were only commenced at the early part of the year, and there are already three vessels in course of construction, the whole of the machinery is not yet placed; there are, however, very powerful bending rolls and planing machine capable of taking in 30 feet of plates. This yard is in direct communication with the North-Eastern Railway Company, and the whole will be fitted up with the electric light.

Constant communication is kept up between the two establishments with a steam launch, which runs the distance in about four minutes.

EDWARD WITHY & CO.'S SHIPBUILDING YARD.

The extensive shipbuilding and repairing yard of Messrs. Edward Withy & Co. is conveniently situated at Middleton, on the south bank of the entrance to Hartlepool Harbour. At the time of the Institution's visit, there were four large vessels over 300 feet in length on the stocks, and they had just completed a steamer of similar size for Australia. On the building berths keels may be laid up to 500 feet long. Messrs. Edward Withy & Co. have made a speciality of well-deck steamers, and the majority of these have been built on the cellular bottom and web frame principle. It is satisfactory to note that during the last ten years not one boat of this class has foundered, which speaks volumes for the seaworthiness of the type of ship constructed at these works. The yard is replete with every appliance for carrying on work expeditiously and economically. The machinery is of the most modern description, and includes manhole punching machines, flanging machines, hydraulic riveting machines, etc. Permanent rails or portable tramways are laid all over the yard to facilitate the transit of heavy weights. A feature in the shell plating here is the length of the plates, which run from 24 to 26 feet. Instead of using chain cables in launching, Messrs. Edward Withy & Co. were the first to introduce strong steel wire rope checks. The large smiths', fitters', carpenters', joiners', and mast makers' shops are filled with machinery of the latest type. The general and drawing offices are contiguous to the main entrance of the yard; the scientific department of the drawing office has the newest instruments for making stability calculations, etc. One pleasing feature in the drawing office is the employment of young ladies for panel painting and other artistic work in connection with the saloons and cabins of vessels.

T. RICHARDSON & SONS' HARTLEPOOL ENGINE WORKS.

This business was commenced 56 years ago in a small works at Castle Eden by the late Thomas Richardson, and transferred to more commodious works at Hartlepool in 1846. The works are now carried on by the present Thomas Richardson, Member of Parliament for the Hartlepools, in partnership with his two sons.

At first the works were employed in iron founding and railway plant, then in building stationary engines principally for collieries, and afterwards in making locomotives.

In 1851, the first marine engine was built, and during the ten years that followed the marine engineering branch increased rapidly, and became in 1861 the chief manufacture. Since then marine engines of various types have been constructed; and, in 1883, the first triple expansion engine on three cranks was built for the S.S. "Para," owned by Messrs. Steel, Young, & Co., of West Hartlepool, this being immediately followed by another of larger power for the Dutch Mail Company. Since then very few engines of any type but this have been built.

In 1885, the two-cylinder compound engines of the Union Company's steamer "Anglian" were converted into three-crank triple expansion engines by the addition of a high-pressure cylinder with Wyllie's patent valve gear. This alteration was attended with such success that six engines more of this Company's Cape mail steamers have since been altered, also several belonging to the Castle and Orient Royal Mail Companies, as well as others in steamers of the mercantile class.

The "Roslin Castle," which may now be seen at Hartlepool, is one of the largest of these steamers, having engines with cylinders 36 inches, 60 inches, and 96 inches, by 60 inches stroke, and three double ended boilers, each 14 feet 4 inches diameter by 17 feet 9 inches long.

In 1886, the first pumping engines on the three-crank triple expansion type were built for the East London Water Works, their capacity being three million gallons per day, lifted to a height of six hundred feet.

The works (see Plate III.) consist of engine building shops, iron and brass foundries, forges, and all the usual departments necessary for the construction of marine engines.

The Iron Foundry has a capacity for making all the machinery and other metal castings required in the engine works, besides supplying a large outside trade, the total being about 400 tons monthly. The buildings consist of three spans of 53 feet, 43 feet, and 33 feet respectively, the total length being 350 feet.

The Forges have a capacity for making 200 tons of forgings monthly, and besides all the heavy forgings and shaftings for the engines made in the works; they also supply a large outside demand.

The Boiler Department consists of two shops, one having two spans of 55 feet and 43 feet respectively, and a length of 270 feet; the other having two spans of 45 feet each, and a length of 142 feet. The principal hydraulic machines are a large flanging press, a 140-ton riveter, both by Tweddell. The boiler finishing shop is served by a 75-ton self-contained overhead crane by Booth.

The Machine Shops, as will be seen from the Plan, occupy a large portion of the works, and contain machinery capable of dealing with the largest class of marine engines. Amongst which may be noticed a crank shaft lathe by Shanks & Co., which is 30 feet between centres, and capable of turning a diameter of 12 feet. On this lathe the crank shaft of the "Roslin Castle" was finished in one piece, the diameter being 17 inches, and the total weight 30 tons. In the heavy machine shops there is also a vertical and horizontal planing machine by Shanks & Co., capable of planing a surface 18 feet 6 inches high by 20 feet long, as well as a large horizontal boring and milling machine by Campbells & Hunter, of Leeds.

The Erecting Shop is 170 feet long, consisting of two spans, 60 feet and 30 feet respectively, with a height of 50 feet from the floor to the crane rail, and is served by a self-contained crane by Booth, and 5-ton hydraulic jib cranes by H. Smith, of Glasgow. The present output of the establishment is about 4,000 indicated horse-power per month.

In addition to the works shown on the Plan, there are Repairing Shops at the Central 80-ton Sheers, the Union Dock 80-ton Sheers, and the Victoria Dock 60-ton Sheers, the head-quarters of the outside department being at the Union Dock.

CENTRAL MARINE ENGINE WORKS.

As these works were fully described in Volume III. of the Proceedings of the Institution, in the course of a paper read by Mr. Thomas Mudd, on "The Plan and Construction of Marine Engine Works," it is needless here to give more than a few of the principal details.

The works (see Plate IV.) were built during 1883 and 1884, and occupy a site on the north side of the North Basin, which lies between the deep water entrance from the Harbour and the great Central Dock.

The works have a frontage of 830 feet facing the Dock, and there is a set of 80-ton Hydraulic Sheers immediately in front of the works on the Quay. The works cover about 8 acres of ground, and comprise Iron and Brass Foundries, Engine Shops, Boiler Shops, and shops for all the subsidiary trades which combine to produce marine engines and boilers.

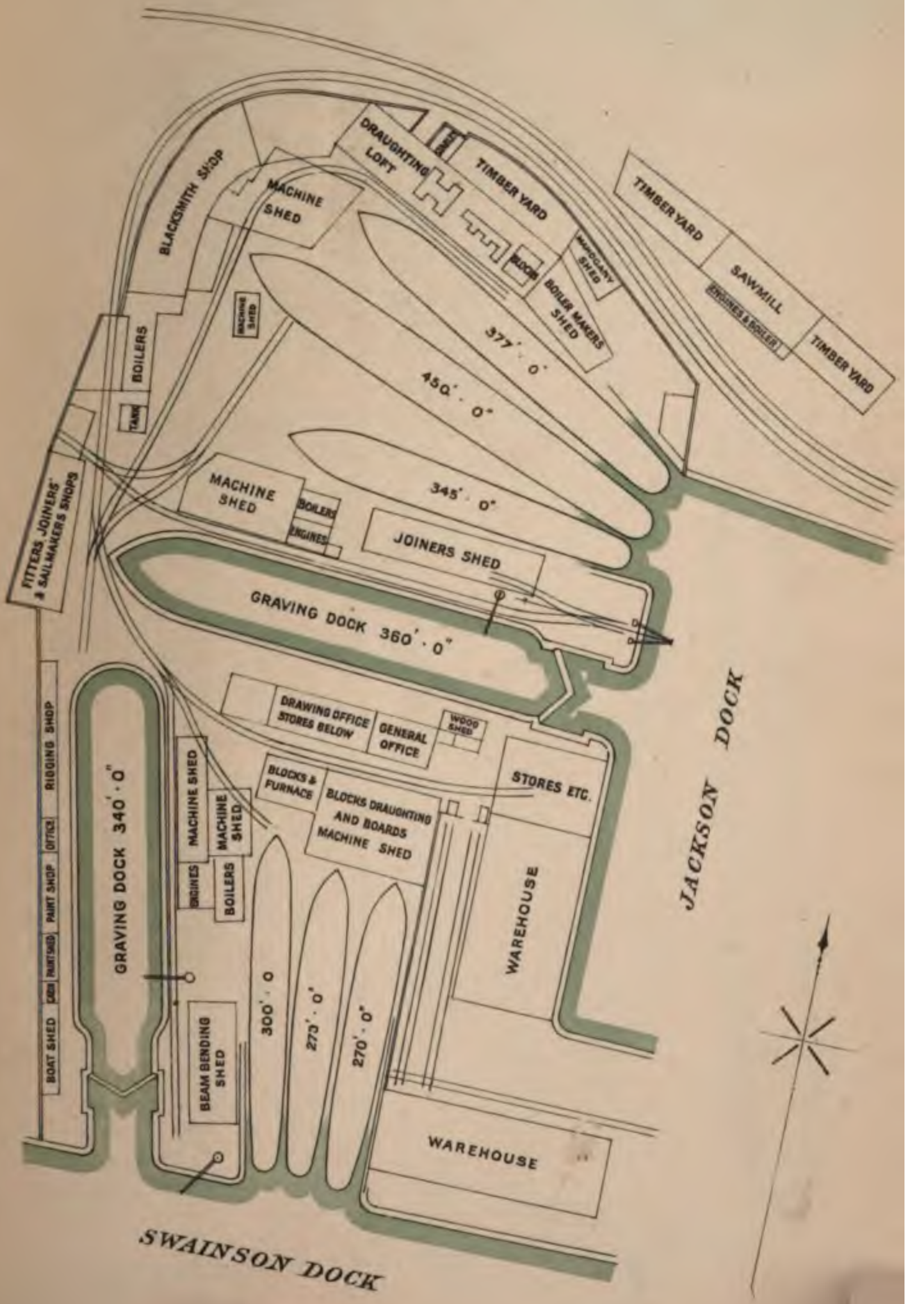
These works being of quite recent date are constructed on the most modern and approved system, and are replete with all modern machinery and contrivances. Commencing exactly at the time when triple expansion engines began to supersede the older two-cylinder compound type, *Visit of the N.E.C. Inst. of Engineers & Shipbuilders to the Hartlepools*

20th Oct. 1888.

PLAN OF W. GRAY & Co.'s SHIPBUILDING YARD.

WEST HARTLEPOOL.

Total Area 15 Acres.



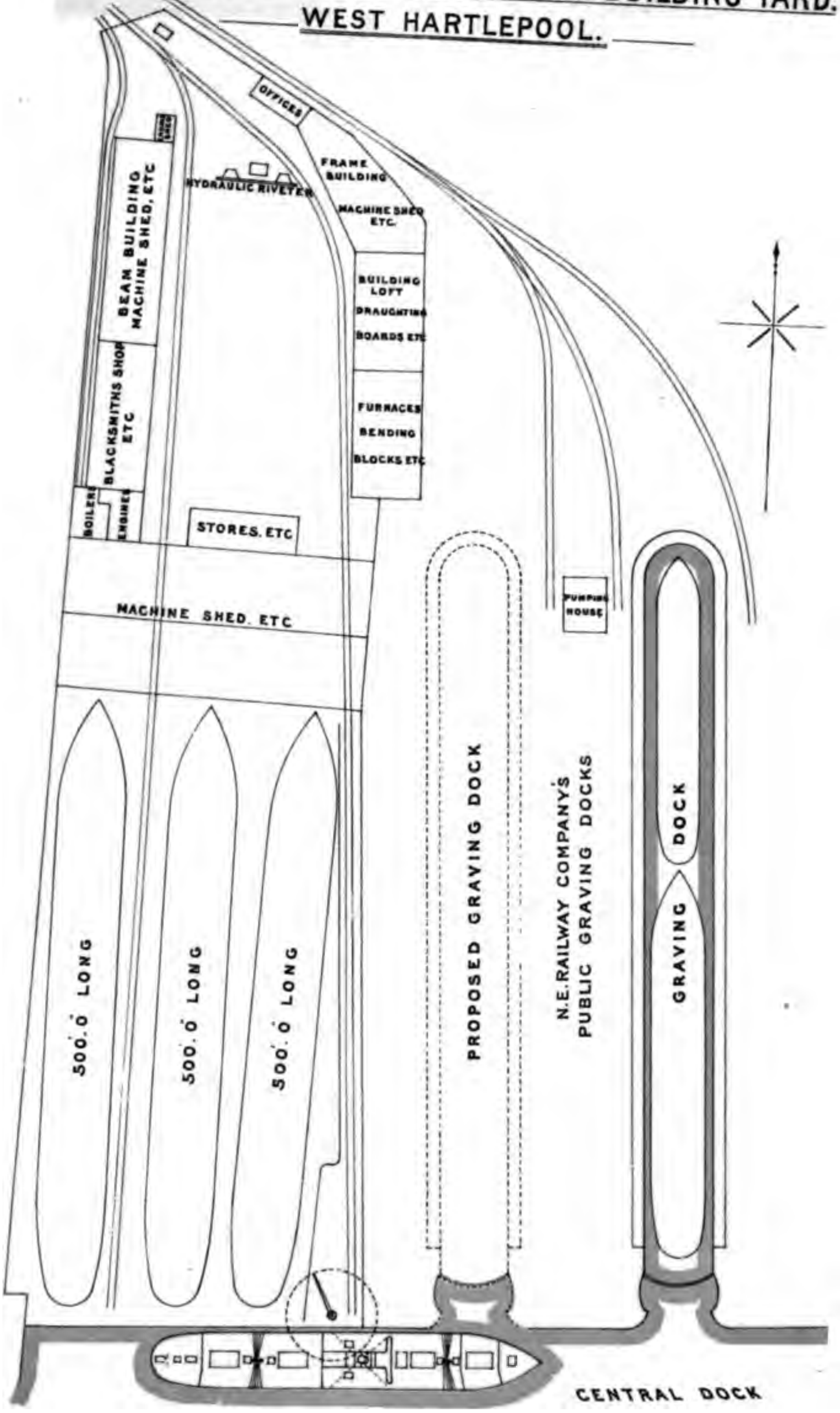
Vol. V Plat

Visit of the N.E.C.Inst. of Engineers & Shipbuilders to the Hartlepoo

20th Oct. 1888.

PLAN OF W. GRAY & Co's CENTRAL SHIPBUILDING YARD.

WEST HARTLEPOOL.



Visit of the N.E.C. Inst. of Engineers & Shipbuilders to the Hartlepoo

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PLAN OF W. GRAY & Co's CENTRAL SHIPBUILDING YARD.

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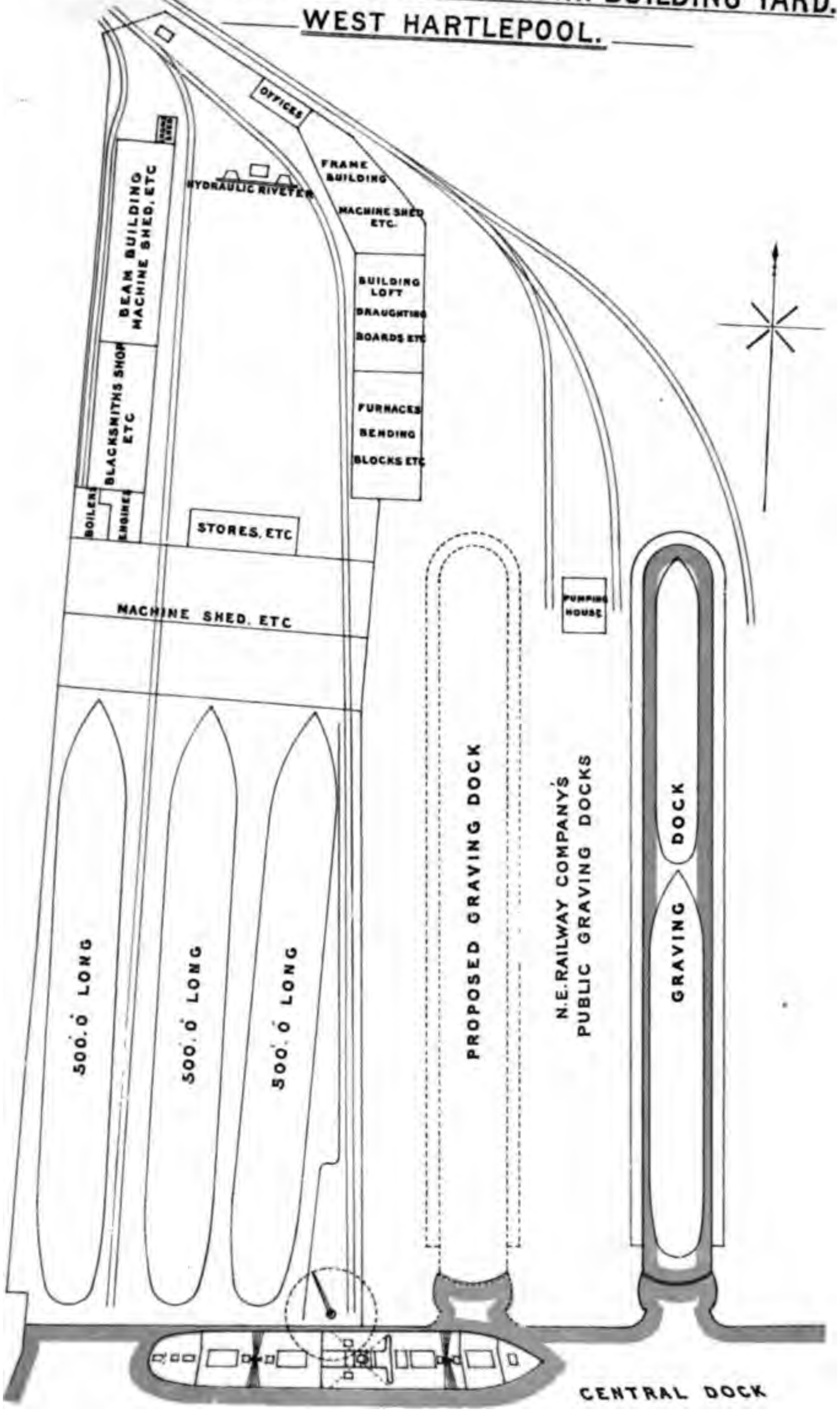

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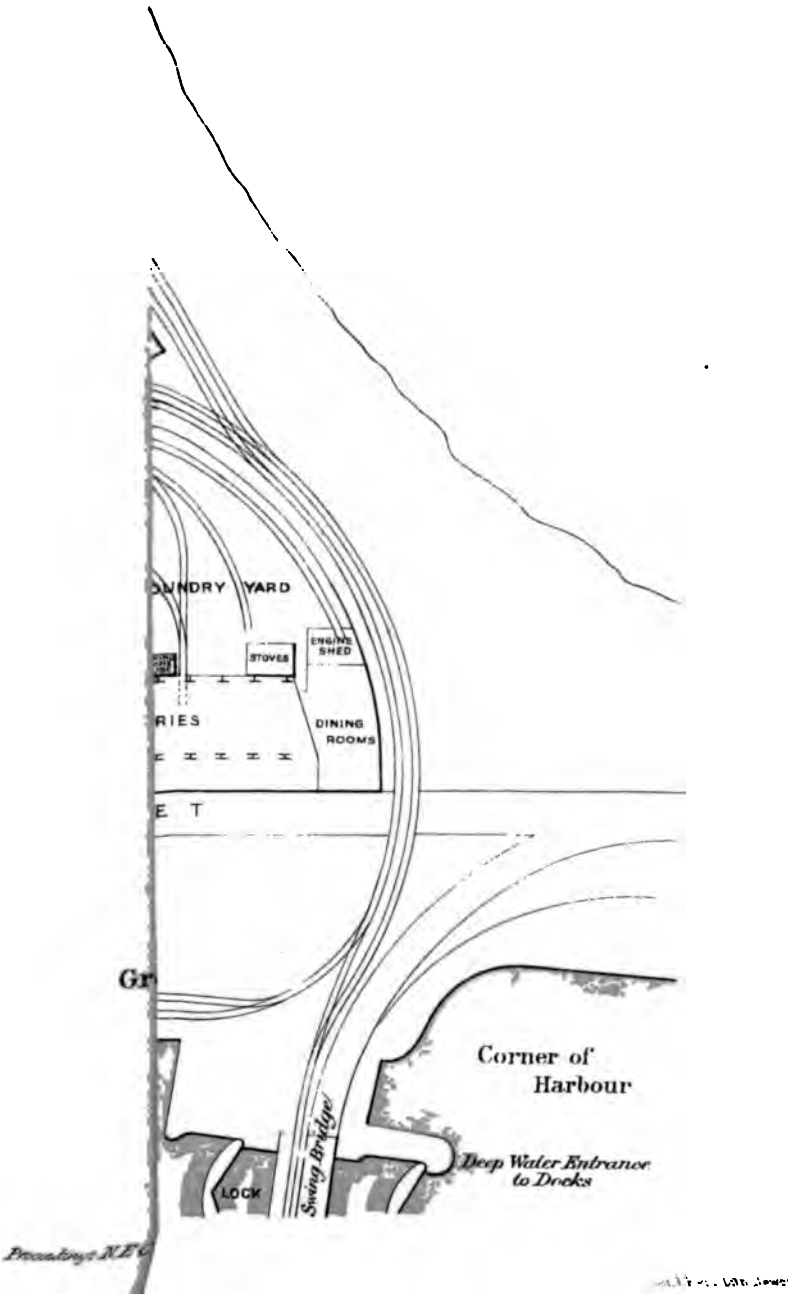

the Central Marine Engineering Company were fortunate in being able at once to get up patterns for the triple type, their very first engine being on this principle, which engine was shipped exactly three years ago. Since then over thirty sets of engines, ranging from 600 to 1,800 horse-power, have been turned out, and the present increased activity in the shipbuilding trade has necessitated the commencement of extensions to several of the departments. A Forge and Stern Frame Shop have also been commenced, and when these additions have been completed the works will be dependent on the outside world for little more than mere raw material.

THE WEST HARTLEPOOL STEEL AND IRON CO.

These works are situated at the south-east end of the town, in proximity to the North-Eastern Railway, and are spread over 8½ acres.

Until recently nothing but iron was made, but owing to the increasing demand for steel, this firm has erected a most complete Siemen's steel plant.

The Puddling Forge is at the south end of the works, and consists of forty furnaces with a 24-inch train, three hammers, etc.

Alongside this, but to the west, lies the Melting Shops, consisting of six twenty-ton Siemens-Martin furnaces with sixteen Ingham gas producers.

At the end of the bench is the laboratory, fitted out in a most complete manner.

To the north of the forge, and east of the melting shop, is the Cogging Mill, with its three ingot heating furnaces, which are charged and drawn by an hydraulic crane. The mill has rolls 36 inches diameter, driven by a pair of reversing engines 42 inches diameter and 5 feet stroke. The ingot when cogged is sheared into slabs, which are taken away hot to No. 2 Plate Mill.

No. 2 Plate Mill has rolls 7 feet long by 28 inches diameter, driven by a single cylinder engine 36 inches diameter by 54 inches stroke, the reversing being done through the ordinary wheel gear.

No. 1 Plate Mill is a mill in which the thinner plates are rolled; this is a pull-over mill, the train not being reversed, but the plate being passed over the roll from back to front.

A third Plate Mill is in process of erection, which will have a pair of reversing engines, 42 inches diameter by 5 feet stroke, to drive them; the mill being arranged so as to take in rolls capable of rolling the largest boiler plates, but the usual work being done in 7 feet rolls 28 inches diameter. On the completion of the extensions an output of over 1,400 tons of plates per week is expected.

In connection with the works are the usual Repairing Shops, and near them lies the Test House, which is provided with one of Messrs. Joshua Buckton & Co.'s fifty-ton testing machines.

In the test preparing house are the preparing machine, bending machine, etc.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIFTH SESSION, 1888-89.

PROCEEDINGS.

THIRD GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LIBRARY, FAWCETT STREET, SUNDERLAND, ON FRIDAY EVENING, NOVEMBER 23RD, 1888.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in West Hartlepool, on Saturday, October 20th, which were approved by the members present, and signed by the President.

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

MEMBERS.

Barclay, James, Lloyd's Register of Shipping, Newcastle.
Bell, William, Rosehill Terrace, Rosehill, Wallsend.
Black, J., Messrs. J. Merryweather & Co., West Hartlepool.
Bond, C. P. W., 27, Leadenhall Street, London, E.C.
Bourne, J. J., Lloyd's Register of Shipping, Newcastle.
Brown, E. D., Tees Conservancy Commissioners, Middlesborough.
Cochrane, James, 25, Aduana, Cadiz, Spain.
Connell, Charles, 2, Broomhill Drive, Partick, Glasgow.
Dobson, William, Low Walker-on-Tyne.
Forster, C., 6, Ellison Place, Newcastle-on-Tyne.
Graham, T. S., 11, Brougham Street, Hartlepool.
Gray, A., Fairfield, Stockton-on-Tees.
Hall-Brown, E., 15, Moor Terrace, Hartlepool.
Hamilton, J. H., 61, Lovaine Place, Newcastle-on-Tyne.
Harrold, F., 14, Rowell Street, Hartlepool.

Jackson, A., 22, Ward Street, West Hartlepool.
Jorgensen, F., Inspector of Engineering to the Austrian Lloyd's, Constantinople.
Napier, R. J., Lloyd's Register of Shipping, Newcastle.
Noble, Harry, Northern Machine Tool Works, Forth Banks, Newcastle.
Parsons, P. B., St. George's Wharf, Deptford, London, S.E.
Pepper, W., The Groves, Yarm Road, Stockton.
Piaud, Leon, Bureau Veritas, 8, Place de la Bourse, Paris.
Rendel, H. W., 17, East Parade, Newcastle.
Rimmington, R. F., 6, Cliff Terrace, Hartlepool.
Roger, Robert, Engineer, &c., Stockton-on-Tees.
Sharpe, Henry R., 11, Zingari Terrace, Upton, Forest Gate, London.
Smith, C. E., Messrs. T. Richardson, Sons, & Co., West Hartlepool.
Stewart, H., 10, West Moor Terrace, Pallion, Sunderland.
Swan, A. S., Grove House, Gosforth.
Vick, R. W., Messrs. E. Withy & Co., West Hartlepool.
Warren, G. R., Lloyd's Register of Shipping, Constantinople.

ASSOCIATES.

Armstrong, S., 14, Victoria Place, Hartlepool.
Coverdale, R. H., Messrs. J. Coverdale & Sons, Steamship Owners, West Hartlepool.
Iley, D. W., 1, Elmwood Street, Sunderland.
Yeoman, F., Messrs. Murrell & Yeoman, West Hartlepool.

GRADUATES.

Nicholson, C., 82, Brougham Street, Hartlepool.
Strang, T. R., Bath Lane, Newcastle.

VISIT TO THE HARTLEPOOLS.

The PRESIDENT said it was his privilege and pleasure to bring before the meeting a vote of thanks which it gave him the greatest satisfaction to propose. It was as follows:—"That the best thanks of the members of this Institution be given to the Hartlepool members and their Local Committee for the interesting visit to the engine works and shipyards at Hartlepool, and for the generous hospitality with which they entertained the members on that occasion." He (the President) was sure there could only be one feeling with regard to the interest of the meeting at Hartlepool. From its initiation, from the earliest stages of the movement, it was taken up most heartily by the Hartlepool people. In the case of Institutions of this kind, it was certainly a matter of great importance that they should extend their influence as far as possible, and seeing that this was an Institution, not of one locality only, but of a district extending over a considerable area, that is, embracing four rivers, namely, the Blyth, the Tyne, the Wear, and the Tees, it was of the utmost importance to them that they should extend their influence to these distinct localities. At the suggestion and invitation of their friends in Hartlepool they visited that place, and whether they looked at that visit from the point of view of interest to the members from the northern parts of the district, or from the extended influence of the Institution, or from the great increase of members which had resulted from that meeting, he submitted that the visit had been of the utmost interest and value to the Institution. It was therefore with very great pleasure he moved this vote of thanks. It placed them, as was said at the meeting, under a large responsibility with regard to the future. Their visit to the Hartlepools necessitated at any rate that they should invite the Hartlepools back again to some other locality, and the probability was that before the close of the session they would be asked to accord an invitation to their entertainers to some other part of the district, either to the Wear or to the Tyne, in order that they might have another of those meetings which had proved so very interesting on their visit to Hartlepool. He had very great pleasure in moving this resolution.

Mr. W. **Boyd** (Past-President) had very much pleasure in seconding the resolution which had been proposed by their President, and endorsing everything that had been said by Mr. Marshall in reference to it. He (Mr. Boyd) was quite sure that all who were present at Hartlepool would thoroughly appreciate the way they were received and the very interesting works that were opened for their inspection. He had an opportunity at Hartlepool of proposing the toast of "The Town and Trade of Hartlepool," and expressing these same sentiments, and he had very great pleasure in repeating them now. So far as the Institution was concerned it was a decided step in advance, and one to the credit of their friends at Hartlepool, and notably their friend Mr. Fothergill. He hoped that something that was said at Hartlepool would be remembered, viz., that it might be the beginning of similar visits exchanged between the different localities which combined to make up this Institution, and that they on the Tyne, and Wear too, might in some future year throw their establishments open for the inspection of their brother engineers and shipbuilders, for such a thing could only do the greatest possible good; and he was quite sure, at least he hoped, that the example set by Hartlepool would be followed by other parts of the North-East Coast as years go by. He had very great pleasure in seconding the resolution.

The resolution was put to the meeting, and carried by acclamation.

APPOINTMENT OF TRUSTEES.

The PRESIDENT explained that suitable offices for the Institution having been taken on the first floor of No. 4, St. Nicholas' Buildings West, it was necessary that trustees should be appointed, trustees for the first piece of property they had acquired in the way of rooms and furniture. On behalf of the Council, he had to nominate Messrs. W. Boyd and W. Theodore Doxford, Past-Presidents, and Mr. F. C. Marshall, President, but it was for the meeting to elect them or any other members as trustees.

Mr. H. MACOLL said, when the constitution was drawn up for the organisation of the Institution they did not realise their becoming possessed of property. And when the necessity of having offices for the Institution, together with a room for a library arose, it was quite evident they would be getting into the position of tenants and occupiers, if not land and property owners, which would entail entering into a lease. It was to all intents impracticable to have the whole body of the Institution undertaking such agreements, and it was therefore necessary to appoint some responsible tangible individuals to represent the Institution and sign documents and so forth on their behalf. He did not conceive they could have better known or more suitable gentlemen than those nominated by the President, and he had much pleasure in moving Messrs. Boyd, Doxford, and Marshall be elected as their trustees.

This was seconded by Mr. JOHN GRAVELL, and Messrs. Boyd, Doxford, and Marshall were duly appointed trustees for the Institution.

Mr. JOHAN JOHNSON then read a paper "On a New System of Shipbuilding to facilitate the Application of Machine Riveting to Shell Plating."

ON A NEW SYSTEM OF SHIPBUILDING TO FACILITATE THE APPLICATION OF MACHINE RIVETING TO SHELL PLATING.

By JOHAN JOHNSON.

[Read before the Institution in Sunderland, on November 23rd. 1888.]

Although competition and the increasing dimensions of ships have compelled shipbuilders to adopt heavier and improved plant in their yards, no very advanced changes have taken place in the methods of preparing and combining the material but, in the main points, the old traditional system that developed out of wood shipbuilding is still in vogue.

The necessity of improvements in the art of shipbuilding has been felt ever since the introduction of iron and steel, and papers suggesting new systems of constructing vessels have from time to time been read before other societies.

The disposition of the material and the mode of combining the various parts of a ship's structure, in order to obtain the greatest amount of strength and economy of workmanship, can never be too well considered; and as no paper treating on this important question, from either a practical or theoretical point of view, has yet been read before this Institution, the writer ventures to entertain a hope that this paper will at least lead to an instructive discussion and cause the members to give their opinions on how improvements should best be effected.

Labour-saving machines of the very best description can now be had to perform work of the most intricate character. Hydraulic machinery is used in several yards for riveting the transverse framing, beams, etc., before these are erected in their positions, but only in isolated instances has hydraulic machinery, as yet, been applied with encouraging results to the shell and the heavier interior parts. All efforts to introduce such appliances on a more extensive scale have always proved of no avail on account of the shipbuilders' inability to change the accepted methods of carrying out the work.

It is impossible to touch on what has been achieved by way of improvements in iron and steel shipbuilding, without referring to the writings, inventions and labours of the late Mr. John Scott Russell, whose name will always occupy a predominant position in the history of shipbuilding. He protested, ever since the infancy of iron shipbuilding, against the manner in which the earliest builders followed the traditions of wood shipbuilding and with his extraordinary independent mode of thought and action he set himself to work out an entirely new method, viz., the *longitudinal system*. On that principle he built his second iron vessel, the "Storm," in 1834, and, as the method of construction adopted in that craft has formed a basis for a good many suggestions with regard to the framing of vessels, it may be of interest to notice briefly the novel and ingenious contrivance out of which evolved longitudinal shipbuilding.

In the "Storm" the bulkheads were unusually numerous. Being spaced about the beam of the ship apart they provided for the necessary transverse strength. The longitudinal frames consisted of T iron bars, wrought on the landings of the shell plating so that these landings were flush plated. In larger vessels he afterwards modified this arrangement in fitting broad stringers, and web frames instead of the closely-spaced bulkheads. The earliest ships built on the longitudinal system turned out to be so strong and successful in every respect that whenever Mr. Scott Russell had his own choice he built his ships on that principle and had the courage to prophecy that the time would come when the longitudinal system must take the lead of the transverse system. Obstacles arose, however, beyond his control and, contrary to his anticipations, the longitudinal system is at the present day never practised in the building of mercantile vessels, except in certain modes of framing double bottoms.

So much has been written—particularly by Mr. Scott Russell, whose arguments hold good at the present day—in order to point out the superiority of the longitudinal system that it would be out of place for the writer to recall any but its most prominent advantages.

In a vessel with longitudinal framing the bow is stronger, so that in the event of collision this part of the hull is not liable to such total collapse as is mostly the case in a transversely framed ship. The vibration of the stern is spread over a larger portion of the structure and conveyed to its stronger parts. The sides are not so readily cut down by collision and adequate local strength anywhere in the ship can be obtained with more facility. Where unequal stresses are liable to exist—such as, for instance, in the way of bulkheads—these are distributed by means of the longitudinals over a larger surface. The engine and boiler seatings can with considerable advantage be secured to the longitudinal frame work. The disastrous results of bilge water washing back and forward is greatly diminished.

One of Mr. Scott Russell's principal reasons for adopting the longitudinal system was, however, on account of the superior strength such a system gave in the long narrow ships of the period.

As previously mentioned, the introduction of the longitudinal system met from the very beginning with many difficulties. Chief among these were the workmen, who, trained to the old methods of carrying out work, for various reasons looked askance at any new departure from the system they had made themselves familiar with.

The registration societies have also frequently been blamed, to a certain extent, for hindering the accomplishment of new ideas in variance with their own rules and recommended modes of construction. Of this censure Lloyd's have had to take the brunt, but on the other hand it must not be forgotten that Lloyd's are placed in a very delicate position whenever a deviation from the old routine is contemplated. Moreover, great credit is due to them for having taken the strength of merchant ships seriously into consideration and investigated the stresses such ships are subjected to, so that the material is now better utilised, both the longitudinal and the transverse strength more uniformly provided for and vessels built in accordance with their rules are on the whole much stronger than formerly.

For the sake, therefore, of obtaining more strength no new system is now necessary; but another important motive, viz., the want of mechanical aid in the laying off, riveting, etc., demands an advanced method. The writer is of opinion that it will hardly ever be possible to introduce machine riveting to the shell plating, unless ships are constructed on some sort of a longitudinal principle.

But before any longitudinal or other new system can be introduced, it must fulfil the following conditions compared with the present system:—The cargo space not to be less; access to all parts of the iron work made easy for inspection and painting; the skin plating to be well supported; and lastly, but not least important, the weight of material and the cost of labour not to exceed but if possible to be less.

Vessels built to Lloyd's rules can be safely taken as being sufficiently strong in every respect; all that is needed, therefore, is to produce in a ship built to a new system equivalent strength to the scantlings provided for in these rules. Mr. John and other eminent authorities on the strength of ships have pointed out that there was a tendency at one time to consider that, if a vessel was made strong enough to resist longitudinal stresses, it followed as a matter of course that the transverse strength was also sufficient. But the elements of transverse and longitudinal strength are mutually dependent on each other, the rigidity of the transverse framing is responsible for the preservation of shape and on this again largely depends the longitudinal strength.

The transverse stresses experienced by ships have not been very extensively ascertained. In a paper read before the Institution of Naval Architects in 1882, by Messrs. P. Jenkins and T. C. Read, this question was dealt with from a theoretical point of view in a most able manner, and their investigations show most clearly how enormously the transverse strength is increased by the use of web frames. The tendency of late years has also been to increase the number of web frames and, indeed, in this some builders have exceeded the demands of Lloyd's rules, and the intermediate ordinary frames are now of use only in supplying local support to the shell plating. Web frames, carrying extra strong deck beams and spaced from 10 to 12 feet apart, are undoubtedly a superior arrangement for the preventing of racking strains, as their connections, or the beam arms, can be made considerably stronger than ordinary frames and beams. Besides, web frames are more rigid in resisting the deflection of the bottom and the bilges, which is due to the downward action of the weight of the sides and decks of a vessel when being docked.

On Plates V. and VI. are shown side elevation and sections of a longitudinal system of framing vessels, devised by Mr. N. Arthur—the inventor of the well-known frame bevelling machine—and by the writer, and is the outcome of an idea which originated with them a few years ago while engaged in shipbuilding in Scotland. Last year, through the courtesy of Messrs. Joseph L. Thompson & Sons, they had an opportunity of maturing the scheme and comparing the weight and strength with a vessel built by that firm.

The plans referred to represent a well-decked cargo steamer, 275 feet long, by 36 feet 3 inches breadth moulded, by 19 feet 8 inches depth moulded.

In Fig. 1, Plate V., is shown the general arrangement of the structure and spacing of bulkheads and web frames.

Fig. 2, Plate VI., is a section in way of the web frames; the left part of the section is taken at the after-hold and the right part at the main-hold.

The longitudinals consist chiefly of bulb angle sections—Figs. 4, 5, and 6, Plate VII.—which would probably answer best in a ship of this type and size. In some particular cases channel, Z, or T bars may be found preferable, but there are certain drawbacks in connection with adopting these sections, such as, for instance, if channel bars were used it would be difficult to apply an ordinary riveting machine, and Z bars would be somewhat costly to bend and twist, unless special appliances were adopted for the purpose. T bars would be suitable where flush plating is required, although the amount of riveting would be doubled. Moreover, channel and Z bars are difficult to make tight where passing through bulkheads.

The shell plates are from 4 feet to 4 feet 6 inches broad, with a longitudinal on each landing, taking the same rivets and one intermediate longitudinal on the centre of each strake; this latter may be dispensed with at the ends where the distance between the landings tapers off to less than 2 feet.

Shell packing is done away with almost entirely.

The floor plates or webs in the cellular bottom are spaced from 4 to 8 feet apart, depending on the amount of local strength required. It will be noticed here that the bottom plating is well supported by the longitudinals and the transverse webs.

Deck erections, such as poops, bridge houses and forecastles, could be either constructed with broad web frames and longitudinals, or, if this arrangement was found to trespass too much on the room reserved for cabin accommodation or cargo, short frames connected to the beam arm next below it could be fitted, as shown in Fig. 3, Plate VI.

The ceiling in the bottom is wrought in the ordinary way and the cargo battens are fitted vertically and secured to the longitudinals by means of hooks or cleats.

In the prevalent transverse system, the material which constitutes the longitudinal strength is weakened by not being united, since the shell plating is partially separated from the stringers and keelsons by the transverse framing. As most of the stringers and keelsons have to be carried out to the shell plating and connected thereto, a great deal of strength is lost through having to be scored over the frames, which arrangement is also rather costly. In this longitudinal system, which is submitted to the criticism of the members of the Institution, all the longitudinals are attached to the shell, both combined giving the same longitudinal strength as if the ship was built in the ordinary way. The strong transverse web frames are all inside the longitudinals and spaced on an average of about 12 feet apart. The web frames and the broad stringers are securely connected with diamond plates and, independent of the shell plating, the whole framework is more rigid than the ordinary transverse framing.

It is very essential to have the shell plating as rigid as possible, since both the local and longitudinal strength to counteract the varying stresses in a seaway depends mostly on this. Buckling of the shell is better prevented with longitudinal than with transverse framing. In small vessels, or any vessel of light construction, it is difficult to keep the landing edges of the thin steel plating fair, unless these landings are supported by longitudinals in a similar manner.

The amount of furnace work would be considerably reduced. All the longitudinals are wrought as nearly as possible normal to the surface of the shell plating, they are then more efficient in strength than if bevelled.

With the exception of the bulkheads there are no transverse stations on the shell to regulate the position of the butts and the plates can be kept equal in length, or nearly so. The shell butt straps do not require to be cut to allow the longitudinals on the centre of the strakes to pass through, but these longitudinals will be wrought over the butt straps; this will form a very efficient stiffening. The rivet holes would have to be countersunk to a standard gauge and the rivets made with their heads to suit the same gauge, put in from the countersunk side and clenched up on the inside.

The want of mechanical aid in laying off and punching becomes here most obvious. A considerable saving of time would, no doubt, be effected if the shell, as well as deck plates, could be punched and shaped before any framework was erected. Mr. Arthur and the writer have given this question their fullest attention for some years and have devised a system of mechanical templating and punching, whereby the accuracy and economy of workmanship is ensured, but regret that, owing to the nature of the patent laws, they are not at liberty to give particulars.

With regard to the transverse strength, one web frame ought to be equal in strength to six ordinary Lloyd's frames and reverse frames, and the results of the calculations give :—

Moment of resistance of one plate web frame = 63·2
,, ,, six ordinary frames = 37·1

which shows that the provision of transverse strength is much superior in the proposed system. The longitudinal strength of the proposed system is also slightly—about 3 per cent.—stronger than the transverse system. With the scantlings as arranged on the sections the weight of *ng to facilitate the Ap*

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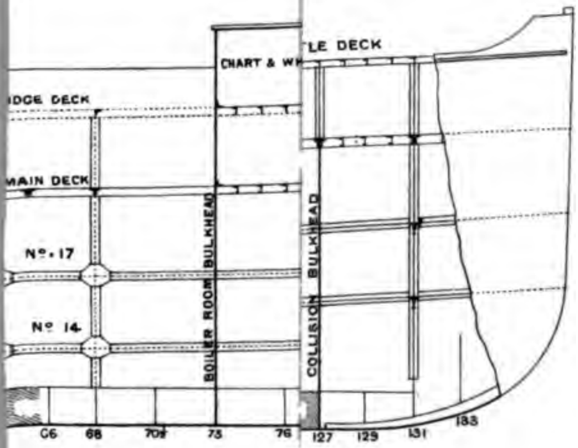
ELEVATION.



Andw Reid, Newcastle

iron would be about 45 tons less, or 5 to 6 per cent. of the total weight of iron. In this saving of weight about 10½ tons of shell packing is included.

From this it is evident that, without decreasing the dead-weight carrying capacity, as compared to a vessel with transverse framing, the vessel in question could be made very strong by adding a trifle to the scantlings.

The erection of the structure would best be carried out in the following order:—First, the keel plates and the centre keelson to be raised and the preliminary riveting in connection therewith completed. Then the bulkheads and the principal web frames to be fixed in position; through their rigid nature they will serve as correct supports to the remainder of the framework and no alteration of shape can take place on the stocks. Next, the longitudinals, previously punched and bent to the required shape, to go up with each strake and riveted by machinery as the work proceeds. Very few ribbands are necessary, which will in itself tend to reduce the working cost. No cumbrous frame-work will be in the way of the riveting machines, which can then be suspended above the vessel by means of cranes or travellers.

If machine riveting is to be successfully applied to shipbuilding the plant must have independent supports, clear of the hull of the structure, as it is too costly to move heavy machinery of that kind, with their pipe connections, about inside a vessel.

When the height of a deck is reached this can be built in and the whole iron work below it thus being finished, any cementing or wood work in the interior may be taken in hand, instead of having to wait until the whole structure is nearly completed.

The chief aim in planning this system has been to ensure sound and accurate workmanship in plating and riveting, without being solely dependent on the varied skill of the mechanics, and to reduce the cost of production by substituting for skilled labour every mechanical aid within our reach.

The writer begs to specially thank Messrs. Joseph L. Thompson & Sons for the interest they have taken in the system; having been stimulated by the encouragement given by them, he has ventured to bring the system before the notice of the Institution.

DISCUSSION.

The President said, they had in their hands, and they had listened to a very interesting paper on a new mode of ship construction, treated in the true spirit of the progress which they were all so anxious to see, the adoption of the application of machinery of all kinds in conjunction with hand labour for the production of work at the lowest possible cost. The paper was now open to discussion. He preferred not to say anything upon this question—one about which he, as an engineer, ought not to be too positive. Engineers were not supposed to be shipbuilders. There were engineers' shipbuilders, but they preferred that night to hear the opinions of their shipbuilding friends on this question. It was a most important one, and one to which a great many people had devoted their attention, and he hoped they would have a lively, interesting, and intelligent discussion.

Mr. Robt. Thompson said, his firm had taken considerable interest in this new system of construction to which Mr. Johnson had devoted much time and labour, and he thought he had displayed no small ability in placing these sections before them that night. That ship was not a mythical one, it was a sister ship to one built on the ordinary raised quarter deck and web frame system. The owner felt rather disposed to build such a vessel as they saw before them, but when the designs were sent to Lloyd's, they were told the system was a new one for which they had no data; and looking round, he thought they had no staff to work out the calculations necessary to say whether it was equal to the previous ship built to their rules. Probably the staff they had in their own yard was double that which Lloyd's had, and he was not surprised that they threw cold water upon the new designs, for the simple reason that they seemed to have more to do than they could on the old lines without tackling this new one. They had since heard (he had heard there that night) of another society that might take it up, and he could only say they would do their best to get a ship built of that type, because they were satisfied from the amount of time and consideration they had given to it, that that was the next step some one would have to take. They had heard a good deal in papers recently as to the amount of machinery and mechanical appliances for cheapening labour, or rather increasing production, and he thought the previous paper seemed to show that although they increased or multiplied their mechanical appliances yet their labour also increased. He (Mr. Thompson) really would like some criticism that night from shipbuilders and draughtsmen engaged in the same business, because he thought the sections before them had put something within a workable distance of what could be built as an improved type of ship, and as this other society had hinted that the thing might be carried through, probably they would have to leave Lloyd's Committee until such times as they better understood the requirements of the shipbuilding trade.

Mr. **Gravell** (Bureau Veritas) said, he submitted a copy of the paper and some drawings of the system now under discussion to the Committee of Bureau Veritas. He was glad to say they accepted the system, and thought it was a decided improvement on the old style of shipbuilding, and they were quite willing to accept a similar section for classification, provided some slight alterations or additions were made. One of the suggestions they would like to make was in the double bottom. They thought there should be more brackets in order to stiffen it in case the vessel grounded. In loading or going up shallow rivers there was always a risk of the vessel touching the ground, and the distance between the floors was such that they considered it would be necessary to fit additional bracket floors between the solid floors, as the bulbs shown on the section were hardly sufficient. For the same reason in consequence of the great distance between the web frames, a larger number of stringers should be fitted, and these stringers connected to the skin between the web frames by brackets, so as to prevent any alterations in the shape of the longitudinal bulb angles. There did not seem to be sufficient connection between the inside framing and the skin of the ship. In reply to the President, Mr. Gravell further explained in the drawings what he meant.

Mr. G. W. **Sivewright** said, the construction of web framed and cellular bottomed ships had occupied his time during the last twelve years, and any improvement in that line was sure to meet with his approval. He was pleased to notice that in one part of the paper, Mr. Johnson specially mentioned Scott Russell's name and thought that every shipbuilder, or anyone having to do with ships, ought to feel a deep debt of gratitude to Mr. Scott Russell because he considered that when they looked at all the web framed and cellular bottomed ships now building, these were only modifications of Mr. Scott Russell's principle. But Mr. Johnson had gone further than this in his design, which showed that a very good attempt had been made to build a ship in a more mechanical manner than by the old system, and the more mechanical aids we can get to do shipbuilding the better the class of work will be. There were two or three small matters in the section that he considered were not quite perfect, the principal one appeared to be the three-ply riveting at the plating seams, but he had no doubt that this objection could be got over by good mechanical riveting, and after a ship or two had been built to the design, the defects or objectionable parts of the first plan would be surmounted. He quite agreed with Mr. Thompson that we were getting beyond the stage in which shipbuilders could only build a ship in one way, that is, the way set out by Lloyd's rules. There was no doubt that Lloyd's had many interests to consider, and in his opinion this was the reason they were so careful about making any alterations to their rules. The delay caused by this had the effect in many instances of deterring new designs. He would not go so far as to say that the Bureau Veritas would cut out Lloyd's, but by helping shipowners they would encourage many improvements shipbuilders would like to get introduced.

Mr. H. **Macoll** considered they had had placed before them by Mr. Johnson something like what he had no doubt would be the style of ship in the future, especially when of considerable length. There had been in the past several attempts and proposals to introduce longitudinally constructed vessels. Hitherto they had been "sat upon" by their esteemed friends the classifying registrars at Cornhill and others exercising similar functions as well as by the operatives who did not take at all kindly to the introduction of the proposal. Hence, those people engaged in the construction of ships usually found the ordinary incidental troubles and bother attendant on the business quite sufficient for them without complicating matters by endeavouring to introduce novelties which entailed a sort of all round fight to obtain their introduction. However, it may be hoped by the spread of intelligence and the great adaptability of the modern machine tool that it may be practicable for the enterprising shipbuilder to pull along somewhat more satisfactorily than has hitherto been done in this direction. Mr. Johnson lays down several conditions to be fulfilled in the new, or shall we say improved style of ship? Still it would seem that two very important factors are not defined, nor are the means by which they are to be fulfilled stated except by inference. First, the strength of the proposed ship as compared with the present system. This should be clearly and distinctly proved and set forth, that is so far as figures may go to do it. Next, the means of applying the riveter to the vessel. The system of construction of the vessel being granted, how is the riveter to be applied to the work? Considering the width of shell plates now in use, and as this is not likely to be lessened in the future, the riveter must be an article of considerable range and consequently of considerable weight. In a ship of 40 to 50 feet beam and 300 to 500 feet long, the riveter must be capable of swinging easily from the centre line of the ship to the outside of the shell plating, consequently it must be hung from a travelling crane, which in turn must be supported on columns placed between the vessels, and a line of columns outside the outside vessel, the crane designed to be of sufficient height to clear the upper deck and have appliances for lifting over the beams, bulkheads, etc., rapidly and easily. Granted this done, it would be a splendid arrangement for hoisting the framing, plating, and other material into position. Looking at the matter more in detail, it would seem to be necessary to have at least twelve cranes to each ship with two riveters hung from each crane so as to command and work both sides of the ship, and each riveter should be hung from a sort of inverted crane secured to the travelling crane, which should be of considerable radius so as to work without interfering unduly with the riveter on the other side of the ship hanging on to the same travelling crane. All this could not be done without a very large and expensive addition to the present shipbuilding plant, and was a factor requiring a great deal more attention than has been paid to it in the paper. Then as to the additional strength in the bow gained by the system, he was afraid in some cases the remedy was worse than the disease. In the event of a heavy collision in the stem, it was quite possible these longitudinals, if they did not buckle up, would disturb, and to a certain extent, destroy the collision bulkhead as he had observed in several cases even with the ordinary style of construction. There was not the same objection at the after-end of the vessel, on the contrary great benefit would be derived from having a better, more direct and rigid attachment from the stern frame to the adjacent framing and shell plating. Another matter he desired to draw attention to was the drainage of water down to the pumps. How was the water to get down? Say from the upper part of the bilges to the rose boxes near the centre line of the bottom; and as this was a somewhat important matter it was desirable that some arrangement should be indicated for the purpose. So far as he could see by the plans, the longitudinals would either have to be filled up with cement, which was a heavy and rather old-fashioned way, or holes would be made in the longitudinal bars. Looking at the size of these bars, and considering they were unsupported between the web frames, he did not consider they were strong enough to admit of holes being made in the webs. In fact the longitudinals seemed rather light altogether for the work they were supposed to do in supporting the shell plating as they were shown, and that brought him to what he had been considering for some time: the writer had not put before them the particulars of the calculations of the comparative strengths of the present and the proposed section. It had to be taken pretty much as a matter of faith. In the paper it was stated one web frame was so much and six ordinary frames were so much, but it was advisable to see the steps by which these results came about. In a comparatively new departure like this, the strength of the proposed vessel should as far as possible be placed beyond question. Most of them had only now seen the diagrams for the first time, and for his part, however willing he might be to accept the results which had been stated, he found it difficult, very difficult, to do so on the information supplied.

Mr. Johnson said he would give the calculations as an Appendix to his paper. (See p. 96.)

Mr. Macoll—There was another matter which did not appear very clear to him, namely, the longitudinals going over the shell butt straps would involve considerable trouble and expense in joggling the bars. Judging from the fact that all the thicknesses were given in sixteenths, he presumed the material was intended to be iron. His experience in joggling iron bulb angles was not such as would lead him to adopt it if it could possibly be avoided. Even with steel bars and the use of hydraulic or other powerful machinery he was rather doubtful as to the effect of joggling on the strength of the bar, but believed it would be considerably weakened thereby, and on the whole it might be quite as well to use the packing even at the disadvantage of the extra weight. He hoped his friend Mr. Johnson would not think he was an opponent of his scheme, on the contrary he desired again to express his appreciation of the proposal and of the labour he had expended in placing the matter in so clear, intelligent, and he might add talented, manner before them. Still it was not by ignoring difficulties or objections that the proposed method of shipbuilding would be advanced, but by meeting and overcoming these objections when reasonable in themselves, and not simply the result of prejudice.

Mr. T. Millar said, that since receiving a copy of the paper he had not been able to give the subject the attention he thought it deserved. He was very much pleased that Mr. Johnson had placed before them such a very interesting and instructive paper. There were one or two points upon which he did not quite agree with the author and some of the previous speakers. The system of longitudinal framing proposed, was, as far as he could see, a modification of Scott Russell's, and judging from the plans now before them he thought a considerable advance in the right direction, as it brought within range the use of sections of material which could be worked easily and to great advantage. He was pleased to hear that a recognised society was quite prepared to accept the vessel, as this got over one difficulty; all that was now necessary being the assistance of some enterprising shipowner willing to spend some money, who would give the system a fair trial. It would be a very difficult matter indeed to give an approximate estimate of what a vessel built on this system would cost, owing to the trouble there was in getting workmen to accustom themselves to anything new, there being quite sufficient trouble at times to get them along with the present system of framing if any new departure was made. The method of framing seemed to him open to serious objections. In the present transverse system of framing it was possible to get a large body of men drafted on to a vessel in a very short time, whereas in the proposed system of erection, making due allowance for the benefits which would be derived from the use of riveting machines, the vessel would require to be very far advanced in some directions before a large body of men could be employed profitably. He thought the three-ply riveting through the shell and longitudinal frames objectionable, as there was trouble in getting fair holes even in the present system where the number of three-ply holes is limited. Of course if the holes were drilled this difficulty could be surmounted, but the work would be retarded and the cost of production increased. Again, he noticed from the section that the lugs for attaching the web frames to the longitudinal frames were shown fitted to the bosom of the bar. This arrangement he thought would interfere with the riveting of the shell behind the lugs; an objection, however, which could be got over by using a section of bulb angle with the bulb inside and placing the lug on the back of the frame. But perhaps it was the intention to rivet the shell before the lugs were put on.

Mr. Johnson—No. The intention was to rivet the lugs on first.

Mr. Millar—Then he should certainly place the lug on the opposite side of the frame, as, if placed there, it would not interfere with any of the riveting. He also thought that it would be advisable to keep the landing edges of the shell clear of the longitudinal frames, but quite close and parallel to them. One of the previous speakers proposed the introduction of additional brackets to strengthen the longitudinals in the double bottom. This he thought would be unnecessary, as the frames were spaced quite close enough to support the shell and had sufficient strength in themselves to do all the work required of them between the transverse floors, which Mr. Johnson states are 4 to 8 feet apart on an average. Regarding the drainage of the vessel, although this at first sight appeared troublesome, it could be got over by punching small limber holes through the frames, which could be done without materially affecting their strength, and which he thought would prove efficient. With reference to the framing being carried out to the stem affecting the peak bulkhead in case of collision; while agreeing with one of the previous speakers, that there might be some danger of this occurring in the present arrangement of transverse framing where the stringers are fitted inside the frames from the stem to the bulkhead, or for some distance abaft same, the danger would be greatly lessened in the proposed system, as the shock would be taken by the frames and continued aft to a certain extent clear of the bulkhead altogether, thereby minimising the danger of doing any damage to the bulkhead. He should like to see as many as possible of the longitudinal frames carried right aft and strongly attached to the stern-post, as there was always considerable vibration there, especially in vessels in which the engines were placed aft. Another objectionable feature to the longitudinal framing was the increased number of bulkhead collars which it would be necessary to fit, this being, as they were well aware, very expensive and difficult to make a good job. At the same time these difficulties could be overcome, and whatever extra cost was incurred would no doubt be balanced by considerable savings in other directions, and nothing would give him greater satisfaction than to assist in introducing some improved system of framing where riveting machines could be used advantageously. Mr. Johnson said, and advisedly, that in any new system introduced it must in no way differ from the present system so far as cargo space, etc., was concerned, as any infringement of cargo space or difficulty of free access to the skin or other parts of the vessel would at once condemn it. There would, he thought, be some difficulty in bending the frames, although from the arrangement proposed they could no doubt be all bent cold, by so doing both time and money could be saved. The fact of the shell being fitted close to the frames would do away with a considerable amount of packing, and he thought that Mr. Johnson was very moderate in his estimate of this saving. The joggling of the frames over the butt straps was another thing he took exception to as reducing the strength of the frames. He did not think that it was at all necessary to do this, as the butt straps could be cut and fitted close to each side of the frame, or if this was objected to the butt straps could be stamped and fitted into the bosom of the frames, and this he thought could be done at less cost than it would be possible to joggle the frames. There would be some trouble in countersinking the rivet holes to a standard gauge, but no doubt it could be got over. Most of them engaged in shipbuilding were fully alive to the advantages gained in being able to get the work templated and shaped before any frame work was erected, and they would be only too pleased if Mr. Johnson was able to develop some method by which this could be done correctly and rapidly so as to lessen the cost and increase the rapidity of production. Seeing that the strength gained by the introduction of web frames is fully recognised, he thought that if the ordinary transverse frames were made lighter in the present system, the number of web frames increased and additional longitudinal stringers introduced, the strength of vessels might be greatly increased with the same weight of material and at about the same cost. He hoped that at no very distant date they would have the pleasure of seeing Mr. Johnson's proposed system reduced to actual practice, and he wished him every success in the working out of his ideas.

The **PRESIDENT** observed that all the speakers had referred more or less to machine riveting, and the difficulties incident to its application. Mr. Tweddell was present and might say something to them, he having applied the machine. He (the President) fancied there had been many arrangements adopted to get over these difficulties.

Mr. R. H. TWEDDELL said, he came that evening not to speak about hydraulic riveting machinery, but to hear what was the nature of the proposed alteration in ship construction by which the application of such machinery could be facilitated. He (Mr. Tweddell) had in a paper read by him before this Institution already pointed out that it was not the absence of suitable riveting appliances which prevented mechanical riveting being applied to ships as successfully as it had already been to bridge and boiler work, but that shipbuilders would not alter their mode of erecting and constructing ships. The author of this paper however had approached the subject in the right way, but before they could expect to see ships mechanically riveted shipbuilders would have to spend an amount of money in tools and crane appliances far exceeding, in proportion, that now laid out by boiler and bridge builders. His friends Messrs. J. L. Thompson & Sons had made a good commencement in that way, and seeing that the author of this paper had the best wishes of this firm, as expressed in the paper just read, he hoped that they would soon see their way clear to still further develop the application of machinery to riveting ships in their yard. As was well known, the question of riveting the top and bottom members (so to speak) of a ship—looking upon the structure as a girder—was now satisfactorily solved, and it would seem strange if the intermediate plating could not also be done by machinery. The various objections to triple plate joints, etc., would disappear at once when done by machinery. He (Mr. Tweddell) had recently spent a day with Mr. William Arrol on the Forth Bridge Works. It was worth any shipbuilder's while to visit that remarkable work, and after such a visit the question of "templets" laying down and erecting of the most complicated ironwork would resolve itself merely in a question of highly educated and trained foremen and draughtsmen. There is not a straight line in the Forth Bridge, yet everything is so well done in the moulding loft and yard that the putting together *in situ* goes on much faster than the preparatory work. The question again of bending the plates to various curves is solved in a very satisfactory manner, although in this respect shipbuilders have not perhaps much to learn of anyone. It all resolved itself into a question of first outlay, and if anyone will consider for a moment the relative ratio of money laid out in tools and labour-saving appliances in proportion to tonnage of steel or iron worked in a shipyard, as compared with that laid out in an engineer's or bridge builder's shop, this will be at once apparent. For example take the almost entire absence of lifting appliances and tramways (in many yards) compare the number of labourers lifting frames and beams to the working of a small hydraulic crane, which would pick them up, put them on a rolley, and which would again be drawn along by a hydraulic capstan. In some shipyards he (Mr. Tweddell) was employing hydraulic capstans to draw the frames out of the furnace and bend them to shape, etc., but it was not necessary to go into details of that kind. The main question is, the application of machinery to riveting ships; and in conclusion he (Mr. Tweddell) would only remark that the difficulty did not lie in the want of machinery to do the work, but in the unsuitability of the present mode of construction for its application. The author's paper is one of the first steps towards removing this objection, and it will be not the least of the good results of the formation of this Institution, if the North-East Coast takes the initiative in a matter which is of vital importance, not only to the maintenance of its present position in the shipbuilding world, but also to the ensuring excellence in quality combined with cheapness in cost of production.

Mr. Chas. S. Allott, M.Inst.C.E., a visitor from Manchester (by invitation), had not, he said, come there to take part in the discussion, but merely to hear the paper read by Mr. Johnson. It had given him great pleasure to be present that evening, and had also afforded him a great deal of instruction. He could not lay claim to being a judge of the respective systems, not being a shipbuilder; but he thought he could go so far as to endorse pretty well all that Mr. Tweddell had said as to the difficulties and how they could be got over. He (Mr. Allott) thought, too, that it was merely a question of arranging the cranes. If they could get the machines where they were wanted there would be no difficulty in applying them. The system that he was interested in was rather different to that of Mr. Tweddell's; it was the compressed air system. It had its special advantages, just as the hydraulic machine had its advantages. One of the advantages they claimed for the compressed air riveting machines was the low-pressure they worked at. They used ordinary four-ply flexible hose, and could take it anywhere about the vessel; they found they had no leakages or anything that way. They could also utilise the compressed air in other ways. Mr. Tweddell spoke of the hydraulic drill, they had also compressed air drills, and used the same compressor for the oil burning rivet furnaces as well as the Lucigen Lights. Considering this system was only recently introduced into England he considered they were doing remarkably well, and were at the present time fitting up some of the yards on the Clyde, and they had them working in their own town here. As far as regarded the number of plies to be riveted it did not matter whether it was three or a dozen. At present they were riveting up as many as twelve thicknesses of plates in bridge building, putting in rivets eleven inches long and one inch in diameter. As to the laying off he could only endorse what Mr. Tweddell had said, at present they had very little difficulty.

Mr. W. Theo. Doxford said that the paper which had just been read was a very interesting one and one upon a subject which was becoming of increasing importance, if they were to apply mechanical means for the riveting up of the shell, etc., of iron or steel vessels. A good deal of reference by the various speakers had been made to Lloyd's, and by many Lloyd's Committee were blamed for not agreeing more readily than they did to suggested improvements. They must, however, consider that Lloyd's was a very important body, and had to safeguard important interests, not only the interests of the shipbuilder, but also those of the shipowner and underwriters, and when they consider that, they should not be too hasty in their judgment when they found that Lloyd's were slower in acting than they should like them to be. However, from what Mr. Gravell had said it was apparent that the Veritas Association was prepared to accept something on the basis of the proposal they had before them, and if so Lloyd's would be compelled to follow suit; unfortunately there were no definite calculations in the paper showing how the strength had been worked out, but as Mr. Johnson had promised to add this to the paper for the Transactions its value would be very much increased, as the calculations would assist them very considerably in coming to a right judgment upon the valued proposals before them. On the section upon the wall they had the size of plates, frames, etc., for the proposed vessel, but unfortunately not the corresponding scantlings for a similar vessel built strictly in accordance with Lloyd's rules so that they were not able to form an opinion as to which parts of the vessel had been reduced, so as to save the weight claimed by Mr. Johnson. If this had been done by reducing the thickness of the shell plating, he for one would object to such a course being adopted, as he thought that the shell plating was thin enough at present. As the proposal at present stood it was difficult to say whether the support given by the longitudinal frames would be equal to that given by the ordinary vertical frames and he would like to know whether the longitudinal frames were continuous through the bulkheads or not?

Mr. Johnson—They are continuous.

Mr. Doxford—If so there would be considerable difficulty in making the bulkheads tight around them. Mr. Johnson mentioned the necessity of not reducing the internal capacity of the ship, but from the appearance of the plans before them he (Mr. Doxford) rather feared that the internal capacity would be very considerably reduced as the web frames were very close, and would probably have to be closer still to meet Lloyd's requirements, as would also probably be the case with the longitudinals. Mr. Gravell had already told them that Veritas would require these closer. Now, if this were so, certainly with some description of cargo the internal width of the ship would practically be reduced for 12 inches to 18 inches from what it would be by the ordinary method of construction, which would be a very serious loss. He was sure that the members who knew Mr. Tweddell were glad to meet him there once more, but he (Mr. Doxford) was rather disappointed at what he had said; the intention of the paper was to suggest a system of plating vessels which would facilitate mechanical riveting of the shell, etc., with a view, as he understood it, of reducing the ultimate cost of the work, but the impression that he had got from what Mr. Tweddell had said was that they need hardly hope to reduce the cost of the work in that way.

Mr. Tweddell (explaining) rather meant to say it would not reduce the cost per hundred, but five times the speed would in that way reduce the cost; the construction too would be improved. By the present mode of hand riveting they had no guarantee of the workmanship, but with mechanical riveting there was no doubt about it.

Mr. **Doxford** was very glad to hear Mr. Tweddell say so, but he (Mr. Doxford) was satisfied that with the present mode of construction it was perfectly impossible to apply hydraulic or any mechanical means of riveting of the shell plating of vessels.

Mr. **Tweddell**—I have given it up long ago.

Mr. **Doxford** (continuing) said, if they could get a better and cheaper method of construction the sooner it was introduced the better. From what Mr. Tweddell had said it only required the shipbuilder to have sufficient courage to lay out capital in the necessary plant, etc., to enable a complete system of hydraulic riveting to be adopted, but before builders would be inclined to lay out the extra capital, which would be no small amount, they would want to be pretty sure of getting a fair return upon the money expended.

Mr. **Geo. N. Arnison**, Jun., said, it was gratifying to have Mr. Johnson's paper read before the Institution, as if any practical result accrued the North-East Coast Institution of Engineers and Shipbuilders would to a certain extent share in the honour of having taken the first step in the adoption of longitudinal framing in place of the present practice. They had brought before them the arrangements and scantlings of an ordinary "dead-weight cargo" steamer with no hold beams, but he should like to have seen how the author would propose to arrange a large passenger steamer with several decks laid. Some years ago he (Mr. Arnison) got out a design for a twin screw steamer, 660 feet in length, 70 feet beam, in which it was proposed to adopt the longitudinal system, but with the longitudinals at least twice as wide apart as those shown in the drawings accompanying Mr. Johnson's paper. The vessel was also intended to have a complete central fore and aft bulkhead. He (Mr. Arnison) would like to know had the writer of the paper in calculating the longitudinal strength of the vessel designed to be built on the new system taken either the "hogging" or the "sagging" strains, or both ? Only having seen the scantlings that evening he could not speak positively, but it appeared to him that it was likely the longitudinal strength must be more than three per cent. in excess of that of a similar vessel transversed framed, built according to the rules of Lloyd's Register. He thought the longitudinal strength might be fairly reduced, and that it would be advisable for a shipbuilder in designing a vessel of this class to keep the scantlings below what he was actually inclined to finally adopt in the vessel, for when midship sections, etc., were submitted to Lloyd's Surveyors and Committee, alterations and additions were almost certain to be required. They had heard that this was so during the present discussion in the case of Bureau Veritas as regards Mr. Johnson's proposed vessel. If they made the most perfect arrangements and submitted them to the approval of Registration Societies, Surveyors, and Committees, the latter would want some scantlings increased. Probably it would be better therefore to propose scantlings which did not quite come up to their ordinary requirements. This was not, he believed, being done in the present instance, in which, on the whole, he (Mr. Arnison) thought the scantlings were excessive, more especially in the close spacing of the longitudinals. Placing these frames on the seams he considered a great mistake; that was his personal opinion. He would prefer that the longitudinals should only be placed at midway between the seams of the shell plating, short disconnected ordinary transverse frames being fitted from longitudinal to longitudinal at suitable spacing, so as to supply the requisite stiffening against buckling. A question alluded to by Mr. Doxford had previously attracted his attention, viz., that between the water-tight bulkheads there was no actual transverse support to the shell plating. For instance, assuming the distance measured on the skin of the vessel from the fore-end bulkhead of the after-hold to the after-end bulkhead was 100 feet, multiplying that quantity by the distance between the longitudinals, viz., 2 feet, gave an area of unsupported shell plating of no less than 200 feet. Now, in ordinary practice with the present system of transverse framing, with intercostal keelsons and stringers connected to the shell plating, say every 7 feet, the unsupported area would only be about 14 feet. Was it a proper arrangement so greatly to increase the unsupported area of the shell plating? Certainly the question should be carefully considered; also as to whether there was sufficient transverse support to the shell plating. More especially did these points require attention in vessels with thin plating. He (Mr. Arnison) agreed that Mr. Johnson's proposed system would give additional strength at the stern, but he thought that even on the transverse framing system vessels had been built with equally as strong fore-ends. He remembered a vessel where they introduced between each tier of beams, orlop and lower, lower and main, main and upper; another tier of beams with stringer plates connected to the shell plating forward, and the collision bulkhead, as well as panting beams abaft and lower down, breasthooks, etc. If this vessel were to come into collision with an iceberg he felt sanguine that, as in the case of the S.S. "Arizona," the vessel would still float. It was not necessary to have a departure from transverse framing to secure greater strength at the bows of steamers than what is often at present provided. Some of the difficulties of carrying out longitudinal framing in practice had already been mentioned. One of the great difficulties would be to get workmen to accept piece-work prices, as they would hardly know what to ask, or would ask something outrageous. The first vessel would probably have to be built on time wages, and as had been pointed out by Mr. Millar it would be very difficult to form an approximate estimate of the cost. A point in the paper that surprised him (Mr. Arnison) was that in the writer's reference to Lloyd's Register he gave that society so much credit for the existing system of scantlings. He (the speaker) did not think a great amount of credit was due to Lloyd's Register. What were some of the facts? In 1855, when the Committee first issued tables of scantlings, they were based so much upon the practice in wood shipbuilding as to require for an A1 vessel frames 16 inches apart, and shell plating of a minimum thickness of 1 inch for a vessel of 3,000 tons; and when in 1857 the frame spacing was increased 2 inches, the entire shell plating was increased one-sixteenth in thickness. The late Underwriters' Registry for Iron Vessels deserves special mention in any discussion as to the fitness of existing rules and scantlings for modern shipbuilding. Prior to its existence "surplus scantlings" were in vogue, and how long they would have continued to be so, if it had not been started in 1862, who could say? The Underwriters' or (as it was commonly known) the Liverpool Registry at once commenced to class vessels built on considerably lighter scantlings, and in 1863, apparently to compete with its mode of classing vessels for twenty years, etc., the Committee of Lloyd's Register announced in future iron vessels would be classed Aa, Ab, Ac, and widened the spacing of frames to 21 inches. Will anyone deny this was largely, if not entirely, due to the opposition of the Liverpool Registry? Again, the latter society early based most of the scantlings on the dimensions and proportions of vessels, while Lloyd's Register employed the tonnage as their basis; but in 1870 this bulwark of Lloyd's Register was removed, and to the great amusement of many connected with shipping they again altered the symbols of classification, and made them for new iron vessels 100A, 90A, 80A, etc. It was only just that the credit of the improvements in the scantlings and strength of iron and steel vessels should be properly assigned, and no small share of it was due to the Underwriters' Registry for Iron Vessels. Some remarks had been made about the excessive cost entailed for watertight collars at the bulkheads by Mr. Johnson's proposed arrangement of building vessels. No doubt the cost would be great if collars were smithed from angles, but a firm in the north of Ireland, which had both engineering and shipbuilding establishments at no great distance from one another employed cast iron or cast steel collars, and he had not the slightest doubt a better fit was ensured, and in all probability with economy. Nothing was more important than to have thoroughly efficient water-tight collars. In ordinary practice they were generally required to be made tight with stop-waters, red lead, putty, etc. He had frequently seen water-tight collars which had to be fitted to keelsons formed of top and centre plates and four angle bars, in which none of the joggles at the corners perfectly fitted, so that a knife could not be inserted before caulking. As to three-ply riveting he agreed with those who objected to it. Even with hydraulic power it was objectionable. Greater care had necessarily to be exercised in obtaining absolutely fair holes. The three-ply riveting was a great objection to the fitting of longitudinals at the seams. In conclusion, he (Mr. Arnison) while agreeing that Mr. Johnson's proposed longitudinal framing arrangements deserved every encouragement, at the same time thought there was room for improvement in its details.

The PRESIDENT said, it became his pleasant duty to propose a vote of thanks to Mr. Johnson for this paper. They could not expect Mr. Johnson to reply to the very interesting discussion that night; in fact according to the rule the discussion would be continued at their next meeting to be held in Newcastle. For the moment they would satisfy themselves in giving expression to their sentiments of their very high appreciation of the paper they had just heard read. He would just make one or two remarks before putting the motion to the meeting with regard to several points raised that night. The great matter urged by Mr. Johnson in the introduction of this system was the facility it would afford for the introduction of hydraulic riveting, or riveting by pressure of some kind. That, he thought, was very ably replied to by Mr. Tweddell and Mr. Millar; but he did not think Mr. Tweddell quite did himself justice. He might possibly have shown them some of the methods by which hydraulic riveting was carried on in such large structures as bridges that had been built for India and other parts of the world, where hydraulic riveting was used exclusively and in quite as difficult positions as a large proportion of ships with which they had all to do. Possibly something of that kind might be done on another occasion if Mr. Tweddell had an opportunity. With regard to plating, Mr. Tweddell referred to the Forth Bridge. That was a marvellous structure and an exhibition of the application of machines worked by hydraulic and air power. Perhaps no such concentration of engineering ability and force has ever existed anywhere as they had an opportunity of seeing in the Forth Bridge. The engineering skill brought to bear upon that structure was simply (to his mind, and he knew he expressed the opinion of many others) marvellous, and of immense credit to the gentlemen who had the charge and responsibility of that work. With regard to the workmen a great deal had been said, and one had to be very careful in speaking here, so that they put their views very clearly. The difficulty at the present day was not that they had too many men, but that they very presently would have far too few men. At this moment the great difficulty in many places was to get men. What they wanted was for the shipbuilders to increase the power of the men by the application of machinery and capital, and capital would be invested to much greater advantage than in paying it away in wages from day to day. The time of the meeting was now expired. He should have liked to have said more. He thought their friends of Lloyd's had received a little hard hitting that night. He did not say they did not deserve it. On that subject there was a consensus of opinion in the shipbuilding community that did not exist on any other. He did not know that what had been said by Mr. Johnson and Mr. Gravell would have any effect; if not, they would have to work in some other direction, and Lloyd's would naturally move in their own interest. He could bear out what Mr. Arnison said about the Underwriters' Registry. He happened to be in the midst of it, and his friend Mr. Martell, and himself had had several brushes on the subject; but he was quite sure Lloyd's, when they were shown by the engineering talent of the country that ships could be built in a specific way, would yield. He though shipbuilders should study more than they did what had been accomplished in bridge building. There was more shown in bridge building, in accurate plating and manipulation of plating, than had ever yet been attempted in shipbuilding. He had nothing further to say than to move for their acceptance a very cordial vote of thanks to Mr. Johnson for the able paper he had read, which had led to such a valuable and interesting discussion.

The vote was cordially given, and the discussion was adjourned.

The meeting then closed.

APPENDIX TO MR. JOHAN JOHNSON'S PAPER.

CALCULATION OF LONGITUDINAL STRENGTH.

TRANSVERSE SYSTEM.

Part of Structure.	a.	h.	h^2.	x.	x^2.	$\frac{h^2}{12}$.	$x^2+\frac{h^2}{12}$.	$a(x^2+\frac{h^2}{12})$.
Bottom plating, A to E ...	139·7	1·35	1·82	7·64	58·4	·2	58·6	8,186
Bilge " F to G ...	68·8	6·00	36·00	4·34	18·8	3·0	21·8	1,500
Side " H, J, and K	91·1	10·90	118·81	4·16	17·3	9·9	27·2	2,478
Sheerstrake and doubling ...	41·3	3·33	11·09	10·66	113·6	·9	114·5	4.729
Centre keelson plate ...	10·2	3·00	9·00	6·54	42·8	·8	43·6	445
" " angles ...	8·4	...	...	6·54	42·8	...	42·8	360
No. 2 girder plate	11·6	2·50	6·25	6·22	38·7	·5	39·2	455
No. 3 "	11·3	2·30	5·29	6·04	36·5	·4	36·9	417
Wing plate	13·6	2·20	4·84	5·84	34·1	·4	34·5	469
" shell plate	2·9	...	...	6·79	46·1	...	46·1	134
Tank top plating	64·5	...	...	4·89	23·9	...	23·9	1,542
Bilge stringer plate... ...	5·3	...	...	·34	·1	...	·1	1
" " angle ...	2·4	...	...	·34	·1	...	·1	...
" " face T ...	4·3	...	...	·34	·1	...	·1	...
Side " plate ...	5·3	...	...	5·36	28·7	...	28·7	152
" " angle ...	2·4	...	...	5·36	28·7	...	28·7	69
" " face T ...	4·3	...	...	5·36	28·7	...	28·7	123
Main deck stringer plate ...	23·7	...	...	11·76	138·3	...	138·3	3,278
" " angle ...	4·2	...	...	11·81	139·5	...	139·5	586
Deck plating	69·0	...	...	12·11	146·7	...	146·7	10,122
	584·3				½ Moment of inertia			35,046
								2
					Moment of inertia...			70,092

$$\text{Moment of resistance} = \frac{70{,}092}{12{\cdot}11} = 5{,}788.$$

a = area in square inches.
h = depth of flange in feet.
x = distance of centre of gravity from neutral axis.

PROPOSED LONGITUDINAL SYSTEM.

Part of Structure.	a.	h.	h^2.	x.	x^2.	$\frac{h^2}{12}$.	$x^2+\frac{h^2}{12}$.	$a(x^2+\frac{h^2}{12})$.
Bottom plating, A to E ...	122·1	1·32	1·74	7·49	56·1	·1	56·2	6,862
Bilge " F to G ...	60·0	5·80	33·64	4·29	18·4	2·8	21·2	1,272
Side " H, J, and K	87·0	11·15	124·32	4·21	17·7	10·4	28·1	2,445
Sheerstrake, L	36·8	3·50	12·25	11·06	122·3	1·0	123·3	4,537
Centre keelson plate ...	10·1	3·00	9·00	6·39	40·8	·8	41·6	420
" " angles ...	8·4	...	...	6·39	40·8	...	40·8	343
No. 2 longl. bulb angle ...	4·4	...	...	7·69	59·1	...	59·1	260
No. 3 " plate	13·1	2·95	8·70	6·34	40·2	·7	40·9	536
" " angles	4·9	...	...	6·34	40·2	...	40·2	197
No. 4 " bulb angle ...	4·3	...	...	7·59	57·6	...	57·6	248
No. 5 " plate	12·8	2·85	8·12	6·17	38·1	·7	38·8	497
" " angles	4·9	...	...	6·17	38·1	...	38·1	187
No. 6 " bulb angle ...	4·3	...	...	7·37	54·3	...	54·3	233
No. 7 " plate	11·8	2·60	6·76	5·99	35·9	·6	36·5	431
" " angles	4·9	...	...	5·99	35·9	...	35·9	176
No. 8 " bulb angle ...	4·3	...	...	6·97	48·6	...	48·6	209
No. 9 " plate	11·3	2·10	4·41	5·64	31·8	·4	32·2	364
" " angle	2·3	...	...	6·59	43·4	...	43·4	100
Tank top plating	66·0	...	...	4·74	22·5	...	22·5	1,485
No. 10, longl. bulb angle ...	4·7	...	...	5·89	34·7	...	34·7	163
No. 11, " " ...	4·3	...	...	4·59	21·1	...	21·1	91
No. 12, " " ...	4·3	...	...	3·01	9·1	...	9·1	39
No. 13, " " ...	4·3	...	...	1·29	1·7	...	1·7	7
No. 14, " plate	8·0	...	...	·41	·2	...	·2	2
" " angle ...	3·8	...	...	·41	·2	...	·2	1
" " face T ...	4·3	...	...	·41	·2	...	·2	1
No. 15, " bulb angle ...	4·3	...	...	2·21	4·9	...	4·9	21
No. 16, " " ...	4·3	...	...	3·96	15·7	...	15·7	68
No. 17, " plate ...	8·0	...	...	5·71	32·6	...	32·6	261
" " angle ...	3·8	...	...	5·71	32·6	...	32·6	124
" " face T ...	4·3	...	...	5·71	32·6	...	32·6	140
No. 18, " bulb angle ...	4·7	...	...	7·53	56·7	...	56·7	266
No. 19, " " ...	5·3	...	...	9·33	87·0	...	87·0	461
No. 20, " angle ...	4·2	...	...	11·91	141·8	...	141·8	596
Main deck stringer	26·8	...	...	11·91	141·8	...	141·8	3,800
" plating	69·0	...	...	12·26	150·3	...	150·3	10,371
	642·1				½ Moment of inertia			37,214
								2
					Moment of inertia...			74,428

$$\text{Moment of resistance} = \frac{74{,}428}{12{\cdot}43} = 5{,}988.$$

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIFTH SESSION, 1888–89.

PROCEEDINGS.

FOURTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, DECEMBER 17TH, 1888.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting held in Sunderland, on November 23rd, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. T. Milton and J. J. Campbell to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Bartliboi, Jehangir Framji, Bombay, British India; (temporary address) 1, Olive Street, Sunderland.
Boddy, John, 39, Milton Road, West Hartlepool.
Cama, Nusserwanji Bomanji, 17, Gergaum Back Road, Bombay, British India.
Faruffini, Capt. M. C., 6, Claremont Terrace, Newcastle-on-Tyne.
Hardwick, Norman, 140, Rye Hill, Newcastle-on-Tyne.
Harvey, Alfred, Messrs. Darlington Forge Co., Darlington.
Haswell, Robert, Messrs. Harland & Wolff, Belfast, Ireland.
Pascoe, James Roger, Tyrmount, Woodford, Essex.

Pease, J. F., Messrs. Darlington Forge Co., Darlington.
Pike, James J., 6, Corta Street, Peckham, London, S.E.
Proud, Anthony, Tyne Docks, South Shields.
Robinson, Frederick F., 26, Wilkinson, Street, Albert Square, Lambeth, London, S.W.
Rodgerson, William John, 7, Wycliffe Terrace, Gateshead.
Spence, James C., Messrs. Tyne Boiler Works Co., Low Walker.
Swinney, W., 2, Conway Terrace, Tyne Dock.
Tulip, George, 48, Blenheim Street, Newcastle-on-Tyne.
Worsdell, Wilson, North-Eastern Locomotive Works, Gateshead.

ASSOCIATE.

Harland, George, 1, Westoe Crescent, South Shields.

GRADUATES.

Finch, Herbert K., 10, Eversley Place, Heaton, Newcastle-on-Tyne.
Liebert, Richard A. E., 214, Portland Road, Newcastle-on-Tyne.
Ross, Wm. Chisholm, 74, Heaton Park Road, Heaton, Newcastle-on-Tyne

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The following Bye-laws, drawn up by the Council for the management of the Library and Reading Room were submitted to the meeting for confirmation :—

THE LIBRARY AND READING ROOM BYE-LAWS.

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.

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

3.—The Library Committee shall be appointed annually, at the first meeting of the Council in each session, and its members shall be eligible for re-election.

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.

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 Bye-laws for the management of the Library, subject to the approval of the Council, and present an annual report to the first meeting of Council held after the annual scrutiny of the books, referred to in Bye-law No. 13.

6.—Except when closed by special order of the Library Committee, or when the Council is sitting, the Library shall be open for consulting, borrowing, or returning books, every week day, except Christmas Day, New Year's Day, and Good Friday, Monday and Tuesday in Easter week and Whit week, and from the first to the second Saturday in March, as mentioned in Bye-law No. 13. On Saturdays it shall be open from 10 o'clock a.m. till 1 p.m., and from 3 p.m. till 9·45 p.m. On other days it shall be open from 10 a.m. till noon, and from 1·30 p.m. till 9·45 p.m.

7.—Books shall not be lent to any persons except members, associates, or graduates of the Institution, but a person entitled to borrow a book may send a messenger with a signed order for it

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.

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.

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

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.

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

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.

13.—All books belonging to the Library shall be called in for inspection and the lending out of books shall be suspended from the first to the second Saturday of March, inclusive, of each year, and members shall be red b timation inserted in the notice calling the preceding meeting of the Institution to return all books in their hands before the period mentioned.

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

14.—Members are requested, when in the Reading Room or Library, ontribute to the general comfort by carefully abstaining from loud ng, noise of any kind, and from smoking.

15.—Any member being twelve months in arrears with his subscrip-ns to the Institution shall not be at liberty to use the Library or eading Room after the commencement of the first session following.

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

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he PRESIDENT said, they had heard the Bye-laws read, which had been approved of by the Council. They were now submitted to them for their confirmation. The whole question was open to discussion, and it was for them to say Yes or No to their adoption.

On the motion of Mr. J. T. MILTON, seconded by Mr. ROBERT THOMPSON, the Bye-laws were adopted.

Mr. JOHAN JOHNSON replied to the discussion upon his paper "On a New System of Shipbuilding to facilitate the application of Machine Riveting to Shell Plating," after which Mr. JOHN A. ROWE read a paper on "A New Wave-Motor."

ADJOURNED DISCUSSION ON MR. J. JOHNSON'S PAPER ON A NEW SYSTEM OF SHIPBUILDING, ETC.

The **PRESIDENT** invited further discussion on Mr. J. Johnson's paper "On a New System of Shipbuilding to facilitate the application of Machine Riveting to Shell Plating." Generally, he thought, the system was approved as being an useful and valuable one, provided they could get Lloyd's and the other registries to adopt it.

As there appeared to be no more speakers on the subject, the **PRESIDENT** called upon Mr. Johnson to reply to the discussion.

Mr. J. **JOHNSON**, in replying, said the Registration Societies had been mentioned a good deal in the discussion, and of course the prospects of ever getting a new system introduced depended so much on their ruling, that if a ship of this type could be classed half the battle might be considered won.

As Bureau Veritas had already given their entire approval, it was to be hoped, that if Lloyd's could be persuaded to look into the matter thoroughly they would also give a favourable verdict. He begged to express their gratitude to Mr. Gravell, for laying the system before the Bureau Veritas Committee in Paris, asking them to give their opinion, with the favourable result mentioned. Additional brackets, connecting the longitudinal bulb angles to the transverse webs in the double bottom, as recommended by him, might be very valuable indeed and would not materially increase the cost. Details of that kind would be further completed in the course of experience.

Mr. Sivewright and other speakers objected to three-ply riveting, but he thought Mr. Tweddell and Mr. Allott had altogether disposed of that difficulty. It was impossible to build a ship without introducing three-ply rivets in a large portion of the structure, and if only the holes were fair and the material properly closed up, as when using machine tools, there could be no objection whatever to this. A well arranged system of travelling cranes above the building berths to carry the riveting machines, as well as transporting other weights to and fro, would be of very important assistance, but they need not be of such a complicated character as to incur any large outlay of capital.

With regard to the draining of the water in the double bottom from the sides to the centre, this presented no difficulty as small oblong limber holes could be cut in the standing flange of the longitudinals, without depriving these of any strength worth mentioning. Holes of that kind were often cut now in the transverse framing for allowing the water to pass fore and aft.

If the joggling of the longitudinals over the butt straps was done with machinery, as proposed by Mr. Tweddell, he thought there would be nothing left to be desired in the quality of workmanship.

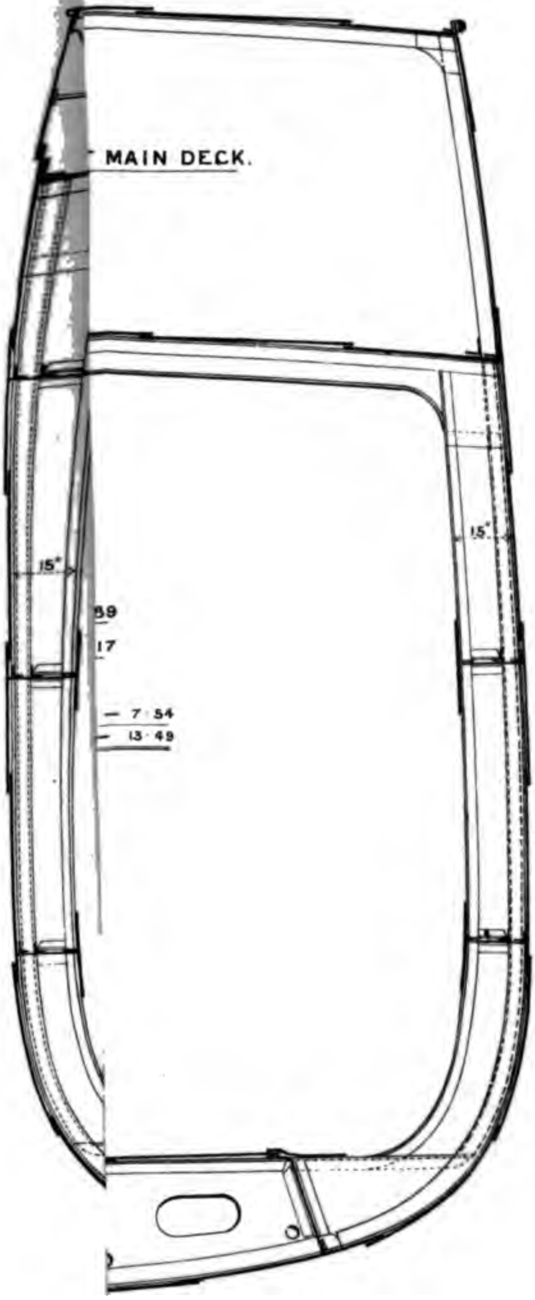
Mr. Millar objected to the proposed method of erecting the structure on account of the small number of men that could be employed at first before the work had reached a certain height. But if they were able to lay off and prepare the most of the material before any frame work at all was erected—as in bridge building for instance—the saving of time in putting together the various parts of the hull would be considerable. While scheming this system they had had the desirability of saving time constantly before their minds, as in competition the rapidity of construction was every day becoming a factor of more importance. In the transverse system they had first of all to erect the whole framework complete and very few men could then be employed. It was only after the ship was in frame that they could admit the shell platers and other iron workers, who had to take their moulds and sets from the framework.

The bulkhead collars would no doubt be somewhat costlier than in a ship with transverse framing but, as Mr. Millar said, they hoped to effect considerable saving in other directions and this extra cost was not of much consequence.

In answer to Mr. Doxford he begged to state that the shell had been slightly reduced on the section (Fig. 2, Plate VI.) in order to give in connection with the longitudinals as near as possible the same longitudinal strength as if built on the transverse system.

By adopting web frames the stowage was not broken to such a large extent as was generally supposed at first glance. Hold beams, extra broad hold stringers and keelsons protruded into the holds and broke stowage quite as much. That there could be very few objections to web frame ships was proved by the general favour with which these ships had been taken up of late years by the shipowners. The ship with which this longitudinal system had been compared was a ship of that type, and Messrs. Thompson had kindly given him (Mr. Johnson) permission to prepare for that meeting a section (Fig. 7, Plate VIII.) showing the arrangement of stringers and web frames. In the longitudinal ship the

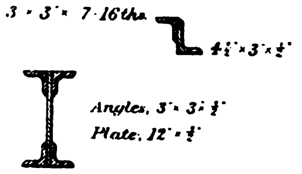
To illust Machine Rivetting to Shell Plating."



web frames stood 1½ inches deeper from the shell than in the sister ship, built on the transverse system and, as these web frames were spaced the same distance apart in both vessels (see Fig. 1, Plate V.), there was very little hold capacity lost.

Mr. Arnison asked how they proposed to deal with a passenger vessel, but, of course, as far as the iron or steel structure was concerned, there would be no difference whether the ship was intended to carry passengers or cargo, and any extra number of decks would not make it more complicated. From the calculations of the longitudinal strength (see Appendix, page 96) Mr. Arnison would at once see that it was not attempted by the writer to ascertain the actual stresses for "hogging" or "sagging" either in still water or in a seaway, but only the *comparative* strength between the two systems. Mr. Arnison first thought the longitudinals too close, and then again said he considered the shell was not enough supported. The longitudinals did the same service in supporting the shell between the web frames as intermediate transverse frames, spaced 2 feet apart, so that if these longitudinals were also 2 feet apart the shell ought to get the same amount of support, and Mr. Arnison's proposal to fit "short disconnected ordinary transverse frames from longitudinal to longitudinal" would, in addition to increasing weight and cost, be absolutely useless.

A copy of the calculations of the longitudinal moments of resistance of the two systems was appended (page 96). The figures given in the paper for the transverse strength were simply the moments of resistance of six Lloyd's frames against one web frame, thus,



The "moment of resistance" was taken as the moment of inertia divided by the distance of the neutral axis from the furthest edge of the section.

In conclusion, he could only say that he was very much indebted for the kind reception his paper had met with. He thought the discussion had proved most conclusively that more labour-saving machinery was wanted in the shipyards, and that shipbuilders, on the North-East Coast especially, were agreed upon one point, viz., that a change of some kind in the present method of construction was bound to be introduced sooner or later. He trusted the day was not very far off when machine riveting would be successfully applied to the shell plating.

The President moved, and the meeting unanimously agreed, that their best thanks be given to Mr. Johnson for his very interesting paper.

Mr. JOHN A. ROWE read the following paper on "A New Wave-Motor":—

A NEW WAVE-MOTOR.

BY JOHN A. ROWE.

[READ BEFORE THE INSTITUTION ON MONDAY, DECEMBER 17TH, 1888.

FOR several years the writer has been engaged in attempting to construct an apparatus to automatically discharge the heavy guns of men-of-war when the vessel is on a level keel—and only then. The usefulness of such an instrument was forced upon his mind by his experiences afloat in H.M.S. "Lord Warden," one of the stiffest vessels of H.M. fleet, and the heaviest roller. Shot intended for the target would occasionally, in spite of the utmost care, ascend skyward—others less ambitious sought a watery grave as soon as they left the muzzle of the gun. If good shooting was desirable in 1870, it is absolutely necessary now that the discharge of one shot from a large Armstrong gun costs not less than £100. The thought has for years been present with the writer that the man who could give to the British Navy an instrument that would in stormy weather at sea enable the guns to be fired with the same accuracy as is obtained from batteries on shore, would, at least, double its offensive power. In his search after a reliable gun-firing apparatus the writer found the Wave-Motor, an invention that at first seemed to have successfully solved the gun question, and other questions also. Before describing the motor, perhaps it would be well to say a few words on the subject of wave-power, and if the preliminary explanation given in this paper should appear to some of the members as more or less elementary, the writer would respectfully point to the composition of this Institution, which embraces shipowners as well as shipbuilders—youthful engineers as well as heads of important establishments.

With the object of learning what were the accepted opinions of authorities on matters relating to a ship's motion at sea, the writer has turned to the Transactions of the United Service Institution, and also to the work of J. Scott Russell on *Naval Architecture*. The two great experimenters and writers, Froude and Scott Russell, seem to have more carefully and fully worked out the problems of wave-action and the behaviour of vessels among waves than any other men of this or foreign countries; and, happily, the former is succeeded by a son, Mr. R. E. Froude, an experimenter probably as talented as his father. A simple experiment by Scott Russell is worth describing here.

In a small channel (Fig. 1, Plate IX.) he placed a certain quantity of water. At both ends of the channel he built reservoirs, and in one of them he poured water to a height shown by the line A B. The centre of gravity of the water in the channel is at G; the centre of gravity of the water in the reservoir is at G_1. In the water contained in the reservoir he dissolved a little colouring substance for identifying purposes, and then he opened the sluice door A.

Instantly as the water fell from G_1 to G a wave was generated (K, Fig. 2, Plate IX.), which travelled from A_1 to C, and was caught in the reservoir (D, Fig. 3, Plate IX.) by opening the door for its reception and swiftly closing it again. An examination of the water at A_1 disclosed the fact that the wave which travelled so rapidly from left to right was a symbol of force rather than a permanent material entity. The coloured water whose fall produced the wave was found at A_1, and the force derived from gravity was transmitted from left to right in wave-form (K) by an agitation of the particles of water communicated from one to another throughout the entire length of the channel. Most of us have seen a pack of cards fall by an impulse given to one only. This phenomenon roughly illustrates the manner in which motion is imparted. Some of us have watched a housewife engaged in the homely task of ironing tablecloths, and have observed the occasional presence of a refractory crease. Now, a crease in a tablecloth advancing before the ironing-box throughout the entire length of the table is not unlike the water-wave. The form remains; the atoms constituting the form change incessantly.

There is, however, an important difference between a linen crease or wave and a water-wave. To preserve motion in the former the hand must be kept in motion; arrest the hand and the crease comes to rest. Not so the water-wave: it continues to advance, and would move for an indefinitely long period but that its own partial viscosity, and the resistance of the sides and bottom of the channel ultimately effect its degradation, and bring the particles to rest.

To realise the extreme mobility of water it is only necessary to raise the door C (Fig. 3, Plate IX.), when the imprisoned wave will descend and rush towards A_1 with nearly the same velocity that it before rushed in the opposite direction, and if, instead of catching the wave in either reservoir the doors be left wide open, the wave will simply rush to and fro through the length of the channel, until the resistances referred to bring the water to repose. This little experiment gives one a vivid idea of the genesis of waves, and the relation of waves to water.

If any one should doubt the ability of waves to develop mechanical power in floating or other structures, an ocean trip to the home of long prevailing winds will soon set his mind at rest; for there huge walls of water are heaped up, which advance with the regularity of trained soldiers and with the force of mountains in motion. But without going from home we can witness wave-power disintegrating the rocks of our coast, and flinging great masses of masonry from one point to another in a manner that would be inexplicable but for the knowledge that water though possessed of less specific gravity than most rocks, is like the rocks, a material substance. Sails spread to the wind impel a vessel through the water; why should not a force exerted upon the hull be made to produce a powerful *propelling* effect? We will proceed to consider this point.

It is not the writer's intention to refer to any form of motor except one existing in the ship herself, and a moment's reflection will satisfy one that the more powerful the ship is as a pendulum, and the more rapidly she rolls, the more efficient will she be as a generator of power. Now the formula for ascertaining a ship's period when rolling in smooth water is:—Period in seconds $= \pi\sqrt{\frac{k^2}{g\,m}}$, where $k =$ the radius of gyration, $g = 32{\cdot}2$, and m is the vessel's metacentric height. To build a vessel for gun-firing purposes—to build a steady ship—the period is increased by increasing k and decreasing m. But for motor work the reverse course would be followed, and m made as great as possible.

Fig. 4, Plate IX., represents a vessel heeled to an angle of 30 degs. Her metacentric height is 6 feet, her displacement 9,500 tons, and let it be assumed that she makes twelve oscillations per minute, each oscillation being 60 degs.

B and B_1 are centres of buoyancy, G is the centre of gravity, G Z is the righting arm, M G is the metacentric height, Z G_1 is the versed sine of the angle of roll.

Now the work put into the vessel by the waves per roll is approximately her total weight multiplied by the height her weight is lifted through, viz., the versed sine of the angle. And whatever work is put into the ship must be taken out of her by some agency or agencies, otherwise she would never stop rolling. These agencies (omitting gravity) are usually the vessel's irregular form at bow and stern, her keel and bilge clogs, and the skin friction. But this is useless work, except so far as steadying the vessel is concerned. Occasionally rolling is reduced by disparity between the ship's period and the period of the waves, and in such cases bilge clogs would probably be of little use; but when a vessel happens to roll among synchronous waves she depends greatly upon irregularity of form to prevent her capsizing through excessive rolling. It is interesting to compute the work done, or rather the work that could be done, by the vessel referred to as 9,500 tons weight, if a sufficiently powerful motor were fitted to abstract the assumed wave energy, and the ship rolled through the angle mentioned. Here it is:—

$$\frac{\overset{\text{Tons.}}{9{,}500} \times \overset{\text{Lbs.}}{2{,}240} \times \overset{\substack{\text{Metacentric height.}\\ \text{Feet.}}}{6} \times \cdot 134 \text{ versed sine of } 30^\circ \times \overset{\text{Oscillations.}}{6}}{33{,}000} = 3{,}000 \text{ horse-power.}$$

Before proceeding further the writer wishes it to be understood that he does not contemplate as serious any proposal to recover the whole of this enormous power. In the first place, *it is probable that no ship under motor influence could be made to roll 30 degs.; and in the second place, the use of a very powerful motor would render the ship unstable*, but for purposes of comparison, it is proposed to let the above computation stand though it be inaccurate.

That efficient motors could find work to do on board ship is certain, if we may judge by the remarks made by Mr. Martell of Lloyd's when discussing a paper read by Mr. Phillip Watts in 1885 on "The Use of Water Chambers for Reducing the Rolling of Ships at Sea."

"I gathered," said he, "that the excessive rolling of the ship was so great that she rolled herself to pieces. She was loaded with a general cargo from America, and in a violent storm her rudder-chains broke, the vessel got into the trough of the sea, and rolled so tremendously that she began to leak, and they were obliged to forsake her. These ships were from 4 to 6 feet greater beam than it has been customary to build ships of that description and size, and I have a strong opinion that by increasing the beam quite as much, if not more, danger is being incurred than there was before with the comparative smallness of beam to which attention was drawn."

Well, gentlemen, having belonged to a tremendous roller for three years, and having noted her behaviour in storms when sails were set to steady her, and having been in the fleet off Finisterre when the "Captain" capsized through want of stability, the writer would prefer a few feet extra beam to the poor things afloat possessed of comparatively little beam, whose metacentric height is so small that they are quite unable to set a stitch of canvas to the wind when they are laden with homogeneous cargoes. But every man to his taste. The remarks, however, of Mr. Martell, who is a great authority on shipping matters, are worth remembering, as showing that positive danger *may* arise from great metacentric heights if no anti-rolling power be placed in the ship.

We will now proceed to describe the wave-motor, Fig. 5, Plate X. This instrument, originally intended for another purpose, has been variously termed a wave-motor, a seismoscope, as well as an automatic gun-firing apparatus.

S is a hollow sphere containing a liquid—say mercury; C is a cylinder containing an asbestos-packed piston. The cylinder and sphere are connected together by a pipe P. The piston rod, at its upper end, is attached to the lever L. (A connecting rod is omitted.) This lever works on the fulcrum F. On the left hand side of the fulcrum is a long spiral spring. C L is a clock connected by a spindle, shown in dotted lines, to a cylinder R, also shown in dotted lines. At P a pencil is fitted in the lever and made to project through the curved slot, and bear upon paper wound round the cylinder R.

B and B_1 are contact breakers, and the electric circuit is completed by wires which lead to the galvanic battery and the heavy guns.

At the extreme end of the thick mahogany board Z B Y B_1, the arc is divided into 30 degs. below the horizontal line and 30 degs. above it.

Q is a spirit level used for determining the horizontal position of the board. X is a stop-cock or valve, at the bottom of the cylinder C.

The dotted line showing the path traversed by the centre of the sphere S is marked in divisions corresponding to the divisions on the board Z B Y B_1, and at the height of the angular divisions horizontal lines are drawn from the vertical one V T, each line being drawn to scale, and measuring the sine of the angle against which it is abreast of.

With the view of marking off the divisions and fixing everything in the shop prior to fitting the apparatus on board ship, let us, for the sake of explanation, imagine the pipe connecting S and C to be a flexible tube, and further, let us imagine that the volume of S is so much larger than the volume of C that when C is full of mercury there is still a little left in the sphere S. This is to ensure the whole length of pipe being always full.

To set the apparatus, bring S to the angle of 30 degs., as shown in the drawing, and pour mercury into S until it is about half full. Whilst this is being done the upward pressure of the mercury on the piston of cylinder C will cause a tension to be exerted on the spiral spring; screw up the nut of the spring until the lever is perfectly horizontal. Mark these points as zero, as in this position on board ship the vessel will be on an even keel.

By successively raising and lowering S to the heights of the sines of all the angles each division may be accurately marked off, and the apparatus is ready for the ship.

But the invention was intended to perform a useful function in addition to discharging guns. It was intended to obtain by it automatic records of the angles of roll, their magnitude, and period.

Theoretically, the instrument worked as follows:—By placing the sphere S at an angle of 30 degs. from the horizontal when the ship was upright, and balancing the mercury pressure by a long and well constructed spiral spring, a horizontal line was obtained which would never vary if the vessel did not roll beyond the angle of 30 degs.; for inspection of the drawing will show that immediately the vessel heels so as to lower the sphere S in the slightest degree the tension on the spring will cause the left hand side of the lever to ascend. If, on the other hand, the sphere S be moved by the motion of the vessel above the angle of 30 degs., the additional pressure on the bottom of the piston—due to increased head of mercury—will cause the left hand side of the lever to descend; that is to say, the spiral spring exactly balances the head of mercury (it measures it, in fact), and, strange though it may seem at first, *the piston is motionless*, and the vessel—or the cylinder, which is the same thing—moves about it.

During the time that the rolling motion is proceeding, the pencil P, pressing on the cylinder R, traces on its paper the apparent motion of the lever, and, as the cylinder is moved by clockwork, the distance between the crests will enable the vessel's rolling period to be ascertained, and the height of the curve will show the angle of roll.

If suitable for the recording of ocean-waves, why not for land-waves, or earth tremors? Hence the name of "Seismoscope."

Possibly an apparatus with the faults of this one eliminated may yet enable one to accomplish what the writer aimed at; but Froude was able to do all this years ago, with a ponderous wheel pendulum and suitable gearing. "Then why," it may be asked, "go beyond Froude?"

His wheel was a carefully machined apparatus weighing 200 lbs., with its centre of gravity only $\frac{6}{1000}$ of an inch below its point of suspension, and with a period of 34 seconds. It moved on friction rollers, and was so carefully balanced that, "when at rest, a breath on the circumference of the wheel caused it to move perceptibly." But its extreme delicacy renders it unsuitable to the treatment it would be subjected to under the ordinary conditions of nautical life. If a breath moved it, so would a breath or a speck of dust hinder its true action; thus the need of another apparatus becomes obvious.

Regarding the instrument as a wave-motor, let us for a few moments examine the work performed when the apparatus was being marked off ready for service afloat.

When S was raised from T to the angle of 30 degs. (the position on sketch), the work done was the lifting to the height of T N as much mercury as would fill one-half the capacity of the cylinder C. When S was raised to R, we lifted to that height as much mercury as would fill the whole cylinder, or rather, we should have done in both cases what we have said, if the stop-cock X had been closed; but, as the cock was left open, the mercury was gradually flowing down the pipe and pressing up the piston during the whole vertical motion of S. The work performed was not lifting the *whole* weight of mercury through the sine of 60 degs., but one-half the weight through that distance. *And a certain proportion of this work can be recovered.*

Instead of the small cylinder shown in sketch let the cylinder be 2 feet diameter and 4 feet long. Its capacity will be about 12½ cubic feet, and the quantity of mercury necessary to fill it will be (assuming 1 cubic inch to weigh ½ lb.) 10,852 lbs.

Let the radius C T be 20 feet. Let the sphere be moved up 60 degs. from T and down 60 degs. six times per minute. Find the work done. Using the formula we have explained—

$$(1.)\quad \frac{\frac{10{,}852}{2} \times \text{sine } 60^\circ \times 20 \text{ ft.} \times 6}{33{,}000} = \frac{5{,}426 \times 17{\cdot}32 \times 6}{33{,}000} = 17 \text{ I.H.P.}$$

Turning now to the card M V T, we can measure its ordinates which are sines of the angles passed through, and the mean of these multiplied by the radius, multiplied by twelve, will give the mean height of the sines in inches, and this divided by two will give the mean pressure on the piston. Then—

$$(2.)\quad \frac{\overset{\text{Area of cylinder.}}{452} \times \overset{\text{Stroke.}}{4} \times \overset{\text{Lbs.}}{55} \times 6}{33{,}000} = 17{\cdot}7 \text{ I.H.P.}$$

These two results are practically the same, and they are shown in this way in order to establish the truth of the first mode of computing the work done.

A moment's reflection enables one to perceive that the relations existing between the weight S and the spring, or the tension of the spring, are as intimate and peculiar as the positive and negative forces of electricity are to each other, or as light is to shade. One cannot be called into activity without the other appearing, and the disappearance of one means the annihilation of the other.

When S is at T there is no tension on the spring. Weight and tension may as yet (so far as the invention is concerned) be considered non-existing. But the moment S is raised above the centre of the cylinder (its horizontal centre) tension appears; lower S, and tension disappears. Raise S 2 feet or 10 feet, and tension due to 2 or 10 feet appears as a matter of course. They are cause and effect: the tension being the exact measure of the column of mercury, minus piston friction.

But the work done in lifting S is against gravity, and it becomes stored, or potential energy—energy stored in the spring—waiting its opportunity to assert itself in the form of work; and if S should be suddenly let fall from R to T, the potential energy in the spring is capable of performing, as useful work, the amount of work expended in raising S from T to R.

If this reasoning be faulty, the writer will be thankful for correction; if sound, he hopes that the importance of the problem will be recognised, and its lessons applied to the subject of the use of free water on board ship to retard rolling, and to other subjects.

Mr. Froude and Mr. Watts, in their papers on "Rolling Chambers," call attention to an interesting feature of the art of rolling a vessel by manual labour. They say it is customary to cause seamen to run from one side of the ship to another to produce rolling; and the writer has himself witnessed the operation. But running to perform useful work must be scientific, and, in this case, should be *uphill* so as to put as much work *into* the ship as possible. This uphill running produces fairly heavy rolling, and the power thus put into the vessel by the men is analagous to the power put into her by the waves, and by the sphere of mercury.

The work put into the ship by the men would be taken out of her by the men, if, instead of running uphill, they were to expeditiously slide down the inclined deck of the ship and compel the ship to lift them.

"But," it may be said, "such exertion on the part of the ship every time she rolled her *immersed side towards a level keel* would tend to stop her rolling." Precisely so; and this is what the Admiralty water chambers do. They take out of the vessel a portion of the work put into her by the waves, and the work of the chamber ought to be equivalent to the loss of the vessel's metacentric power.

Now, the work done by the small water chamber fitted to H.M.S. "Inflexible" consisted of lifting 70 tons of water $2\frac{1}{2}$ feet high per swing of ship through 18 degs. This height of $2\frac{1}{2}$ feet is obtained by observing the centre of gravity of the water in the chamber when the vessel is upright, and comparing it with its centre of gravity when heeled to the angle of roll. The difference between these two points is the vertical lift given to the whole mass of water. And 70 tons × $2\frac{1}{2}$ feet = 175 foot-tons per swing (double roll). And $175 \times 2{,}240 \times \frac{60}{10{\cdot}7} \div 33{,}000$ = 66 indicated horse-power.

It is, however, worth noticing that the designers of the "Inflexible" originally provided her with water chambers four times as powerful as this one chamber. The work then that would have been done by these chambers, with the vessel rolling through an angle of 9 degs. on each side of the vertical, would have been 66 × 4 = 264 indicated horse-power.

This amount, though not excessive, is not to be despised.

Among heavier waves and rolling through greater angles the power would be proportionately increased.

According to Mr. Watts it is "probably within the truth to say that the water chamber when about half full (70 tons) reduces the mean angle of roll by from 20 to 25 per cent. when the ship is rolling broadside on through moderate angles among waves of from $9\frac{1}{2}$ to 10 seconds mean period." And according to the tables he furnished the diminution was, roughly speaking, from 12 degs. to 9 degs. for an expenditure of 175 foot-tons in the water chamber. What metacentric power was lost by the ship by this reduction of the angle of roll?

Now, the weight of the "Inflexible" is about 12,000 tons. The versed sine of 12 degs. = ·01285; the versed sine of 9 degs. = ·01231; the metacentric height is, say 8 feet; the metacentric power lost is the weight of the ship multiplied by the metacentric height multiplied by the difference between the versed sines of 12 degs. and 9 degs.

$$12{,}000 \text{ tons} \times 8 \text{ feet} \times ({\cdot}02185 - {\cdot}01231) = 912 \text{ foot-tons.}$$

This result is unexpected and remarkable. One naturally expected the work done in the chamber would exactly equal the loss of metacentric power; but the above computation appears to show that 175 foot-tons in the water chamber "wipe out" no less than 912 foot-tons in the vessel. The writer is at a loss to account for this great discrepancy. He has endeavoured to partly account for it by considering that the metacentric height of 8 feet is excessive; but as Mr. Watts refers to the "Inflexible" as a vessel with a metacentric height of "*about* 8 feet" no trifling modification of this dimension will explain matters. He has also looked at Canon Mosely's formula for dynamical stability, and noticed that the Canon measured the vertical distance between the centres of buoyancy instead of the vertical distance between the centres of gravity; but in this direction it is probable the discrepancy would be increased rather than decreased. Neither is it possible to conceive that the momentum of 70 tons of water moving slowly in an opposite direction to that of the ship is sufficient to diminish, to any great extent, the velocity of a rolling vessel possessed of a period of 10·7 seconds, and weighing 12,000 tons.

There can be no question as to the accuracy of Mr. Watts's experiments. They were carefully conducted by himself, assisted by naval officers and others; and the angles of roll were taken automatically, and checked by batten observations. In addition to this Mr. R. E. Froude's model experiments confirmed the accuracy of the sea experiments.

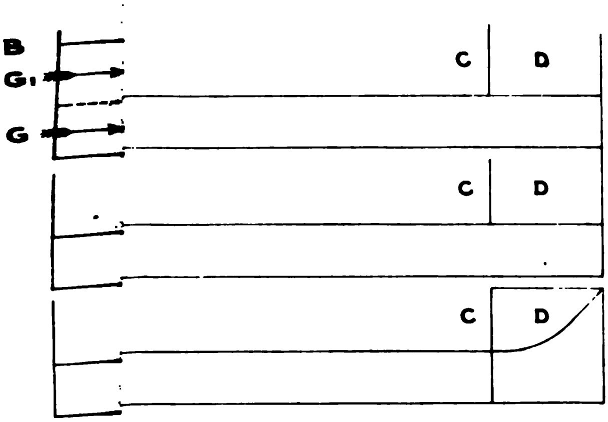
Judged by mere vertical lift the rolling of the "Inflexible" should have been reduced by about 3 per cent. instead of "by from 20 to 25 per cent." If the law of reduction were known it would be easy to build vessels to roll, and to fit motors to check rolling, but any attempt now to determine the suitable dimensions of a motor would be premature with our present limited knowledge of this subject. We need more experimental knowledge, especially with vessels rolling through large angles. It is an easy matter to check vessels rolling through small angles, but extremely difficult to cope with large ones; and this will be understood by comparing the versed sines of several angles, thus:—

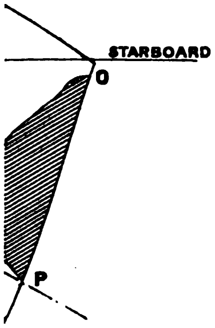
Versed sine of 5 degs. = ·00381.
„ „ 10 „ = ·01519.
„ „ 15 „ = ·03407.
Versed sine of 20 degs. = ·06031.
„ „ 25 „ = ·09369.
„ „ 30 „ = ·13397.

An angle of 5 degs. = $\frac{1}{6}$th an angle of 30 degs., but the versed sine of 5 degs. = $\frac{1}{35}$th the versed sine of 30 degs.

The inadequacy of water chambers to cope with large angles of roll is referred to by Mr. Watts in his paper; he writes as follows:—"These

Motor."

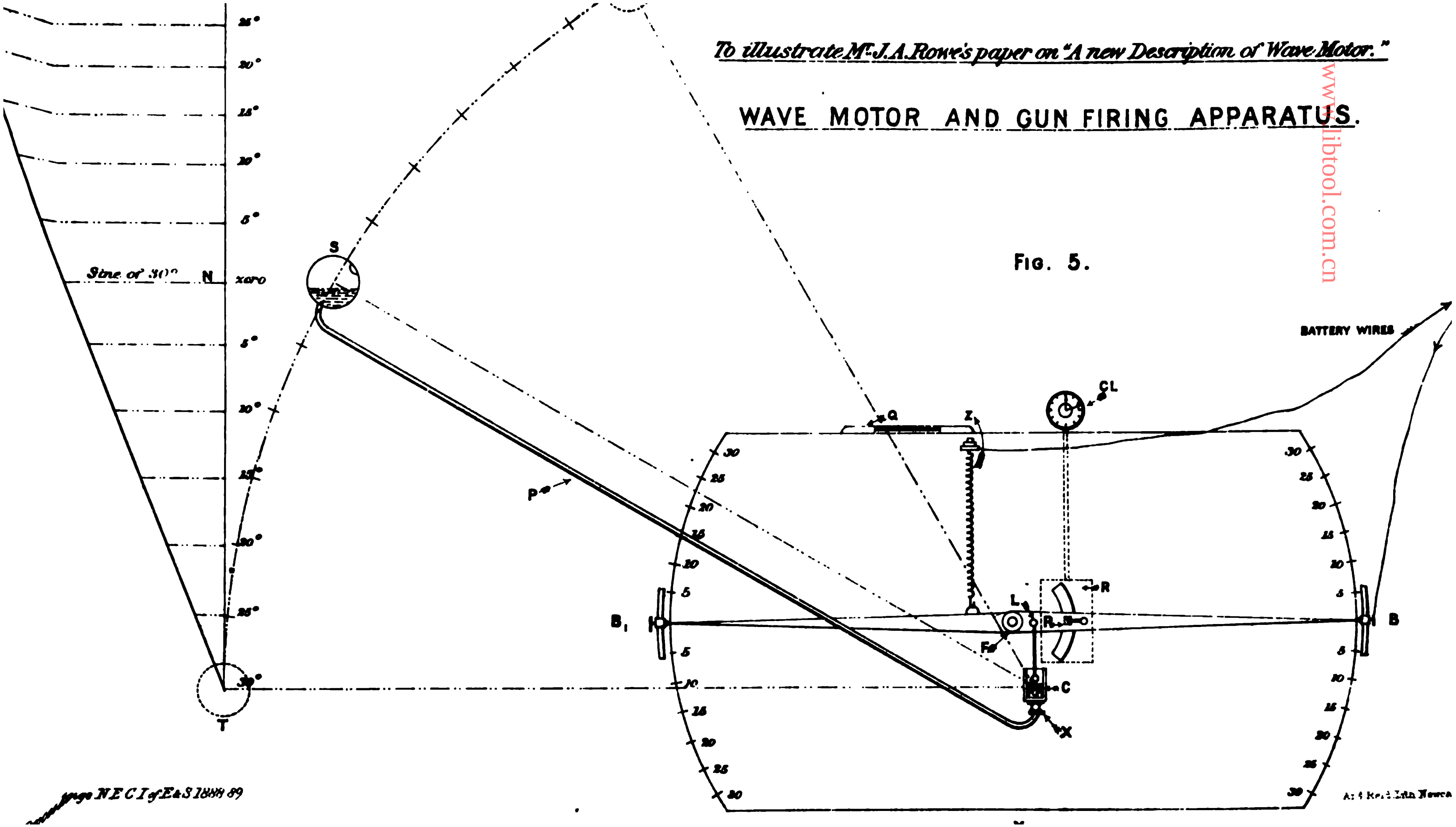




To illustrate M^r. J. A. Rowe's paper on "A new Description of Wave Motor."

WAVE MOTOR AND GUN FIRING APPARATUS.

FIG. 5.



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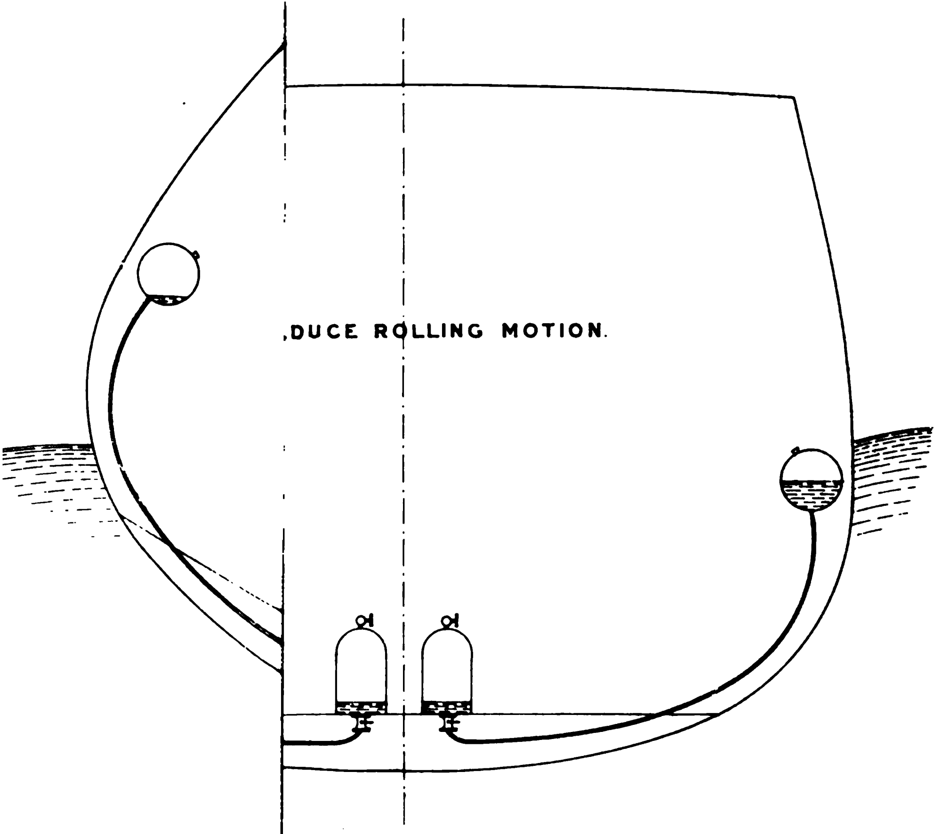
A: & Reid Lith. Newca

Motor."

G WAVES.

FIG. 9.



.DUCE ROLLING MOTION.

Proceedings N.E.C.I. of E. & S.

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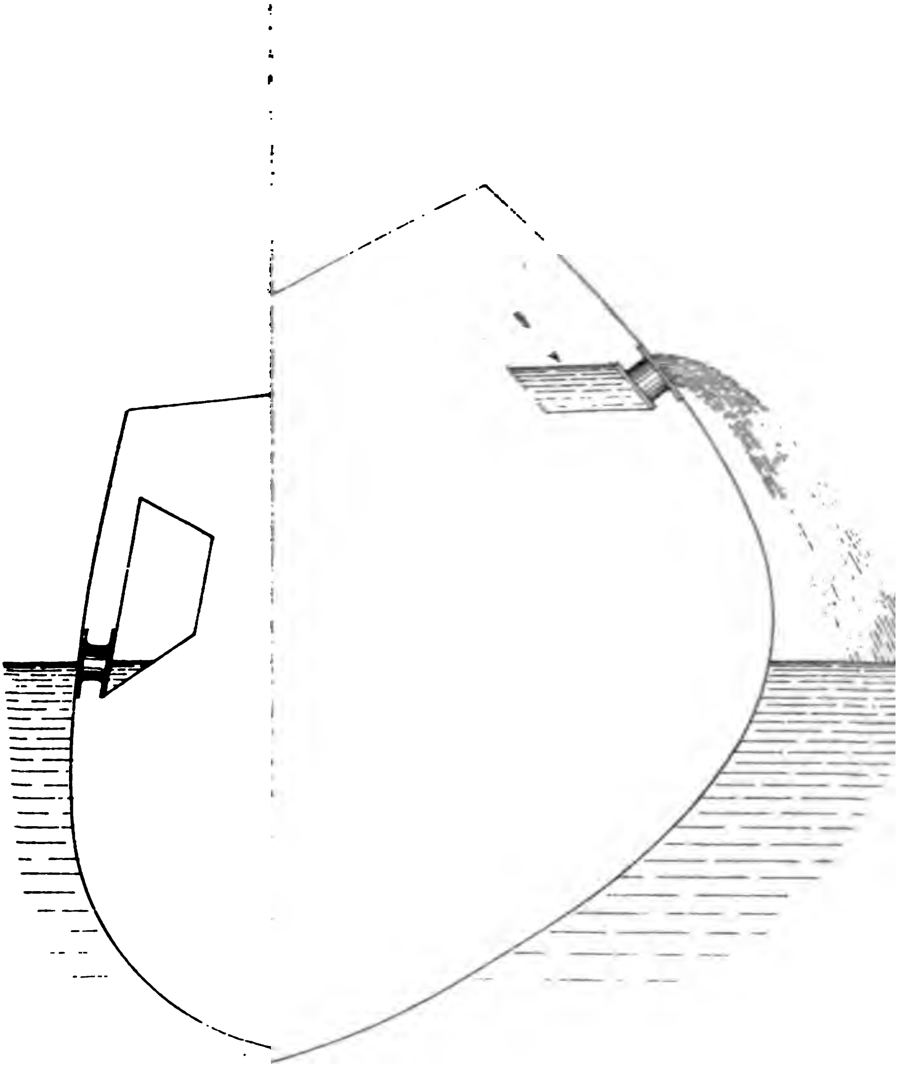
Wave Motor.



Proceedings N.E.C. Inst. [illegible]

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curves" (extinction curves) "show clearly the great resisting effect of water chambers as compared with that of bilge keels and surface friction of ship's bottom at comparatively small angles of rolling, while at large angles the bilge keel and surface friction resistance are the more effective. At 4 degs. the water chamber's resistance has almost reached its maximum." On the same subject, and in the discussion on one of Mr. Watts's papers, Mr. R. E. Froude expresses the same view, viz.:—"I think it probable that for small oscillations of the ship the balance chamber will have proportionately a much more quelling effect than for large oscillations. It is possible that in a small seaway in which the vessel would roll a little that a balance chamber might be found of very large effect, and in a rough sea where the ship would roll a great deal, of small effect."

Thus, for large angles of roll, naval architects would appear to depend on the resistance of large bilge keels to produce a steadying effect upon heavy rolling vessels, even when such vessels are fitted with water chambers for quelling small angles. Now, if mercury were as inexpensive as water, the writer would recommend the removal of bilge keels and all other external resistances to rolling, so that the whole work of arresting the gyratory motion of the ship should be accomplished inboard by a motor or motors that would give back the wave-energy in the form of useful work. But the cost of mercury precludes its use; and the dimensions of cylinders and pipes would therefore be so great compared to the power obtained as to prevent a full cargo being carried except with iron ore. But with vessels engaged exclusively in carrying ore, it is possible that motors might be fitted which in time of distress, such as Mr. Martell called attention to, might save the ship.

So far, attention has been directed to the original idea, Fig. 5, Plate X.; but Figs. 6 and 7, Plate XI., and Fig. 8, Plate XII., show another form of motor attached to and working a lever with a large circular weight at its end. The work of the motor will be readily understood by noticing the relative positions of G, the centre of gravity of the ship and the centre of the circular weight. The work accomplished is lifting the weight, thereby diminishing the vessel's metacentric height, thereby reducing her rolling, etc. Instead of performing this useless work, pumps could be driven forcing water from the ship, and propelling her though but slowly as the "Waterwitch" is propelled; or air pumps might be employed to force air to every compartment of the ship, and to the furnaces. Instead of one motor several may be used; and the writer would, for several reasons, prefer to have at least two.

Fig. 9, Plate XII., represents a motor to be used solely for reducing rolling. The cylinders in the centre of the ship are partly filled with water, but pressing on the surface of the water is air so dense as to support the column of water reaching up to the spheres at the wings. In this form it is an improved Admiralty water chamber. It is an improvement in several ways. In the first place, the water is more under control, and its movements through the pipe and in the chambers would be noiseless, one would think, compared to the violence of the water in the chambers of H.M.S. "Inflexible." In the second place, the action of the motor could be increased or decreased instantly by the motion of a sluice valve, or a cock placed anywhere between the sphere and the cylinder. In the third place, additional stability could be given to a vessel at any moment by opening air-cocks on the top of the cylinders, and (through the escape of the compressed air) allowing the water to fall from an upper to a lower level. This suggestion to give stability needs explanation. Many existing vessels are tender with homogeneous cargoes, and unduly stiff with cargoes of iron ore. The motor, if used in the way suggested, would benefit the vessel in both conditions.

In conclusion, the writer regrets his inability to furnish records of experiments. Experiments might have been made, but on reflection it appeared the better course to bring a subject of so great novelty before the members of this Institution, and learn from their criticism whether the principles the writer has endeavoured to establish are sound, and if so, in what way the motor, if thought desirable, may be rendered suitable for service at sea.

DISCUSSION.

The **President** said this was the first time he had had the opportunity of looking at this paper, having just returned the previous morning after an absence of three weeks. It opened up a subject which was very interesting, a subject of more interest, perhaps, to shipbuilders than engineers. There were a large number of shipbuilders in connection with this Institution, and it would be interesting to hear their remarks upon the subject. It was certainly ingenious, and had clearly given Mr. Rowe a great deal of consideration and thought for several years. They would be very glad to hear any remarks which they might have to make upon the paper. He believed Professor Garnett had come to the meeting that night by special invitation. They would be glad to hear anything he had to say on the subject.

Principal GARNETT said as he spoke at the beginning of the discussion, many persons having greater knowledge of the subject than he had would be able to set the members right on all the points on which he might tend to lead them wrong. He had to thank the President and Mr. Rowe for the opportunity of listening to this paper. It appeared to him that it opened up two or three very important questions, and questions well worthy of further consideration. It was a little disappointing to hear from Mr. Rowe, towards the end of his paper, that he would have to abandon the hope of propelling ships by the rolling motion on account of the expense of the mercury. If there were no other difficulty than that, it would be quite worth while to incur the cost. It had been suggested that the wave-motor should be used as a seismoscope to register earth tremors, but the kind of earth tremors which constitute earthquakes generally consist of exceedingly tiny motions, seldom greater than the eighth part of an inch, the motion being very rapid, so that the whole vibration takes place in a fraction of a second. A vibration through an eighth of an inch was quite sufficient sometimes to fracture a wall. Now, an instrument must act very promptly to register a motion of this sort, and he was afraid the wave-motor was too slow in its action to record anything about earthquakes. The mercury motor appeared to be very important for the firing of heavy guns, but when they considered the rolling motion of a ship occupying, perhaps, ten seconds, and that one of the mercury chambers must be emptied in something less than five seconds, and in some cases much less than that, for some vessels made ten or twelve rolls in a minute, so that one of the chambers must be emptied in two and a half seconds, through a pipe bearing the same relation to the reservoir as that shown in the figure, it must be obvious that the apparatus would never be anything like sufficiently prompt, and the whole action of a gun-firing apparatus required absolute promptness, so that the mercury must exactly follow the ship as the ship rolled. For this purpose the tube should be almost of the same diameter as the reservoir, otherwise there would be a very rapid motion in the pipes, and more pressure required to force the mercury through in the time than was available. If the working of this apparatus required a hundredweight of mercury, with a chamber six inches in diameter, there would be something like 40 cwt. of mercury in the tube between the apparatus and the reservoir. The same considerations applied to the water-motor when employed to diminish the rolling of ships which, when made sufficiently prompt, would resemble the Admiralty water chambers. The noise which was complained of seemed to him to be incidental to any apparatus by which the water would be made to move sufficiently rapid to damp the rolling of a ship. The most important practical point in the paper, he thought, was this question of reducing the rolling, but one of the greatest questions was to get power out of the rolling of ships, and some of the calculations in the paper appeared to indicate that an enormous amount of power was available, and yet the experiments with the "Inflexible" appeared to the writer's mind to be inconsistent with previous calculations. The first point to notice with regard to the determination of the energy in the rolling ship was that when the ship rolled through something like 30 degs. she must not be treated as a pendulum swinging about the metacentre. It led sometimes to perfectly correct results so long as the rolling was exceedingly small, but when the oscillations amounted to several degrees it was very different. If a square prism were floating in a liquid of twice its density it was stable in the position with the diagonal vertical when the metacentre was one-twelfth of the side above the centre of gravity. Turned through 45 degs. so that a side is vertical, the metacentre is one-twelfth of the side below the centre of gravity and the prism unstable. During the roll of 45 degs. the metacentre moved from the point above the centre of gravity to an equal distance below, and it would be fallacious to treat the rolling as though the metacentre remained stationary and the prism swung about it. The same thing was true in a ship. In the case of the "Lord Warden" the energy of rolling might be less than that calculated in the paper, but assuming that when she has rolled through 30 degs. from the vertical she was very near the point of being unstable, there would still be considerably more than 1,000 horse-power available from the rolling of such a ship if the rest of the reasoning in the paper was correct; but the main fallacy lay in the confusion between the power required to *produce* the rolling of the ship and the power required to *maintain* the rolling of the ship. Suppose a ship to be rolling in water with no friction or resistance of any kind: when once set rolling she would roll on for ever, requiring no power to maintain her. They might place a ship in still water and by men running across the deck get a considerable roll. Supposing the ship was set rolling through 12 degs. or 18 degs. and the cargo perfectly stationary in the ship, the friction would gradually reduce the rolling, and having rolled through 18 degs. she would next roll through, say, 14 degs., and the next roll would be through 11 degs., the next 9 degs., and so on, and the vibration would [illegible] be gradually reduced in something like geometrical progression by the mec[illegible] of the friction. Now, what was required to maintain the anything [illegible] the ship through 18 degs.? In making one roll the amplitude was reduced from 18 degs. to 14 degs., and the difference of energy corresponding to these two swings gives the energy wasted by resistance during the roll. By a method of this kind the energy required to maintain the ship rolling through 18 degs. may be determined. The figures given in the paper for the "Inflexible" indicated something of what the result would be. To keep the ship rolling 18 degs. a certain amount of power would be communicated by the waves when they struck. If from the energy so communicated something like 175 foot-tons were abstracted by the water chamber, the rolling was reduced from 18 degs. to three-quarters of that amount, or to 13½ degs. That reduced the energy of rolling down to something a little more than one-half. They took away about 44 per cent. of the energy of the rolling. This seemed to him the state of affairs, that when the "Inflexible" was rolling through 13½ degs. the blows of the waves were just capable of maintaining this and of doing the 175 foot-tons of work besides, which was done in making the water in the water chambers rush to and fro. Without the water chambers the waves would have maintained a roll through 18 degs., so that an idea could be got of the amount of power required to maintain the rolling. If any ship could be started from rest and rolled 30 degs. by one wave, and the ship stopped and again rolled over 30 degs., and this done time after time, something like the power Mr. Rowe had calculated would be obtained for the rolling of the "Lord Warden," but if the action of the waves was only to maintain the rolling against the fluid friction the results obtained would be similar to those deduced from the "Inflexible," and there would be available something like 100 horse-power instead of the amount calculated in the paper. It would then be necessary to introduce more power to propel the ship, and the question arose whether it was worth while to introduce extra machinery to secure the wave-power. There was one other point to notice. It was stated that water chambers were efficient in reducing rolling when the oscillations are small, and that bilge rolls were more efficient in stronger seas. The action of the water chambers was proportional to the distance through which the centre of gravity of the water was raised. The action of bilge rolls and the like, whose action depends upon the resistance of the water to the rolls passing through it, increased at a very high ratio with the speed of rolling, so that a small roll would not be much affected, but a double roll would be resisted to more than four times the amount, and might then exceed altogether the effect of the water chambers.

Mr. J. **Wallau** wished to make a very few remarks to corroborate what Professor Garnett had said. It was not a difficult thing to calculate approximately what resistance the water offered to a ship rolling through a certain angle. This amount of resistance was the power put into the ship by the waves at every oscillation—there were no two opinions about that. Suppose a ship got into a regular roll of so many degrees, there was a certain amount of resistance by the water, principally friction; this could be calculated, and was the power which was put into the ship by the waves every time a roll took place. Of course, as Professor Garnett had pointed out, this was a very much less power than would be necessary to put the whole motion into the vessel at once, as the rolling did not take place suddenly, but gradually. There was an other consideration, viz.: the rolling of the ship could not be used in fine weather, and therefore could not be depended upon. He had no doubt if the matter was gone into it would be found that the power was too small, otherwise, as the problem was simple and old, it would have been long since satisfactorily solved; but he was afraid there was only one solution—the wave-power was of no use on board ship. At the same time it was a very interesting problem, and well worthy of discussion, and no doubt they were much obliged to Mr. Rowe for laying it before the Institution to solve the apparent incongruities which he had pointed out—why so small a power in the water chamber seemed to produce so great a reduction in the power of rolling, according to Mr. Rowe's theory. Everyone knew how very little power it took to set a pendulum gradually in motion, and how long it would move afterwards. In the pendulum they had the friction in the fulcrum and the friction of the air to overcome; but practically it was the same problem. He remembered many years ago Professor Rankine compared the pendulum with wave motion, and he made out that the two were very nearly related. The whole subject was to some extent new to him (Mr. Wallau), and he had only been able to note what Mr. Rowe said that night.

Mr. **Taylor** understood Fig. 6, Plate XI., represented a vessel in the upright position whilst rolling amongst waves, and Figs. 7 and 8, Plate XI. and XII., the same vessel in inclined positions. He noticed that as the vessel rolls the liquid moves with, but faster than the ship, and to the lowest side of the ship, thus tending to incline the vessel farther than the effective wave slope would take her, and the vessel is to the same extent retarded in rising from the inclined position, so that whatever the effect of the liquid may be it does not reduce the rolling.

Mr. STIRZAKER said, what Mr. Taylor had just stated, he (Mr. Stirzaker) was inclined to think was wrong. Mr. Taylor said that the mercury as it fell down the pipe into the vessel assisted the listing of the ship just as much as it retarded the rolling. He did not think that was so, for if he understood the principle of the water chambers of ships, it was that the water lagged behind the ship as it rolled, and thus arrested the rolling.

Mr. TAYLOR—This is not a water chamber.

Mr. STIRZAKER—No; but it acted in the same manner. Water lagged behind as the ship rolled, and when the ship began to right itself again the water was lifted, and was thus doing more work in retarding than in assisting the roll. In that respect he quite agreed with Mr. Rowe's arguments, but in other parts of the paper, where he spoke of the roll of the ship performing an amount of work proportional to the versed sine of the angle of a supposed pendulum suspended at the metacentre, and of a length equal to the metacentric height, he did not at all agree with him. Professor Garnett had pointed out the error of that supposition.

Mr. TAYLOR, by way of explanation, said if the pipes were as large as the reservoir the material might run down and fill the reservoir before the ship reached the greatest angle of heel; but if they were small this would not happen, and the friction would be great: in that way the liquid would be retarded, and only to that extent could the ship's rolling be arrested. Fig. 6, Plate XI., showed that the liquid moves uniformly with and as quickly as the ship in the upright position, and from Figs. 7 and 8, Plates XI. and XII., it would be seen the side reservoirs and pipes are so proportioned that the low side reservoir is filled before or as the vessel reaches its greatest angle of heel, therefore the liquid must come to rest before or when the vessel reaches its greatest angle of heel, and it can have no motion when the vessel is at its greatest angle of heel, and consequently it does not act as a water chamber, or retard the roll in the manner water chambers are said to act. He begged leave to reserve any further remarks he might wish to make till the next general meeting.

The PRESIDENT said the discussion would stand adjourned. He also desired to express their indebtedness to Professor Garnett for coming to the meeting to assist in the discussion. He had thrown very great light upon the subject, and spoken in a way clear and lucid to everyone of them.

The discussion was adjourned till the 14th of January.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIFTH SESSION, 1888-89.

PROCEEDINGS.

FIFTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, JANUARY 14TH, 1889.

H. MACOLL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting held in Newcastle-upon-Tyne, on December 17th, 1888, which were approved by the members present, and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Messrs. H. Charlton and A. Scholefield to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Abey, Henry, 41, Milton Road, West Hartlepool.
Archbold, Joseph G., Messrs. E. Scott & Co., Close, Newcastle-on-Tyne.
Feldtmann, H., Bergen, Norway.
Joicey, Jacob G., Forth Banks West Factory, Newcastle-on-Tyne.
Sowter, Isaac G., 867, East Congress Street, Detroit, Michigan, United States of America.
Tinwell, George, General Gordon Terrace, Sunderland.

ASSOCIATES.

Crowther, Joseph, Dispensary Lane, Newcastle-on-Tyne.
Dodds, A. P., 13, Dean Street, Newcastle-on-Tyne.
Garnett, William, The Durham College of Science, Newcastle-on-Tyne.
Mawson, Rowland, Bank Chambers, Quay, Newcastle-on-Tyne.
Seaman, C. J., 19, Willington Street, Stockton-on-Tees.

VISIT OF THE BRITISH ASSOCIATION.

The VICE-PRESIDENT said they had received a letter from the President of the Mechanical Section (G) of the British Association, and perhaps it would be as well for the Secretary to read it.

LESNEY HOUSE, ERITH, KENT,
January 1st, 1889.

JOHN DUCKITT, ESQ., 4, St. Nicholas' Buildings West,
Newcastle-on-Tyne.

DEAR SIR,—The Council of the British Association has done me the honour of electing me President of the Mechanical Section (G) for the meeting to be held at Newcastle next autumn. I am anxious to embody in my address as much matter specially interesting to the local industries as I can; I should, therefore, feel much obliged if you could let me have a copy of the Report of the Council of the North-East Coast Institution on the Horse-power of Marine Engines, and any other papers that may be of special interest. May I also venture to hope that you will aid me in getting some good papers from local men on Marine Engines and Shipbuilding.

I remain, truly yours,
W. ANDERSON.

Mr. J. DUCKITT (Secretary) said he had sent to Mr. Anderson a copy of the Horse-power Report and also a copy of their present President's Address. The only matter for those present was whether they would be inclined to prepare papers either on marine engineering or shipbuilding to read at the meeting of the British Association.

The VICE-PRESIDENT explained that this letter was before the Council at their last meeting, and seeing that they yet required a paper for the current session of the Institution, they thought it better to lay this before the General Meeting, so that if, after serving themselves, they could possibly assist the Association in Newcastle it would be a very good thing, and the Secretary would be very glad to hear from any of the members inclined to contribute a paper or a series of statistics which might be interesting to the meeting. The matter was meanwhile left in the hands of the individual members of the Institution.

The adjourned discussion on Mr. J. A. Rowe's paper "On a New Wave-Motor" was resumed by Mr. Alex. Taylor, after which Mr. G. Bergstrôm's paper "On the Structural Strength of Cargo Steamers" was read.

ADJOURNED DISCUSSION ON MR. J. A. ROWE'S PAPER ON A NEW WAVE-MOTOR.

Mr. **Alex. Taylor** said, he was extremely obliged to Mr. Rowe for his paper on wave-motors. To him it was an entirely new subject, and he had been constrained to study it as fully as opportunity permitted. Mr. Rowe used the versed sine of the angle of heel as a measure of the vessel's righting power. It could only be correct for a vessel of circular cross sections, in which the relative positions of the centre of buoyancy and metacentre were constant for all angles of heel, for the ordinary form of ship this method must be untrue except for very small angles. The only clear way in his opinion was to conceive of the centre of buoyancy and centre of gravity as each in its own horizontal plane, free to move up or down, then the difference in height between these planes at various angles of heel would be a true measure of the righting power. Therefore the work done was not as the versed sine of the angle of roll, but was in reality the product of the difference between the planes in the upright and inclined positions into the displacement of the vessel. There was another point he would like to say something about, and he had great hesitation in referring to it, for he was not perfectly sure in his own mind that he was right, and he was afraid of making a grave mistake as he knew so little about the subject. It was this:—he understood Professor Garnett to say that the serious mistake in the paper was in supposing that the vessel's roll would give power equal to the product of the displacement into the increased vertical distances of the centre of buoyancy below the centre of gravity, and that instead of this being correct all the force required to keep the vessel's rolling to any given angle was the force necessary to overcome the friction of the water, or words to that effect. This might be correct for a vessel rolling in smooth water, but he (Mr. Taylor) scarcely thought it correct when applied to a ship rolling amongst waves. If they, for the sake of argument, supposed the sketch here given to represent the effective wave, and that the vessel was so proportioned that it always kept normal to the effective

wave slope as sketched, then this vessel was relatively at rest to the effective wave and would continue to roll, that is keep normal to the waves for ever; but if Mr. Rowe's wave-motor was put in action, the liquid would always be found at the low side, tending to heel the vessel farther over, while the wave would equally endeavour to keep the vessel normal to its effective surface. If that should be so then Mr. Rowe's machine would not be dependent for power upon the friction of the water on the vessel's hull, but would be able to develop power in proportion to the weight used and the distance it was lifted. To come to Figs. 6, 7, and 8, Plates XI. and XII., and remember that in looking at these diagrams they were looking at a vessel rolling amongst waves, and that Fig. 6 is upright either in the trough or on the crest of the wave, Mr. Rowe apparently considered that the liquid would be exactly equal on each side of the ship at that moment. How this equality was got he (Mr. Taylor) was not in a position to say, but simply accepted the fact that the liquid was equally distributed on each side of the centre line of the vessel, and therefore the centre of gravity of the liquid must be in the vertical central plane of the ship, but when the vessel rolled over, say into the positions shown on Figs. 7 and 8, apparently the liquid had gone with but faster than the ship and filled the chambers on the low side and practically emptied the one on the top side. The result was that as the vessel heeled over the weights also travelled over to the low side and therefore must have an upsetting tendency, and he supposed this to be the force Mr. Rowe endeavoured to grasp and use.

Mr. R. L. **Weighton** said, that unlike his friend Mr. Taylor, he had found that Christmas and New Year times were not conducive to study, and he must confess he had not gone through this subject as Mr. Taylor had done. He rose simply in order to support the views which were expressed by Professor Garnett. He thought Mr. Taylor must have misunderstood what Professor Garnett said. He was confounding the weight of the ship with the weight of the mercury or other acting fluid in the motor. Mr. Rowe calculated that there could be 3,000 horse-power exerted upon a ship because the ship lay at different angles, but if they considered a little they would see that the figure 3,000 horse-power was arrived at by taking the weight of the ship into account. It was supposed the ship was lifted a certain amount each half roll, but the ship did not need to be lifted at all in order to obtain work from the motor; it was sufficient that the ship should be simply slanted over. In order to show that the method adopted in the paper on page 108, for calculating the work exerted by the water on a rolling ship was fallacious, it had just occurred to him that the case of an ordinary clock pendulum might be taken as an illustration. Of course he did not assume that for all purposes a rolling ship could be compared to a swinging pendulum, but for the purpose of work-calculation they could certainly be compared. Assume a second's pendulum with a bob, say of 3 lbs., and swinging through an angle having a versed sine of, say quarter of an inch, and driven by a weight, say of 30 lbs., which descends during a week through 4 feet. These figures here assumed were simply approximations, but any error will not materially affect the point illustrated. Calculating according to the method on page 108, we have the work done at the pendulum in one week—

$$= \frac{3 \times \cdot 25 \times 60 \times 60 \times 24 \times 7}{12} = 37{,}800 \text{ foot-pounds.}$$

The source of this work can only be the descending weight which, during one week, has performed work $= 30 \times 4 = 120$ foot-pounds. Now, the amount of work expended on the pendulum cannot possibly exceed that due to the falling weight, in point of fact it will be much less owing to friction of mechanism, etc. But this method of calculation shows the work to be over 300 times greater than that due to the source of the work. The fallacy lies in ignoring the inertia of matter. When once the pendulum is *started* to swing very little power is required to keep it swinging. And so with the ship—a very considerable power is required first to heel the ship, but after she is once heeled she will continue rolling from side to side for some time without any additional work being expended upon her. There was certainly work to be got from a rolling ship, but the possible amount of it was not by any means so great as shown by the calculation in the paper.

Mr. TAYLOR asked to be allowed a few words of explanation. He quite agreed with all Mr. Weighton said about the action of a pendulum, but, when he referred to the horse-power, he (Mr. Taylor) did not say they would get that out of Mr. Rowe's machine, but, Mr. Rowe said so in his paper. Here was a quotation from Rankine:—"The permanent rolling of a ship of very great stability and little keel resistance, is governed by the motion of the effective wave surface, so that she rolls *with the waves* or like a raft." Now, Fig. 4, Plate IX., may be taken as a vessel of great stability as it has 6 feet metacentric height, and therefore would go with the effective wave slope *when all weights are fixed,* and what he wished to say was that when the vessel rolled with the waves and Mr. Rowe's machine was put in action, the loose or movable liquid in the motor would go down to the lowest point, and that if it moved thus there must be power developed, and this power was not dependent on ship friction, but on the contained movable liquid and its range. If the machine contained sufficient movable liquid, and this liquid had sufficient range, any horse-power might be developed; although Mr. Rowe's paper did not make it clear to him where or how he was going to grasp usefully one horse-power. It is a well-known fact that as the metacentric height is increased the vessel's period of roll is reduced, and that as a pendulum is lengthened its period is increased; these facts destroy all comparison between pendulums and metacentric heights. But, he thought, if instead of the metacentric height the distance between the centre of buoyancy and centre of gravity was used a correct comparison might be made.

Mr. WEIGHTON remarked, that was exactly what he had said—the power exerted by any such motor was due to the loose weights in the ship, *i.e.*, to the mercury on the motor and not to the weight of the ship.

Mr. ROWE said, from what they had listened to it was evident the subject had been found a somewhat difficult one. He was not surprised at it. Many practical friends had assured him that it was impossible to obtain mechanical power from a rolling ship by any apparatus carried *in* the ship. It was as impossible as to lift one's self by the handle of a basket in which one sat. "It was easy to criticise, but difficult to create." He was much obliged to his friends who had frankly offered their opinions. His only desire was to call attention to what seemed to him a novel and important problem, and to hear from men—some of them more capable than himself—their views as to its practical utility. He was not surprised at finding himself as it were at bay. His critics had seemingly overlooked the interesting problem described in Fig. 5, Plate X., and fastened tenaciously upon the apparent discrepancy between the power put into a ship and the power procurable from her, a discrepancy which he himself had called attention to. To show that he was not surprised at the practical condemnation of the motor to *propel* ships he would quote the substance of a letter written by him about ten months ago to an eminent shipbuilder. After explaining the gun-firing apparatus, he proceeded thus:—"Although from his calculations it seemed to follow that if a vessel possessed of great metacentric height were kept broadside to the waves she could be made to propel herself across the Atlantic by the power of her rolling, he looked upon the scheme as a scientific curiosity rather than as one capable of practical solution." The power could only be realised in stormy weather and steering certain courses, hence its little value as a propelling force.

He did not quite grasp the misunderstanding between Mr. Weighton and Mr. Taylor, but he asked Mr. Weighton to remember that the power of the motor was derived from the weight of water lifted. And to obtain great power several hundred tons of water would be necessary; and to carry *safely* a huge quantity of free water a very heavy ship must be provided. Hence it was not incorrect to say that the power varied as the tonnage of the ship.

He begged to thank Mr. Taylor for the trouble he had taken to master the subject; but he felt that if he replied to Professor Garnett he would in effect reply to all his critics. Professor Garnett, with considerable fluency and animated gesture, had made a speech which their esteemed President had referred to us a lucid one. The speech was, in his opinion, like most other speeches, partly lucid, partly turbid. In the first place, it is probable that the men-of-war to which his gun-firing apparatus would be fitted to discharge 110 ton guns (if ever it were fitted) would be vessels having a rolling period twice as great as mentioned by Professor Garnett. The small cylinder, therefore, would not require to be emptied once in every two and a half seconds, but once in ten seconds; and the number of rolls per minute would not be ten or twelve, but five or six. He merely mentioned these discrepancies to show how exceedingly easy it was to criticise. Again, Professor Garnett said, "If the working of this apparatus" (the gun-firing apparatus) "required 1 cwt. of mercury with a 6-inch diameter chamber, there would be something like 40 cwt. of mercury in the tube between the apparatus and the reservoir." Well, there was no time to test the accuracy of Professor Garnett's figures, neither was there any need to do so, because he had constructed a full size gun-firing apparatus, and tested it; the pipe being about two-thirds the diameter of the cylinder. The pipe held considerably less than *20 pounds* of mercury, not 40 cwt. × 112 lbs. = 4,480 lbs. The whole apparatus complete, ready for fitting on board ship, could be easily carried under the arm so far as weight was concerned. The foregoing indicated a *turbid* state of mind. Coming to the rolling of the heavy man-of-war, Professor Garnett's views were excellent, and *lucidly* explained what he himself wished to bring forward, viz., "If any ship could be started from rest, and rolled 30 degs. by one wave, and the ship stopped, and again rolled over 30 degs., and this done time after time, something like the power Mr. Rowe had calculated would be obtained." But Professor Garnett proceeded to say that in reality the horse-power available from such a ship would be 100 instead of 3,000. Now he wished it to be remembered that he never proposed to exhaust the full measure of a ship's stability: to do so would lead to capsizing the vessel. The 3,000 horse-power was obtained by using the preposition "*if*," as Professor Garnett had used it in the calculation of the weight of mercury. *If* each successive wave heeled the ship through 30 degs., from which with a motor in use she slowly recovered, then, in a suitably shaped vessel the horse-power referred to would be obtained. He did not think this action represented what would really take place at sea. In his opinion the vessel would roll to port and to starboard, but at reduced angles, under motor influence; and the influence of a motor would coincide with the effect produced by raising a vessel's centre of gravity. He and Professor Garnett appeared to be viewing two different sets of physical conditions. He was in the centre of an Atlantic storm, on board a vessel nearly circular in section, after the style of old French war-ships (not prismatic shaped nor saucer-like), rolling broadside-on among waves 50 feet high from hollow to crest, and possessed of a period just double that of the ship's. In his opinion, a motor containing 500 tons of movable water would exert its power through at least the angle of the wave slope, viz., 9 degs. The horse-power from such a motor, assuming the vessel's period to be the same as the "Lord Warden," would be—

$$\frac{\frac{375 \times 2,240}{2} \times \text{sine } 18^\circ \times 70 \text{ ft.} \times 3}{33,000} = 825 \text{ nearly.}$$

In this calculation he had taken the whole beam of the ship. Now, Professor Garnett, viewing, as it seemed to him, entirely different phenomena, naturally arrived at a different result. Instead of the "Lord Warden's" period of 5 seconds, Professor Garnett evidently used the period of the "Inflexible," 10·7 seconds. Instead of furious storm waves, Professor Garnett was evidently contemplating waves so moderate in dimensions that fluid friction was admitted to be a powerful factor to reduce rolling. In his opinion the resistance offered to rolling by the fluid *pressure* against the ship's hull would be insignificant in amount when compared to the energy of storm waves producing rolling motion. In the term "fluid pressure" he did not include the wave-making efforts of the vessel's shoulders. Professor Garnett's views of the rate of extinction of rolling (diagrams of which, with full explanation, could be found in Mr. W. H. White's book on "Naval Architecture," and in Mr. Watt's papers already referred to) clearly proved that his mind was fixed upon still-water experiments.

With regard to an aspect of the question raised by Mr. Alexander Taylor, his answer to any critic who (confused by the relative motions of the ship and the water) declared that the water assisted, as much as it retarded, rolling, was that—If on board ship any kind of apparatus were fitted to lift one pound weight through a height of one foot, the performance of that work, the exhaustion of a foot-pound, obtained through the rolling of the ship, would reduce her rolling. This was a simple and clear mode of looking upon the problem, and he hoped it would not be forgotten. Something cannot be obtained from nothing.

Referring to Fig. 4, Plate IX., he called attention to the triangles, or wedges, of immersion and emersion. X_1 was the centre of gravity of the port wedge; Y_1 was the centre of gravity of the starboard wedge. The position of the vessel's centre of buoyancy B_1 was determined by the transfer of the port wedge to the starboard side, and the centre of gravity of this wedge of buoyancy was moved through a distance of about two-thirds the vessel's beam. A vertical line drawn through the centre of buoyancy B_1, intersected the centre line of ship at M, and G Z was the righting arm, whilst G M was the metacentric height. Now, it had been shown that in a given vessel the rolling period increased (the rolling became easier) the smaller the metacentric height. Let them in Fig. 4, Plate IX., suppose the starboard wedge to be impaired by an indent, shown in shaded lines from O to P, what would follow? The new centre of gravity of the starboard wedge would be found somewhere to the left of its old position, as at Y_2, and the corresponding centre of buoyancy of the ship would be also to the left of the old position, as at B_2. A vertical line through B_2, intersecting the centre line of ship in M_1 would give a reduced righting-arm $G\,Z_1$ and a reduced metacentric height $G\,M_1$. The outcome of this would be a greater rolling period; and, in order to increase the period and reduce the angle of the roll, he suggested the chambers shown in Figs. 10 and 11, Plate XIII. These chambers would reduce a vessel's metacentric height in the way explained: they also imposed work upon the ship as she lifted the chambers above the level of the water.

He hoped that the outcome of the paper would be a stimulus to the study of the use of free water on board ship. His own investigations began through his gun-firing apparatus—they were entirely independent of the work already done by the Admiralty, and were, he believed, original. He was, however, glad to know that his views were in accordance with the results obtained by Mr. P. Watt and Mr. Froude in their experiments on men-of-war and on models.

No doubt members of the Institution were aware that eminent authorities differed on this question of the use of free water on board ship to reduce rolling. Mr. B. Martell, of Lloyd's, speaking with a knowledge that his words would have great weight among shipowners and shipbuilders, said:—"I should be very sorry for it to go abroad that, although we might approve it for purposes for which it is intended, such as the case of war-ships, that it could be adopted for merchant ships in general. At the same time I may say that for some vessels I almost wish it could be."

Mr. Martell's cure for the evils of excessive rolling was to pay great attention to proportion of beam to depth, and be careful in the stowage of cargo.

Mr. W. Denny's comment upon the above was as follows:—"While taking Mr. Martell's caution to heart, let not the idea go forth that we are unable in the mercantile marine to give effect to the admirable work of Mr. Watt and his friend Mr. Froude."

Mr. R. E. Froude's views were admirably explained in the following paragraph:—"In reference to Mr. Watt's suggestion that water chambers might be applied more extensively to ships so as almost to do away with rolling altogether, I should like to point out that there is one very hopeful feature about the idea in comparison with the attempt to do the same thing by putting large bilge-keels. In attempting to diminish the rolling largely by means of adding to the bilge-keels, in proportion as the first additions you make to the bilge-keels are effective in reducing the rolling the effect of the subsequent additions is diminished, because the efficiency of bilge-keels largely depends upon the angle of rolling. On the other hand, every additional foot of aggregate length of balanced chamber along the ship adds a practically equal amount to the extinction, and takes an equal amount off the rolling. I think that is a very hopeful feature."

Mr. Phillip Watts, the author of the paper quoted, was very clear and positive on the matter. He said:—"Mr. Martell told us of a ship which rolled so excessively that she 'fairly rolled herself to pieces.' I think he will agree that if she had been fitted with suitably shaped water chambers she would have behaved very differently, and would doubtlessly have been afloat at the present time. I think water chambers might be fitted with advantage in all ordinary ships that are deep rollers, and where it is important to reduce rolling; and I think it would be found that in such cases they could be introduced to a sufficient extent without danger to the ship."

It would thus appear that the balance of opinion was in favour of the use of water chambers. Having thus grouped together the opinions of the ablest scientific authorities on this interesting subject, and answered his critics in a way that he hoped gave peace of mind, he begged to thank those present for the friendly manner in which they had listened to his attempt to throw light upon a problem that had cost him much trouble, much thought, and considerable loss of time. To some extent he had been repaid by the knowledge that the paper had been felt as a boon by many. It had certainly been the means of instructing himself, and the knowledge he had gained would, he believed, be instrumental in enabling him sooner or later to perfect the gun-firing apparatus, which he hoped would add enormously to the power of the British fleet.

The VICE-PRESIDENT said, it seemed to him that they had only touched the fringe of a very important subject, and seeing the great difference of opinion there was in the matter it required a great deal of thought and consideration to get at the bottom of it. He thought they were very much indebted to Mr. Rowe for bringing the matter before them in such a very clear and intelligent manner. And, so far as the discussion had gone, he was rather doubtful whether Mr. Rowe had not been materially assisted in his praiseworthy attempt to utilise a portion of the power developed by the rolling of ships amongst waves. The aspect of the subject presented by Mr. Rowe was no doubt somewhat novel, and it was to be hoped the subject would not rest there, but that it would be further considered and if possible experimented on, so as to arrive at a practical solution of the matter. He was sure they would all cordially accord Mr. Rowe a very hearty vote of thanks for his able paper.

The proposal was cordially adopted.

ON THE STRUCTURAL STRENGTH OF CARGO STEAMERS.

BY G. BERGSTRÔM.

THE writer's intention in this paper is to lay before this Institution the results of a few calculations of longitudinal strains, compiled from the plans and data of a recently-built steamer.

The steamer in question was constructed and built by Messrs. E. Withy & Co., of West Hartlepool, a few years ago. She is of the well-deck type, on the web-frame system, with cellular bottom fore and aft, as shown on Fig. 1, Plate XIV.

The following are her dimensions, etc. :—Length between perpendiculars, 290 feet; beam extreme, 38 feet; depth (from top of keel to top of beam) in length to main deck, 12·65, to quarter deck, 10·58, and to bridge deck, 9·77. She has a load displacement of 4,940 tons on a mean draft of 20 feet 11½ inches, and carries about 3,250 tons of cargo, exclusive of 340 tons of bunkers. She is built of steel and iron to Lloyd's highest class.

The strains to which a ship floating in water becomes subject in consequence of the unequal distribution of weights and buoyancy—which we can say exists in all ships more or less—may be divided in three classes, viz.:—

1st.—Still water strains.
2nd.—Strains when on a wave crest.
3rd.—Strains when on a wave hollow.

Each of these are again divided into two classes:—First, strains caused by the unsupported portions of a ship tending to drop or shear vertically; and secondly, those which tend to alter a ship's longitudinal shape, by bending her, resulting in breaking the ship across: the former are called shearing or racking strains or forces, and the latter, bending strains or moments.

Knowing therefore the amount, directions, and applications of all these vertical forces it is by simple mathematical methods possible to calculate the straining effect at any transverse section.

Again: a graphical method is applied to represent and illustrate these operations and results.

The writer will now try briefly to explain the various diagrams referring to the strains of the above-mentioned steamer.

As already said, she is of the well-deck type, and in Fig. 1, Plate XIV., and Fig. 2, Plate XV., is shown the main features of her construction.

Before going further it may be mentioned that in calculating the moments of resistance, those of the scantlings which are of iron were treated as steel of equivalent rule-size or area. Whether in so doing, the writer undervalued the material or not, he does not intend to prove in this paper, but hopes on a future occasion to be able to show some data to that effect. For all practical purposes the difference is slight, and may be ignored.

If we now refer to Fig. 3, Plate XIV., we find six curves or diagrams, more or less continuous. A curve represents the light weight of the ship, and by the irregular shape of the same it will be readily seen how the different parts which contribute to make up the light weight are distributed, the most prominent parts being in the engine room space. The value and shape of this curve was arrived at by working out the weight of the ship per foot of length.

It will be understood that to get an exact shape of such a curve or diagram as A is almost impossible.

The next curve in order is B, and represents the light weight displacement or buoyancy per foot of length. The area and moments of curve A must be equal to those of curve B in order to retain the draft and trim of the ship.

The total weight thus found was 1,340 tons—hull, 1,105 tons, and engines, 235 tons—being only a few tons in error from the actual light weight of the ship.

Curve C is laid off in the same manner as curve B, and represents the load displacement or buoyancy in tons per foot of length. The ship in this case is supposed to be on an even keel.

The next operation was to find the weight and distribution of cargo and bunkers, the result of which is shown in Fig. 3, Plate XIV. (D and E curves), laid off on the same principle as previous curves.

Then adding weight of ship to cargo and bunkers, the curve F—ship and cargo—was produced, resembling curve A in shape and irregularity. The area and centre of gravity of this curve must of course agree with its corresponding curve of buoyancy or curve C, of same reason as curves A and B.

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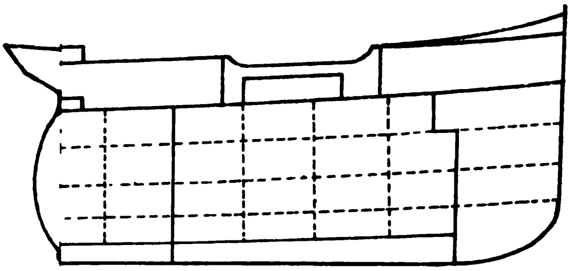

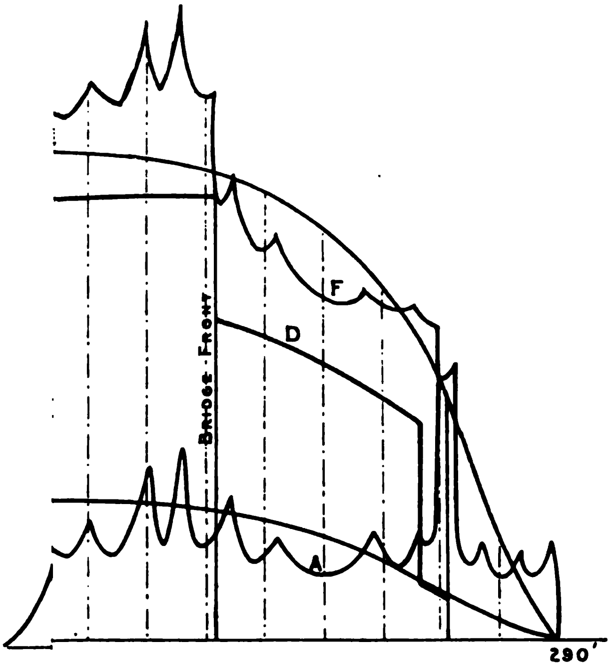

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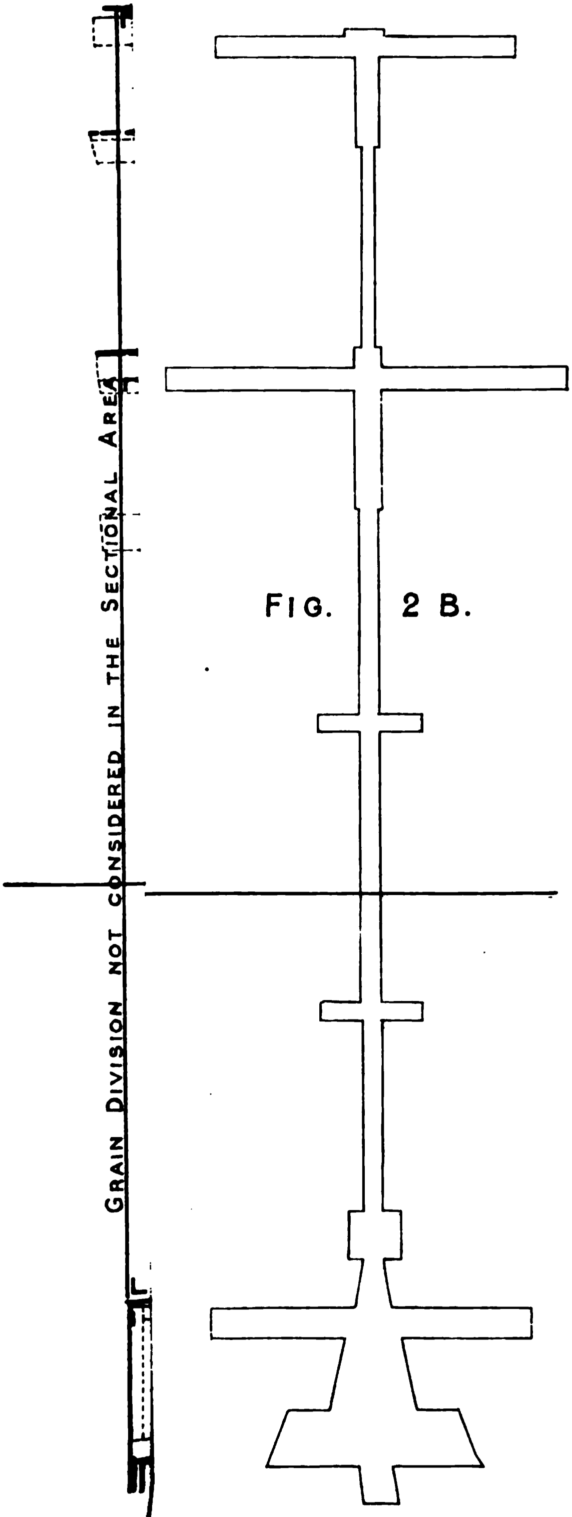

FIG. 2 B.

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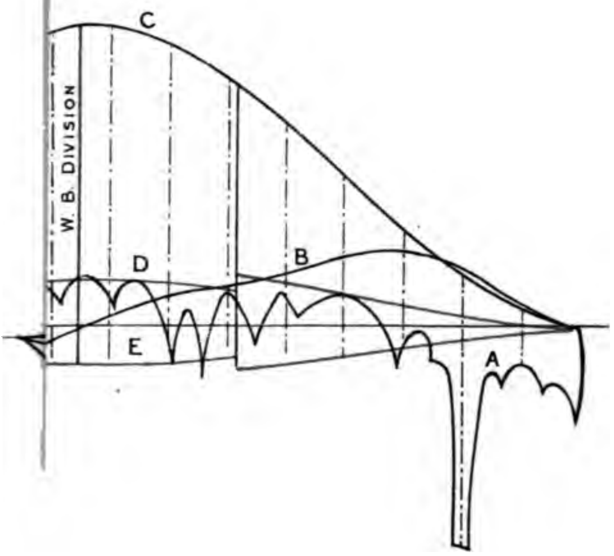

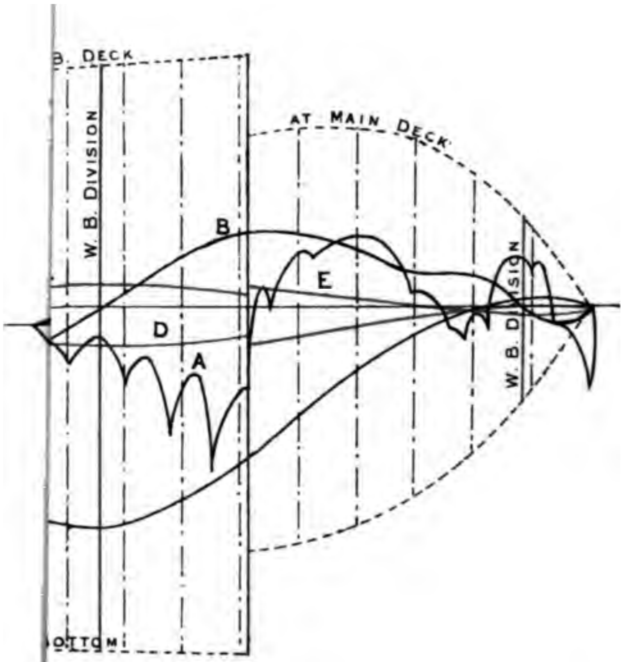

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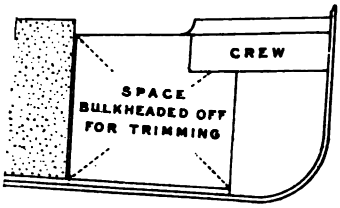
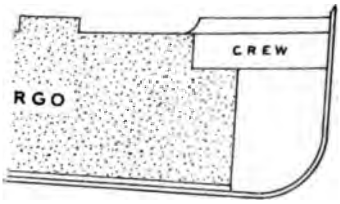
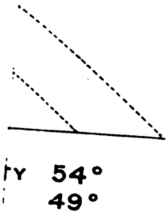
Vol V Plate XX







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From these curves we can by integration, find and construct the curves of loads, racking, and bending. In the different figures, the curves of racking and bending are shown of a more uniform shape. This was done to avoid confusion with the curve of loads, the effect and area being as near to the real shape as practicable.

If we again refer to Fig. 3, and compare the curves A-B and C-F respectively, and knowing the weight of ship, or ship and cargo combined, acts downwards, and their respective buoyancies upwards, we find that although these curves are of the same area and their centres coincide, (A with B and C with F), their shapes are very different, owing to the unavoidable excesses in distributing the different weights.

These excesses or deficiencies of buoyancy and weight are shown by curve A in Figs. 4, 5, etc., Plates XVI. to XX., and is called curve of loads or resultant vertical forces. The excess of weight is shown below and the excess of buoyancy above base line.

In order to retain the hydrostatical conditions of equilibrium, the joint areas and moments of the curve lying above base line must be equal to those lying below.

The points where the curve of loads crosses the base line is known as water-borne sections where weight equals buoyancy, and will consequently occur in pairs.

The curve of loads will give an idea of the manner in which the ship considered as a beam is loaded and supported, the points of support being what is termed water-borne sections and already explained.

From the curve of loads is constructed by integration the curve of racking forces or stresses, and is shown by curve B in Figs. 4, 5, etc. The ordinates of this curve laid off to a certain scale are the measures and relative directions of these stresses; the maximum stresses always taking place in way of water-borne sections.

In constructing the curve of racking forces we may use either end of the curve of loads as the origin of integration (as the same result and loop of curve would be obtained) only remembering that the ordinates have the correct relative signs.

The features of interest in this curve are the points where it crosses the base line and which points or stations—always odd in number—divide the ship in separately water-borne parts before and abaft such stations.

These points or stations are termed water-borne divisions and must not be confused with water-borne sections.

Again, from the curve of racking forces is (on the same principle as previous curve) constructed and represented the curve of bending moments, resulting from the actions of the various vertical forces on the ship. The curve of bending moments is shown by curve C in Figs. 4, 5, etc., Plates XVI. to XX.

There are one or two points of practical interest connected with the construction of these curves of hogging and sagging moment—that is the curve of bending moment.

The first is: how to determine whether it is a hogging or sagging strain, but this is very easily accomplished by finding the sum of the moments of the downward and upward forces respectively at any station on the curve of loads, and if the former are in excess of the latter the moment is of a hogging nature; if the reverse, it is a sagging moment. Secondly, it will be noticed that the maximum or minimum bending, whether hogging or sagging, are always experienced in way of water-borne divisions. In the different figures, the hogging moments are shown above and the sagging below base line.

The bending moments were calculated for this ship under several conditions, viz.:—

1.—Ship light. Still water.

2.—Ship loaded homogeneously (fluing 'tween-deck) with bunkers nearly full and in still water.

3.—Same condition as No. 2, but on a wave crest.

4.—Same condition as No. 2, but on a wave hollow.

5.—Same as No. 2, but bunkers nearly empty.

6.—Ship loaded with iron ore with bunkers nearly full and on a wave crest.

7.—Same as No. 6, but on a wave hollow.

Now, to apply these bending moments in order to find the different longitudinal strains on the material of which the ship is constructed, we must calculate the properties this material possesses to withstand this bending; that is, we must find the moments of inertia and the neutral axis at different sections along the length of the ship, and from them determine the moments of resistance.

These moments of resistance at the bottom-plating, main, quarter, and bridge deck plating, were calculated and set off to curves as shown in Fig. 5, Plate XVI. The moments due to bridge deck running almost parallel to those due to main deck.

To obtain the effective sectional areas of the different scantlings—directed longitudinally—due allowance was made for rivet holes in frames, beams, etc.

The so-called equivalent girder or condensed section is shown in Fig. 2 B, Plate XV., and represents that of the midship section.

This equivalent girder is really of no practical value, inasmuch as to construct a true girder from which to determine the position of the neutral axis and moment of inertia, it requires more time than working direct from the scantlings.

In the case of this ship or any modern ship with an inner bottom continuous fore and aft, it will nevertheless (supposing it is a true representative of the section of scantlings) more clearly illustrate—if so to term it—the value of this inner or double bottom, seeing the low position of the neutral axis.

Having thus found the moments of bending and resistance at any section, we simply apply the well-known formula, $S = \frac{M}{R}$, where S is the strain per square inch at that section, M the bending moment, and R the moment of resistance.

The various strains per square inch are shown in the different figures. The curves marked D represent the strains on upper deck plating, and those marked E the strains on the bottom plating; in all cases the tensile strains are shown above and the compressive below base lines.

Starting now with the strains of the light ship. The only strains she will probably be subject to in this condition are still water strains. In referring to Fig. 4, Plate XVI., we will find that although there is a considerable excess of weight amidships no sagging takes place there, but from midships where all bending is technically *nil* a hogging commences, increasing towards each end until it reaches the water-borne divisions where the hogging is a maximum, and from whence it gradually decreases towards the extremities. The maximum hogging moment in the after-body is somewhat larger than that of the fore-body, exceeding the latter by 600 foot tons.

Passing from moments to strains, it will be observed that the ship is under a tensile straining on her upper deck plating throughout the length, and consequently there is a corresponding compressive straining on the bottom plating; the maximum strain in the fore-body taking place about midway between midships and the stem, the same being the case in the after-body. The greatest tensile strain is in the after-body on the quarter deck plating, and does not amount to one ton per square inch, while those on the bridge or main deck plating are somewhat less.

In most ships the strains experienced, whether tensile or compressive, on the bottom plating or structure are always less than those experienced on the upper structure, and in the case of this ship they are considerably less, owing to a great extent to her inner bottom.

From what has thus been explained and is illustrated in Fig. 4, Plate XVI., we gather that the permanent strains of this ship are very small.

We will now take the strains on the ship in a loaded condition. To illustrate and explain the many and varying strains a ship carrying cargo from port to port will be exposed to during her career would be next to impossible, owing to the variety of cargoes carried, and more so to the many and rapid changes in the sea-road on which these cargoes are conveyed.

In the case of this ship some of the principal features of straining in a loaded condition have been calculated, and the nature and extent illustrated in the various diagrams.

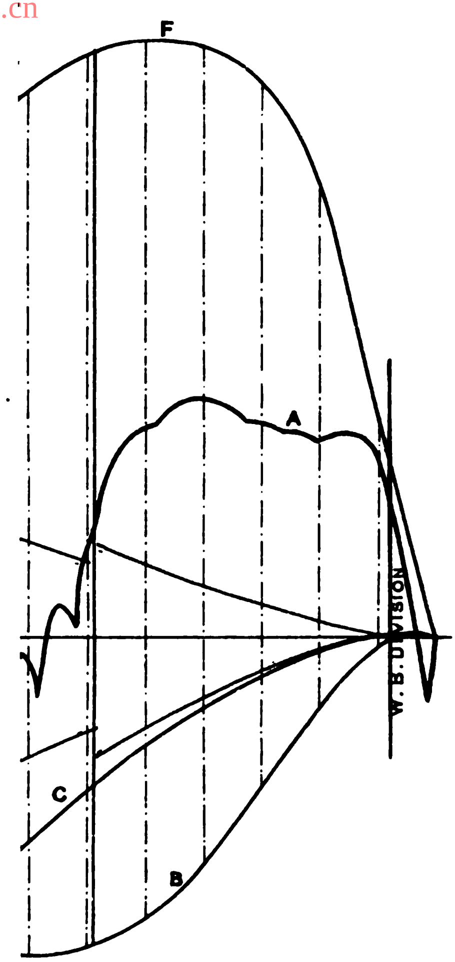
Taking the strains for the loaded ship in the same order as we calculated the various bending moments—that is—starting with the still water strains we will, on referring to Fig. 5, Plate XVI., find that the strains on the loaded ship in still water are very different to those on the ship when empty. While the after-body, as far as the fore engine room bulkhead, is under a hogging strain, the remainder of the fore-body is subject to sagging except at the very end where there is a slight tendency to hogging.

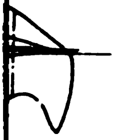
The maximum tensile strain taking place on the quarter deck gunwale does not reach ¾ ton per square inch, and the maximum compressive strain on the bridge deck gunwale is only ½ ton per square inch, the corresponding compressive and tensile strains on the bottom plating being only two-thirds of those on the upper gunwale.

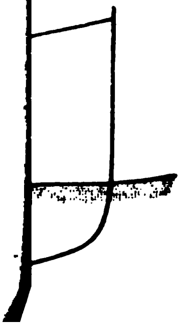
There are one or two matters of practical interest connected with the strains just explained. In the first place it will be noticed that the strains on the main deck in the after end of well are somewhat larger than those on the bridge end, but this is amply compensated for by the doubling plate in way of the break. As this said doubling plate was not recognised in calculating the moment of resistance at this point, the writer tried the effect in the application of this doubling plate, and found that the strains on the main deck were consequently reduced below those on the bridge deck near the break.

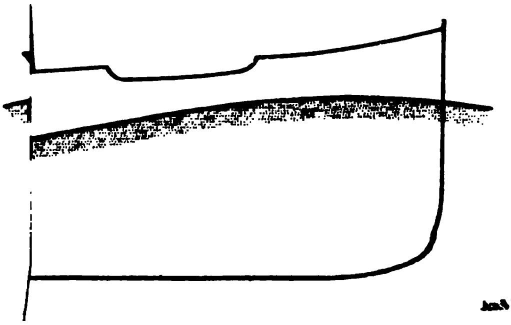
The same argument holds good in comparing the strains at the after end bridge with those immediately abaft on the quarter deck.

Another point of interest is where the change from hogging to sagging takes place. It is evident that, although there is technically no indication of straining at that place, the material nevertheless will be liable to a kind of shearing or separating process, but as the respective hogging 's paper "On the St









and sagging strains are very small the effect will be of little or no consequence.

It will thus be seen that the still water strains when loaded are not only of a different nature to those of the light ship, but also somewhat less in amount.

The ship was next supposed to be on a wave crest of her own length or 290 feet and 20 feet high, reciprocating with a hollow wave of similar dimensions, as shown in Figs. 7 and 9, Plate XVII.

The displacement per foot of length to the wave surface was then found and laid off to a curve F in Figs. 6 and 8, Plate XVII., representing the new distribution of buoyancy.

The strains on the ship when on a wave crest or wave hollow of above dimensions are more important and effective than any of the still water strains. If we refer to Fig. 6—on a wave crest—we notice that in this case there is an uniform hogging from fore to aft, reaching its maximum near amidships in the after-body. The heaviest tensile strains are experienced on the quarter deck plating where the maximum tensile strain per square inch amounts to 4½ tons, while the maximum tensile strain on the bridge deck is only 4 tons. The maximum compressive strains on the bottom plating are 3 and 2½ respectively.

Again, when on the wave hollow the strains are quite the reverse to those when on a wave crest, and in Fig. 8 it will be seen that the ship in this case is under a sagging strain almost her whole length with the exception of the extreme ends where the sagging changes into a slight hogging.

The maximum straining takes place, as in previous case, near amidships, but in the fore-body, and is not so severe.

The heaviest compressive strains on the upper deck gunwales do not in any case exceed 4 tons per square inch, while the corresponding tensile strains on the bottom plating are barely 3 tons per square inch.

It is obvious that to fix any certain limit of strains on a ship when moving amongst waves is rather hazardous; and to test this ship the writer tried the straining effected when rested on waves of above-mentioned size.

A ship has to be prepared to fight all kinds and sizes of waves, and the most trying are probably those of her own length, with a rather slow change of posture.

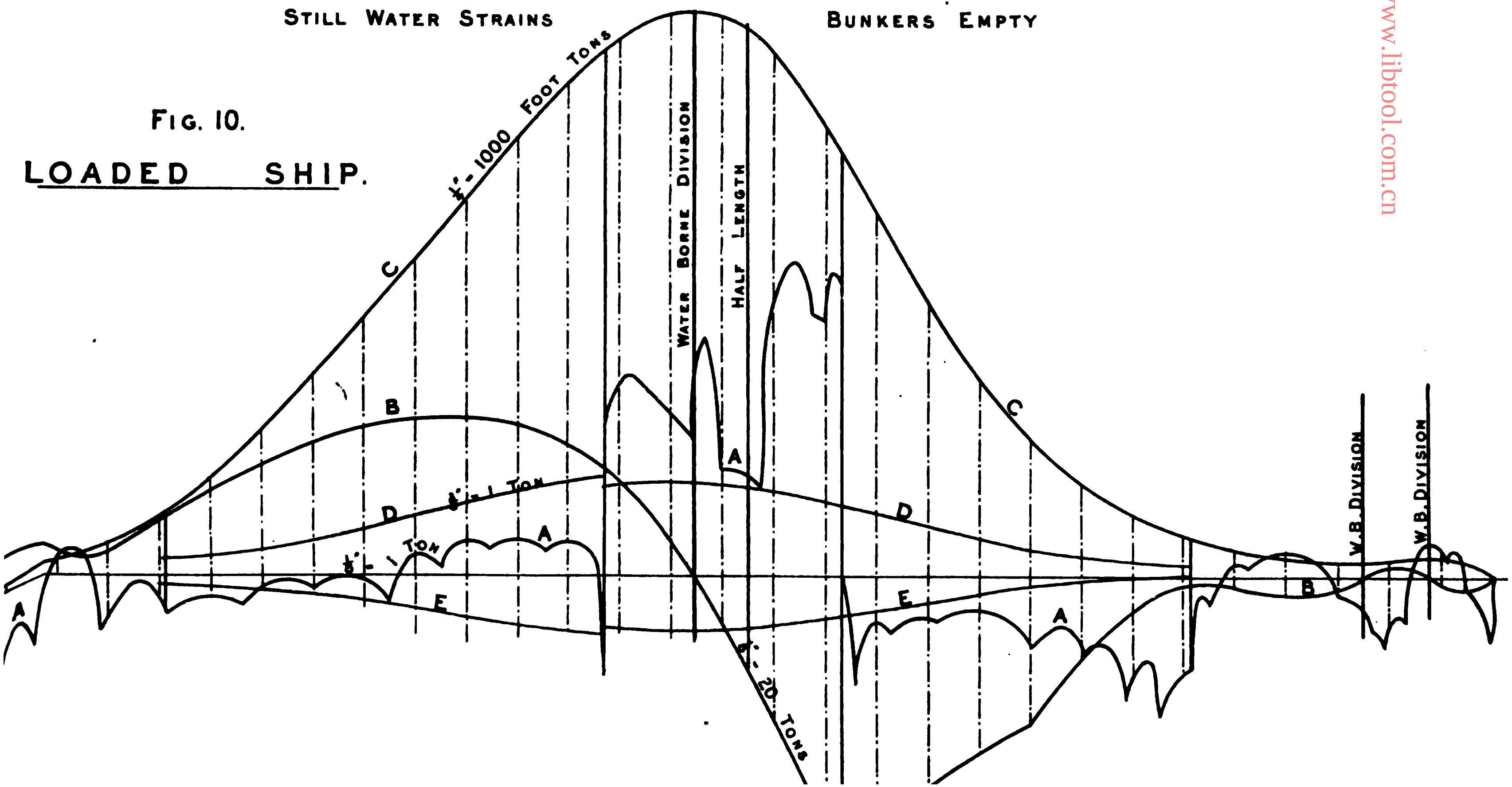
In the three last diagrams previously explained, the bunkers were supposed to be nearly full, but as the contents and weight of these bunkers will gradually decrease towards the end of the voyage it is clear that a change in the nature and amount of the strains will take place.

To illustrate Mr G. Bergström's paper "On the Structural Strength of Cargo Steamers."

STILL WATER STRAINS   BUNKERS EMPTY

FIG. 10.

LOADED SHIP.



We will therefore suppose the ship once more in still water, but with bunkers nearly empty. The change in this case is illustrated in Fig. 10, Plate XVIII.

In comparing these strains with those when bunkers are nearly full, we notice that the sagging in the fore-body has disappeared, and a slight hogging taken its place, while the hogging in the after-body is increased, the ship now being under a hogging strain fore and aft. The absolute maximum hogging occurs in this case as in previous (bunkers nearly full) in the after-body and nearly amidship from whence and forward the hogging quickly decreases for some distance, after which it falls very slowly to a minimum in the way of the well, slightly rising again to a second maximum. The maximum tensile strain on the upper deck plating is barely 1½ tons per square inch, and the compressive strain at any section on the bottom plating is only two-thirds of the corresponding tensile strains.

From what has just been explained we gather that the ship is subject to different and heavier (about twice as large) still water strains near the end of the voyage than at the beginning.

As already mentioned, a ship must be prepared to carry all kinds of cargoes, but it is evident that some are more dense than others, consequently the stowing of and space occupied by a lighter cargo may be very different to that of a heavier description.

In the preceding cases the cargo was of the lighter kind, filling all available space. The ship was therefore—in the second place—supposed to be loaded with a denser cargo, such as iron ore, with her bunkers nearly full and again moving amongst waves.

The iron ore was supposed to fill the after and fore main holds up to the quarter and main decks respectively, the after and foremost holds only partly filled in the usual way.

The different strains on the ship under these conditions are illustrated in Figs. 11 and 12, Plates XIX. and XX.

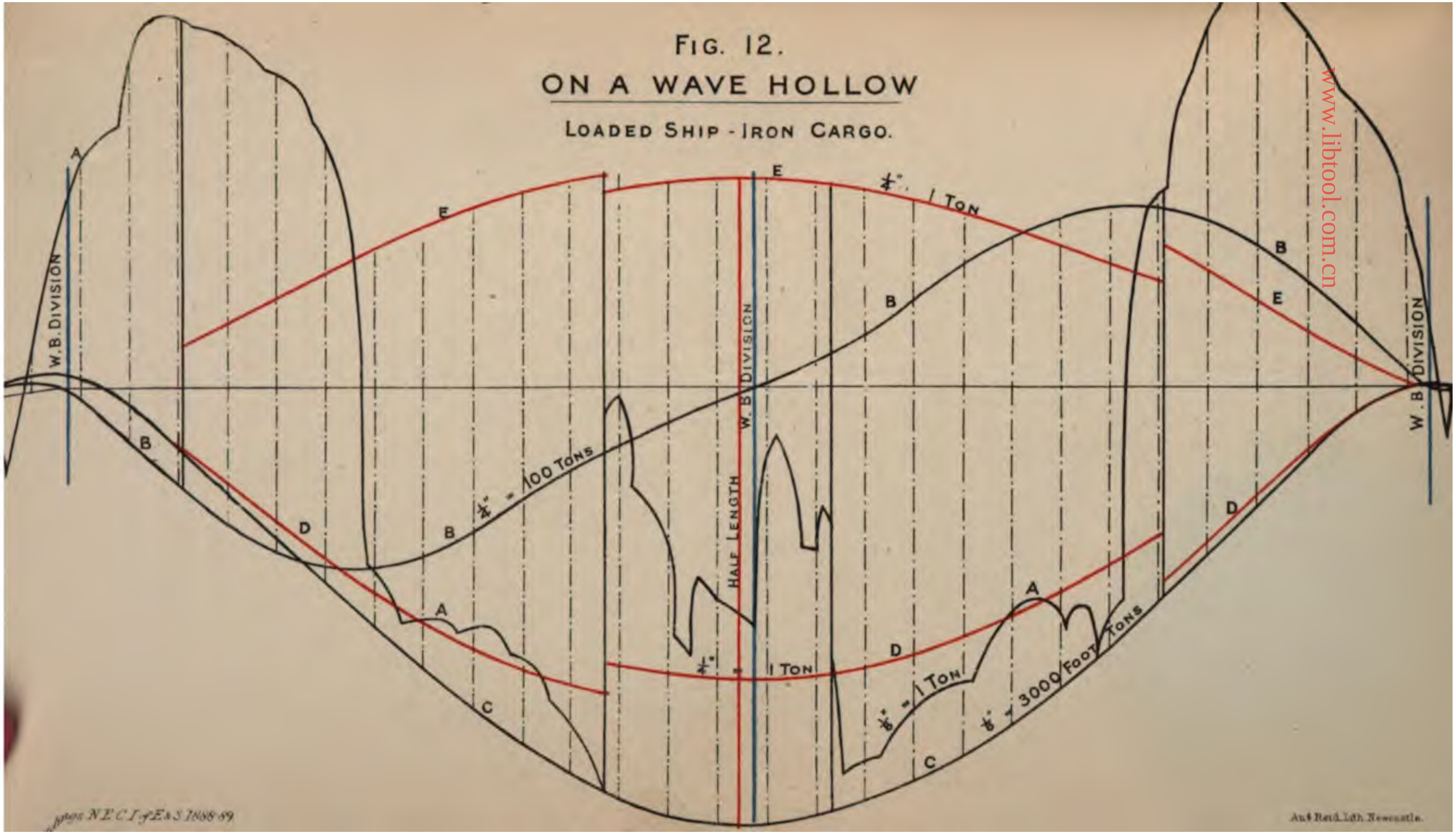
The strains in this case are very similar in nature to those illustrated in Figs. 6 and 8, there being a slight difference in the strains when on a wave crest.

On referring to Fig. 11, Plate XIX., we find that the bending moment in this case does not produce hogging strains throughout the length, but changes into a slight sagging on two occasions. There are consequently three sections where the hogging is a maximum, and two sections where the sagging has a maximum value. The absolute maximum bending takes place near amidships, and is of the hogging nature ; the other

FIG. 12.

ON A WAVE HOLLOW

LOADED SHIP - IRON CARGO.



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cargo boats that is now being built; and it is a matter of congratulation when we consider that vessels of this class can be built to carry iron cargoes of over 4,000 tons weight, and to be able to do this work without straining the structure or in any way endangering the safety of the vessel at sea.

In presenting this paper to the members of this Institution, the writer trusts, where so many of its members are so closely connected with the interests of shipbuilding and shipowning, such an expression of opinion may take place that further improvements may be suggested in this useful class of cargo boat, and at the same time he regrets the brief manner in which so many important points have had necessarily to be dealt with in this paper.

DISCUSSION.

The **President** said, the papers were open for discussion. They would please bear in mind what he said at the beginning that the discussion on the two papers, the paper of last meeting and this, would be taken together.

The **Secretary** (Mr. Duckitt) intimated that he had received a communication from Mr. Ullstrom on Mr. Sivewright's paper, and he was asked to read it:—

COMMUNICATION FROM MR. OTTO ULLSTROM ON MR. SIVEWRIGHT'S PAPER.

DEAR MR. DUCKITT,—I have had great pleasure in reading Mr. Sivewright's able and instructive paper on "The Development of Well-Decked Cargo Steamers," and now beg to make a few remarks upon the same. On page 151 Mr. Sivewright points out that one great objection to flush decked steamers, as shown in Fig. A, Plate XXI., is, that on account of the large capacity of the fore-hold compared with that of the after-hold considerable difficulty is experienced in proper trimming when homogeneous cargo is carried. On page 152 Mr. Sivewright goes on to state that to overcome this objectionable feature of trimming by the head, the long full poop steamers, as shown on Fig. E, Plate XXIII., were introduced, but that the full benefit of the poop was only obtained when filled with cargo of the lightest description, and that loaded under these conditions the vessel trimmed too much by the stern.

From this one might think that the cubical contents of the holds were the cause of faulty trimming. This might be right enough from a shipowner's point of view, but from a practical and technical shipbuilder's it would scarcely be deemed so, as the trimming entirely depends upon the design of the vessel and the position of the centre of buoyancy.

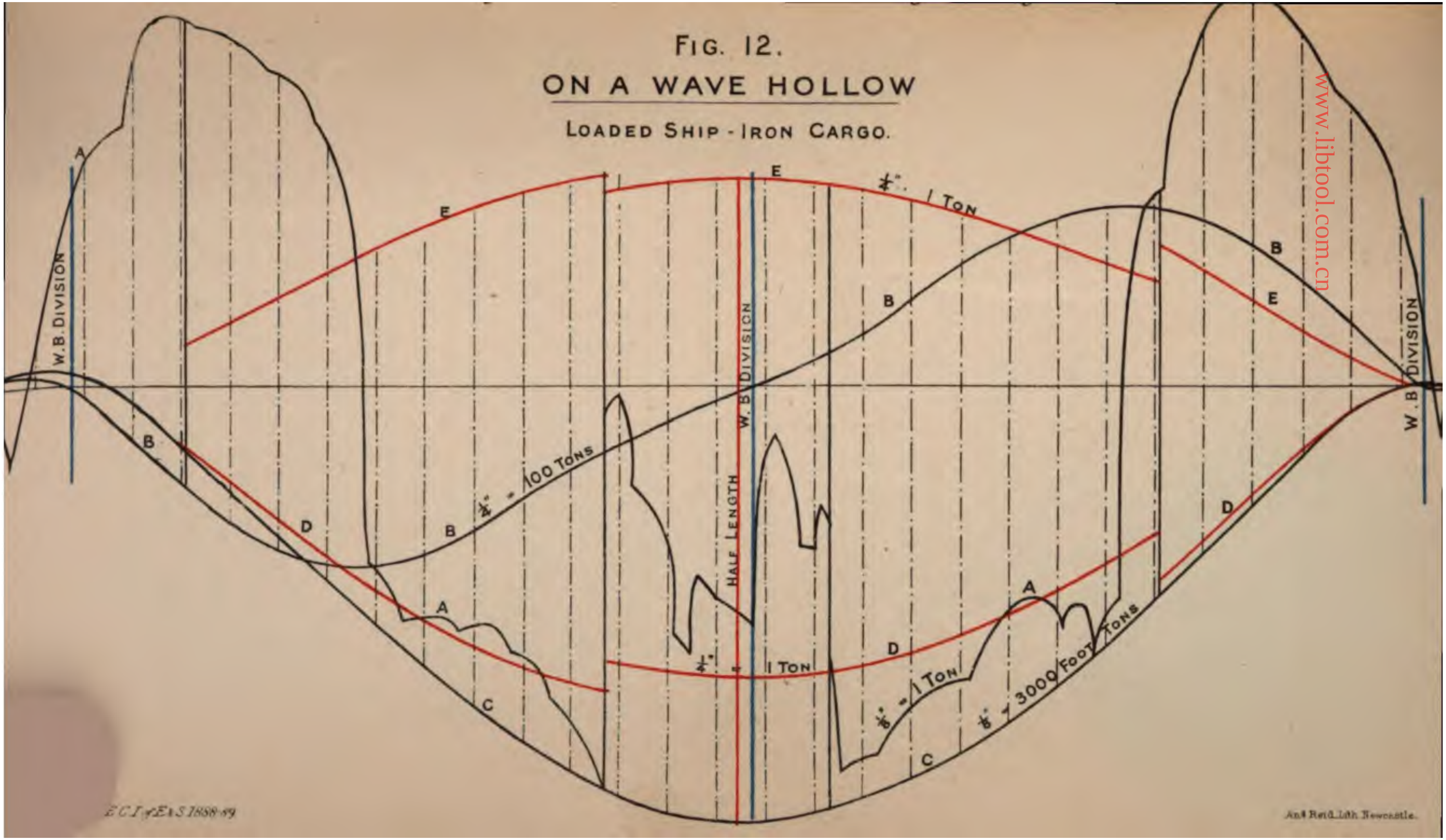
FIG. 12.

ON A WAVE HOLLOW

LOADED SHIP - IRON CARGO.

E.C.I. of E.& S. 1888-89

And Reid Lith Newcastle.

maximum strains, whether hogging or sagging, are exceedingly small. This absolute maximum tensile strain on the bridge deck gunwale does not amount to more than 1¼ tons per square inch, the corresponding compressive strain on the bottom plating being barely 1 ton per square inch.

The strains when on a wave hollow (Fig. 12, Plate XX.) are exactly of the same nature as, but considerably larger than, those illustrated in Fig. 8, Plate XVII., being probably the largest strains experienced by the ship. The maximum compressive strain taking place near amidships on the bridge deck plating reaches as much as 7 tons per square inch, while the corresponding tensile strain on the bottom plating amounts to 5 tons per square inch.

Now, as a final comparison between the strains on the ship, loaded with a homogeneous cargo in one case and a cargo of iron ore in the other, we find that when on a wave crest the strains in the first case are by far the largest, while when on a wave hollow the larger strains are those when loaded with the iron ; in fact, so large as to be dangerous to the ship.

Knowing that every change of the waves reverses the nature and direction of the strains it is evident that this constant and rapid changing, perhaps extended for weeks, would finally be attended with signs of weakness.

On a review of the whole of these investigations we may conclude that the longitudinal strains are not of any serious character or amount.

It is true and above demonstrated that some of the strains when loaded with iron ore stowed in the present manner are very large, but there are two points which must not be overlooked.

In the first place, we may considerably lessen those strains by more evenly distributing the iron in the holds, and thus reduce the straining below that when loaded homogeneously. Another point is—perhaps, the only consolation—that the material is capable of withstanding a much heavier straining ; and if we fix the limit of safety at 10 tons per square inch we would not be far wrong.

Something may be said about the steamer chosen being a well-decker, but the writer had several reasons for so doing. Firstly, she furnished the most extensive and reliable data obtainable ; another reason was, that she represents a type of cargo steamer which is gaining favour every day, and embraces a large portion of our cargo steamers of to-day.

The original intention of this paper was to obtain a more comparative view of the longitudinal strains on cargo steamers of different types and construction ; but, as we well know, there is an enormous amount of work involved in calculations of this kind, and the time at the disposal of the writer did not allow him to extend these calculations beyond what is illustrated in this paper. But, as hinted at the commencement of this paper, he hopes on another occasion to be able to extend this paper to what was originally intended, at the same time trusting that these few illustrations will be of some interest.

Before concluding, the writer begs to specially thank Messrs. E. Withy & Co. for the kind interest shown by assisting him in preparing this paper.

DISCUSSION.

The **VICE-PRESIDENT** said, the paper they had got before them was one capable of a good deal of discussion and worthy of it, and the discussion would, he thought, be as well after some consideration had been given to the paper. If any member was inclined to open the discussion that night, they would be glad to hear them, otherwise it would be better to delay the discussion till next meeting.

Mr. **GEO. N. ARNISON**, Jun., was sure they must all feel grateful to Mr. Bergstrôm for having made such an elaborate enquiry into the longitudinal strains of a cargo steamship, and for presenting the results in the paper just read. It was the first of the kind that had been prepared for the North-East Coast Institution of Engineers and Shipbuilders, and as it had doubtless necessitated a great amount of labour, it was worthy of full discussion. In having selected a "well-decker" of recent construction the results were of all the greater interest, as so many of the members had such considerable experience with this type of vessel, and in this respect Mr. Bergstrôm specially deserved their thanks, for, so far as he (Mr. Arnison) could recollect, the "well-deck" type had not before received such attention in the proceedings of any institution. Mr. Bergstrôm had followed out the mode of calculation adopted first of all by Sir E. J. Reed in a paper contributed to the Royal Society of London on 31st December, 1870, and afterwards by Mr. W. John, who placed before the Institution of Naval Architects the results of similar calculations on the 26th March, 1874. Other experts had adopted the same mode of enquiry into the longitudinal strength of vessels. Without wishing to detract from the value of the paper now read, looking at the various diagrams, he (Mr. Arnison) could not help thinking its value would have been considerably enhanced if there had also been a systematic set of tables showing the analyses of the results. The paper stated under what circumstances and at what point of the vessel the largest hogging and sagging moments were experienced, but did not say what the "moments" were. If Mr. Bergstrôm had no objection to annex to his paper the various "moments," "sectional areas," etc., the interest and value of the paper would be increased.* Sir E. J. Reed presented part of the results of his enquiry into the maximum hogging strains of Her Majesty's vessels as follows:—"Minotaur" maximum hogging strains $= D \times \frac{L}{28}$, with a wave the same length as the vessel and 30 feet in height; "Bellerophon" maximum hogging strains, $= D \times \frac{L}{48}$; "Victoria and Albert" maximum hogging strains, $= D \times \frac{L}{43}$. Where $D =$ load displacement, $L =$ the length of vessel. Mr. John calculated by the same method the hogging strains in a screw steamer of the merchant service, 336 feet long and about twelve depths in length, displacement about 5,000 tons. With the bunkers full he obtained the following result:—$D \times \frac{L}{44{\cdot}5} =$ maximum hogging moments, but after 300 tons of coal had been consumed the maximum hogging moments increase and are equal to $D \times \frac{L}{38}$. In this case the height of the wave is only assumed to be 12 feet, although in length the same as that of the vessel; and taking this into account, as well as the fact that the cargo was assumed to be the same measurement per ton of length, Mr. John came to the conclusion that $D \times \frac{L}{35}$ would be a fair expression of the maximum hogging moments. Such formulæ were of some use for comparison, more especially for similar vessels. The "well-deck" steamer, of which Mr. Bergstrôm had given the calculations of longitudinal strength, was similar in displacement to the mercantile steamer of which Mr. John had given results, and it would be interesting to see how $D \times \frac{L}{35}$, *i.e.*, $\frac{4{,}940 \times 290}{35} = 40{,}931$, in the case of the "well-decker" would compare with the maximum hogging moments obtained by Mr. Bergstrôm under the seven different conditions mentioned in the paper. Again, Mr. Bergstrôm stated (page 143), "on a review of the whole of these investigations we may conclude that the longitudinal strains are not of any serious character or amount, except when loaded with iron ore stowed in the present manner." It was not however clear that this comparative safety could be claimed for a steamer built of iron. Certainly it was questionable that the limit of safety for iron should be placed as high as 10 tons per square inch. Shipbuilding

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* See Table on next page.

division in the stringer plate, but it was quite possible to amply make up the strength of the part, and that had been done by various expedients. He remembered when ships were built with wooden quarter decks—they showed weakness at this point, but in vessels with iron or steel decks that was obviated. The first bridges put on these ships were very poor structures with open alleyways through them, the side plating was very light, and he thought most of the objection that was raised to well-deck steamers was on account of one or two of them having their bridges stove in, but that was clearly a local weakness which had been quite overcome by carrying up the frames to the top of the bridge and by making the side plating and end of the bridge much stronger. The extension of the bridge to the foremast was almost entirely on account of the freeboard tables brought out by Sir Digby Murray. Some builders had closed in the fore well altogether, he thought that a great mistake. The public have generally looked upon the well as a place where seamen were drowned, but its real use was to prevent the water sweeping along the deck to the midship part of the vessel. If the water came over the forecastle and broke into the well the people standing amidships were perfectly safe and dry. At the worst the well could only be full of water, and when the vessel rolled it would soon be pitched out. The present practice of leaving a well 24 feet long still retained that feature, but if that well was filled in then the water swept right along the deck. The question of stability was a very important one; it was mentioned in the paper that a good many flush deck ships had been lost through shifting cargoes. They found in all calculations they had made that the stability of the flush deck ship was not nearly equal to that of the well-deck ship, and he believed that was almost entirely owing to the difference of freeboard. Some people complained that the well-deck ships were allowed to be loaded too deeply, but if they knew the amount of surplus buoyancy they would see that such was not the case. Take one of the ships Mr. Sivewright had shown in his diagrams, the freeboard at the very least would be 2 feet 3 inches to the main deck, but if the vessel was built as a flush deck ship there would be about 5 feet 6 inches to the upper deck, and the main deck would be 2 feet under water, making a difference of nearly 4 feet between the immersion of a well-deck and a flush deck ship. Now, could anyone imagine that the mere filling in of the well forward and raising the quarter deck 3 feet would be sufficient reason for allowing that ship to load 4 feet deeper? He considered the present freeboard for the flush deck ship was certainly too small, and that now assigned for the well-deck ship was an exceedingly fair one. Mr. Ullstrom in his letter said it was a simple thing to alter the position of the centre of buoyancy. So it is, but if it was put 4 feet further forward it would not only increase the displacement forward but also increase the measurement capacity, and so alter the trim very little indeed with homogeneous cargoes. For a ship to be possessed of good sailing and steering qualities there was a certain position for the centre of buoyancy, and it was not advisable to alter its position as suggested by Mr. Ullstrom.

Mr. WIGHAM RICHARDSON—I just want to know whether in flush deck vessels you take the forecastle and bridge into account in your calculations?

Mr. WITHY—No; we do not, as they are not usually constructed in such a manner as to give buoyancy.

Mr. H. MACOLL said, the view expressed in Mr. Sivewright's paper—that ships were to be loaded whilst lying on the ground—was one that should not be tolerated. It was simply a question, if the harbour or river was not deep enough, for the local authorities to make it so. It was practically impossible to build large ships of a type that would pay carrying ordinary cargoes and lie aground whilst being laden or loaded. He was of opinion if this course was adopted there would soon be such heavy demands on the insurance that they would have to lay their account by a pretty stiff increase in the premiums; and therefore he did not think that grounding should be entertained for a moment. It was the business of dock and river conservators to make their places suitable for the vessels, and not to have ships built to suit the ground. Then about the stowing of the iron ore on board the ship so high up and taking so little of the length of the ship's hold, he was of opinion that this matter must be met and provided for by the shipowner and the shipbuilder. As shown in Diagram F, Plate XXIII., the ore was stowed in comparatively short, high masses, and when the ship was under the spouts, loading ore, it was easily and quickly put on board, and both captain and officers well knew that the higher the cargo was kept the more comfortable and sea-kindly was their vessel at sea. Another matter, the higher the cargo the more easily was it discharged, as the stevedore preferred to work from the bottom and get as much as possible of the material to run into the tubs without shovelling. In some vessels they had built on the Wear they had put in large water-tight doors in the bulkhead between the fore and main holds to work out the ore and load cargoes; and with well-built vessels they found no signs of severe straining so far as he had seen. If the ship did strain then additional strength should be given, as he did not think any amount of discussion or persuasion would get those on board ship to stow the ore any lower down and so spread the weight over a larger area of the bottom. Another thing, by keeping the weight well from the ends the pitching and scending movements of the vessel were considerably reduced, and consequently less racing of the engines. With regard to Mr. Ullstrom's remarks about altering the form of the vessel to get more capacity in a particular hold forward, considering that the ordinary cargo steamers often approached and sometimes exceeded a coefficient of ·8 under deck, it was difficult to understand where the margin was for increasing the capacity, say of the main hold, by filling out the lines forward to bring the centre of buoyancy further forward. In a fine-lined vessel there might be some room for manipulating in this direction. Still, even in fine vessels the capacity of the holds before the engine room was not a primary consideration and did not usually enter prominently into consideration when vessels were being designed. As an episode in the history of the well-deck steamer—some small flush decked colliers were sent out from this district to the Crimean war for conveyance of materials, etc., and owing to several hands being injured when at the wheel in rough weather it was decided to fit a short raised break aft as far forward as the cabin extended in order to raise the platform and afford more protection from heavy seas breaking over the stern; this was found to be very beneficial and was shortly followed by fitting a monkey or anchor forecastle forward flush with the main rail. This arrangement, together with the look-out bridge over a small deck house amidships, might be considered the start of the well-deck. But as the vessels inclined to load by the head, the break aft was made higher and extended forward to permit of more cargo being stowed aft; then the low forecastle forward was found to be inconvenient and uncomfortable, so much water went down the companion in rough weather; to remedy this the forecastle was built entirely above the main deck to the advantage and increase of comfort and safety to all concerned. And thus, step by step, this type of vessel had been improved and developed, so that it can now be said, so far as the requirements for conveying the ordinary merchandise of the country, the well-deck steamer has proved not only to be superior in safety, both as regards the cargo, the vessel itself, and the people on board, but it also can be constructed at less cost, will draw less water and be of less tonnage than a flush deck vessel of the same dead-weight capacity. The great bulk of the flush double deck vessels built, until recently, of such proportions as had already been referred to, 280 × 34 × 24 and also about 260 × 32 × 22, when properly and carefully laden and handled, made good sea boats and fair passages. Unfortunately the exigencies of modern commerce did not always permit of proper, not to say careful, loading. The vessel arrived at an outport and the broker or charterer took full charge, and loaded or misloaded the vessel as it happened to suit his convenience, any remark made by the captain or officers was simply ignored. Even the stevedore did not always know the entire composition of the cargo until a considerable portion had been shipped, the result not seldom being that in heavy weather the ship's people would find the vessel on her beam ends and unmanageable, and so cause the loss of valuable lives and a large amount of property. He firmly believed if a large number of vessels of the proportions alluded to had a well between the bridge and forecastle they would be alive and doing well instead of going to increase the number of mysteriously missing vessels. With the well-deckers the cargoes were carried safely to their destinations, and mysterious disappearances were very rare indeed. Of course so far as stranding and collisions were concerned one ship was pretty much the same as the other. With regard to the web-frames he was of opinion that in after-holds, where they attained a depth of 24 feet or upwards, it would in most cases be an advantage to have a tier of intermediate beams fitted. There was little or no increase in cost fitting beams over web-frames, and with the exception of such cargoes as coal, ore, or nitrate there would be an advantage in having a temporary deck laid to relieve the lower portion of the cargo from the great weight of the cargo above. With many kinds of cargoes of a fragile nature the top weight would be likely to destroy or injure the lower portion, and the temporary deck could be removed when necessary for working bulk cargo. To his mind there was a probable source of danger looming ahead in the long extended bridge style of well-deckers, which was well indicated by the stability curve with the long bridge filled with a homogeneous cargo. The righting lever was growing uncomfortably short; and supposing the lower hold badly stowed or incompletely filled, with the space above main deck quite full, it looked very like getting a considerable way in the direction of the cargo shifting due to the double deck. This tendency should be carefully watched and precautionary measures adopted, including well-fitted shifting boards, and in the case of grain and similar cargoes a liberal allowance of feeders. He did not quite understand Mr. Laing's vessel. Supposing the raised quarter deck was carried right forward, and the main deck beams in their ordinary position, it would be difficult to get about in the confined space, or stow cargo, while if the main deck was dropped or lowered the moulded depth became a sort of imaginary line, and would open the way to many curious departures from ordinary practice.

Mr. LAING—It has a raised main and quarter deck, and the main deck is 7 feet below the quarter deck.

Mr. F. YEOMAN (Hartlepool) asked if he might be allowed to say a word or two from the shipowners' standpoint? He had the pleasure of paying his first visit to the Institution, and this paper of Mr. Sivewright's having a special interest for him was the reason for his coming to Newcastle that night. He had been much interested in the discussion so far as he had been able to follow the arguments. He however had been considering the same question from another standpoint for four or five years past, and he thought the result of his investigations, as to the type of steamer under consideration, should be a matter for justifiable pride to the shipbuilders. He had had to tackle the question from a very serious standpoint, that of loss of life at sea, as some present would be aware. He had inquired at the offices of the Well-Deck Steamship Insurance Association before he left home that afternoon, for fear there might have been a break in the record. That association would complete the *sixth year* of its existence in a few days, and he was pleased to be able to state to that meeting that, with an annual average of about 350 steamers insured with the association, *it had not as yet paid for one "missing" steamer*. As to the how or why it had so come about, that was for naval architects to find out, he merely brought them the bare statement that for six years there had not been a single loss under that particular heading out of the 350 steamers. Seeing that about half of the total loss of life at sea was frequently stated to be in "missing" sailing ships and steamers this was a most remarkable immunity as to the type of vessel in question. In regard to the discussion this proved safety had, by previous speakers, been attributed to increased beam in later years. He submitted that within the 350 steamers referred to, must necessarily be found vessels of varying breadths of beam, as also of different ages. About the year 1870, in this locality, the ordinary well-decked steamer was of about 1,200 tons dead-weight; then, in the next rise—say about 1875—it went to an 1,800 ton ship; in the next, about 1877, to 2,000; and in 1883-4, to what they then looked upon as the maximum, *i.e.*, 2,500 tons dead-weight; but within those sizes, on all fair dimensions, from the year 1883 to the present year 1889, they must have had those well-decked steamers in this insurance association, and, taking all trades open to them, such as heavy or light trades, including Atlantic work, they had done their work exceedingly well. When they remembered the hard work, in the way of cargoes, these steamers had often to do, and the single fact that the ordinary work of a cargo steamer involves about 40,000 miles of steaming every year—subject to all unforeseen, as well as known perils—he thought it would be conceded by this Institution that this was a really marvellous record. He should like to see similar records of the double decked steamers. The long raised poop type of well-decked steamer had been under discussion that night. It had been a matter of thought to him that, of any raised quarter decked ships which he had found tabulated under the heading of "foundered"—say with cargoes of barley, etc.—the long poop vessel (with two decks laid aft) seemed to be first to fail, and he was driven to the conclusion therefore, in the face of facts just previously given, that there was some special danger in the more than one deck laid, and to which naval architects, in the interests of the crews, shipowners, and underwriters, would doubtless give their careful attention. He thought this statement deserved their serious consideration—that on the one hand not one of the 350 well-decked steamers is "missing" for six years. On the other hand (and he had closely searched the "Mercantile Navy List" with every anxiety to deal fairly with this question), he found that, during about fifteen months, ranging from December, 1886, to February, 1888, out of about 469 cargo steamers, 13 were reported "missing." These were all double decked ships, and such comparisons seemed convincing to him that, from *some* standpoint, there was some conspicuously inherent safety in the single decked vessel. Mr. Sivewright had touched upon the matter of shifting cargoes. He (Mr. Yeoman) remembered a letter from the captain of a double decked vessel passing Elsinore, in which he mentioned his ship having a three feet list. He could not get at his cargo, the shifting having taken place below the 'tween decks, but he hoped to reach Cronstadt in safety. Whether the shifting of the cargo was the cause of her loss or not of course no one could say with certainty, but he believed that nothing was heard of that vessel or her crew after leaving Elsinore. He merely took that as an example of the difficulty captains and seamen had in dealing with shifted cargo with more than one deck laid. With respect to iron ore cargoes being carried high in the ship he hardly thought Mr. Macoll did shipowners justice to put it as a question of £ s. d. He thought he ought on behalf of shipowners to resent that. He believed it was altogether because the captain found the vessel more sea-kindly with his cargo high; if such cargo was carried low in a steamer she would about roll her masts out. He wished they had captains members of this Institution who could perhaps supply the practical data which at least one gentleman had asked for that night, say with reference to the behaviour of the vessels at sea and as touching such questions as sea-kindliness, strength, stability, etc. With all respect (and as only a landsman) he submitted that 4,000 tons dead-weight, with a single deck, might be a serious enough test, and especially with certain kinds of cargo this would be a matter for careful watching in the future. To the question of beam he was glad to note that in new steamers special attention was being given. He sincerely trusted naval architects would keep their eye on the question of stability—he feared the special weakness with double decked ships. He thought his remarks might be thus summarised: that somehow—he believed in the matter of stability—the single decked ship was inherently a safe type of ship, but the larger vessels might need attention to be given as regarded strength. It was no doubt possible for naval architects to provide sufficient strength if owners would pay for it, even with a single decked vessel and of extreme size. But it might hereafter be found that for these larger vessels a backbone of strength in the shape of a second deck laid was a necessity. Much of the life loss of the double decked vessels might of course be the result of wrongly distributed weight in the ship, from faulty trimming or the settling and shifting of cargoes. In any case, with vessels having more than one deck laid, he asked them, not only as regarded new vessels, but also in the interests of those navigating even the vessels at present at sea, that anything which they could do from a naval architect's point of view should be done to bring those vessels upon an equality as to immunity from serious life loss with the other once maligned but now admittedly safe type of steamer.

Mr. SCHOLEFIELD thought Mr. Yeoman had covered nearly all the ground he would have gone over had he spoken earlier. As to shipowners now speaking, they came there to learn, and before such a scientific body as this it was difficult for shipowners to argue many of the questions raised, but one of the most interesting features in this paper of Mr. Sivewright's was that it dealt with the whole question more from a shipowner's point of view than the papers usually read before this Institution. Mr. Sivewright dealt with it very much from the point of view of money-earning power, and it occurred to him (Mr. Scholefield) on hearing the paper read that its main feature was that it showed in altering from the flush deck to the well-deck ship not only was a type of vessel constructed which was more profitable to the owner, but also was a safer ship, and that he thought was certainly a remarkable factor, for it did not at all follow that a ship which gave greater earning power should combine greater safety. The Board of Trade had not believed that these ships combined greater earning power with greater safety, and it took years for the officials to learn from actual experience that what was asserted by builders and owners was actually correct, and now the Board of Trade admitted all that was asked for the raised quarter deck vessels. He did not believe, however, that the entire improvement arose merely from the substitution of the raised quarter deck for the flush deck, but because coincident with this change of type the dimensions and form of steamers had been much improved. He would illustrate what he meant by an analogy if they would allow him. After they got free trade it used to be believed that all the advantages accrued to the country merely from the abolition of the duty upon corn, and it was only recently that certain people would admit that the introduction of railways, steamships, telegraphs, etc., etc., had something to do with the increased prosperity of the country. So with this well-deck type nothing was said as to the improved dimensions, and he believed if the raised quarter deck ships had been constructed upon the same dimensions as many of the flush deck ships long, lean, and deep, the record would not have been as striking as Mr. Yeoman had quoted that evening. But when these ships were built with more beam and less depth in comparison to the length they had at once a more sea-kindly and safer type of vessel. They had heard something of this extension or lengthening of the bridge. It seemed to him that would never go far in vessels under 2,000 tons burthen. The extension of the bridge to the foremast was not adapted to vessels carrying deck cargoes. It was interesting to hear Mr. Sivewright say that the extension of the bridge did not add to the safety of the ship, as most of them had believed that it would do so. Another point mentioned was that in regard to web-frames and also the introduction of much larger plates. These large plates had one objection: that if damage occurred to one of them the whole plate was condemned, and underwriters would have, perhaps, something to say on the subject of extra cost of repairs. He was sure the shipowners were indebted to any gentleman like Mr. Sivewright who took so much care and attention in bringing before them improvements in the type and design of steamers, advantages which would at all times receive the earnest attention of owners, who were desirous of securing the benefit of all the practical improvements that the naval constructor could supply.

DISCUSSION ON MR. BERGSTRÔM'S PAPER.

Mr. MACOLL said he had after hearing Mr. Sivewright's very interesting paper almost entirely forgotten Mr. Bergstrôm's paper and anything he had to say upon it. One matter referred to at their last meeting was as to the allowance or percentage for rivets that had been made in the calculations. Now this was a very important matter, especially considering the steel scantlings were taken in the paper as being equal to iron. The riveting they all knew in the butt straps of steel ships was considerably increased and closer pitched than in iron vessels by Lloyd's recently, and consequently as a matter of tensile strength the pulling asunder when the wave crest was amidship would be more easily performed than if the rivets were spaced somewhat further apart. The riveting was a most important factor, and when they found experts in calculations of strengths of vessels differing as to the amount to be allowed for rivets or rather rivet holes from 7 per cent. to 22 per cent. there was a considerable margin to reconcile, and being such a prominent feature in the calculation he thought it should be clearly stated and would facilitate comparison. The paper on the whole was a splendid contribution to their transactions, and must have entailed a very large amount of labour in working out.

Mr. T. MILLAR said he thought Mr. Bergstrôm's paper was hardly receiving the attention it demanded, and he was sure that they would agree with him, if they took into consideration the direct bearing it had on the design of vessels, affecting, as it did, the freeboard, stability, structure, etc. Anyone, who had gone into the question at all, and knew the amount of time required to work up the necessary calculations for the production of a set of diagrams such as Mr. Bergstrôm had placed before them, would not allow this paper to pass without taking some notice of it. Although a paper of this description required a great deal of time to get up there was a considerable amount of pleasure derived in seeing the results of one's work placed before them in a graphic form. There were many different phases of the subject which might be discussed with advantage. Although papers on the same lines had been read before several institutions on various occasions he thought the auther had opened up new ground in dealing with the well-deck type of steamer. As this class of steamer seemed to be growing in favour it must be satisfactory to those interested, to learn from the diagrams before them and the results given by the author that they have ample strength to meet any strains to which they are likely to be subjected. At the same time he would like to point out that the published results of calculations of this kind giving strains on upper works, etc., for vessels afloat at the present day were very meagre, but not quite so scarce as information derived from actual practice. He only knew of one or two cases in which any attempt had been made to ascertain the straining of a vessel at sea. He believed the author intended to give them the results of his calculations in tabulated form.* If so, they would be of practical use for purposes of comparison. It seemed to him that so far this was the only use to which they could put information of this kind. The author states that in the vessel with which he is dealing the greatest tensile strain is 4½ tons on the raised quarter deck plating, the vessel being loaded with homogeneous cargo and bunkers nearly full; he however gives no information relative to the strain on the upper works when the bunkers are nearly empty. This must necessarily be greater. In the paper read by the late Mr. Mavor and himself, before the Institution in 1885, the results of their investigations in two different types of vessels carrying the same dead-weight showed, that in a three-decked ship fully loaded and the bunkers full, the tensile strain on the gunwale was 3·382 tons and with bunkers empty 4·014 tons; and for a spar deck ship loaded and bunkers full 3·482 tons, bunkers empty 4·168 tons. The limit of safety of 10 tons which the author gives seemed to him rather high. He knew that there were ships afloat with a factor of safety of three, and although these vessels had been doing their work for years he did not think that it would be very safe to take this as a precedent. To show the variation there is in the strains in different sizes of vessels, Mr. John in a paper which he read before the Institute of Naval Architects in 1874, gives the result of some of his calculations upon steamers from 100 to 3,000 tons. In the vessel of 100 tons the maximum tension on upper works was 1·67 tons, increasing in the 3,000 tons vessel to 8·09 tons. This tended to show that the tension on upper works of vessels over 400 feet long must be somewhere between 8 and 9 tons. If this was correct the limit of safety given by Mr. Bergstrôm for his vessel would certainly never be reached. Dealing with a subject of this kind, with longitudinal strains only, one was apt to lose sight of the transverse and other strains to which a vessel may be subject at the same time. With a vessel on a wave crest or wave hollow, sitting perfectly upright in the water, the calculations were all right, but whenever the vessel heeled over the tensile strain on the higher side was immediately increased. At the same time, for

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* See page 146.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIFTH SESSION, 1888–89.

PROCEEDINGS.

SEVENTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LIBRARY, FAWCETT STREET, SUNDERLAND, ON WEDNESDAY EVENING, MARCH 13TH, 1889.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on Monday, February 11th, which were approved by the members present, and signed by the President.

THE PROPOSED GRADUATES' MEETINGS.

The **PRESIDENT** said, the first point that occurred to him in regard to the minutes just read was that relating to the Graduates' section, and the suggestion that they should form a class for meetings for the study and reading of papers and discussion. He might say that Mr. Macoll and himself met the very few Graduates who came up on the occasion of the meeting they appointed. There were, he thought, four who came, and necessarily, he might say, nothing was done but to defer the question to an adjourned meeting, to be held on some future date, when he hoped their young members would come forward in large numbers to form themselves into a Graduate section. Probably the last time was a little inopportune; there were exciting meetings going on in Newcastle that week, and some of them might be there; but he was quite sure the formation of such a section would be a very valuable adjunct to that Institution, and, he thought, of very great service to many of their younger members.

THE FURNISHING FUND.

The President said, he should also like to once more call their attention to the subscription fund towards the furnishing of their new rooms in Newcastle. These offices and rooms had been found to be really necessary on account of the large number of documents and magazines forwarded to them from many other scientific societies, which were accumulating about Mr. Duckitt's office, and it was scarcely right to expect him to provide accommodation. They had taken the rooms, and furnished them at an expense of something like £160. About £75 towards this fund had been subscribed by Sunderland and Newcastle members. He was glad to say that at their last Council Meeting Mr. Fothergill, of Hartlepool, who was always ready to do what he could towards advancing the general interests of the Institution, produced a list of subscriptions from the Hartlepools amounting to £32 10s., which he had himself collected. If others were to aid them in the same personal and direct manner this would be an extremely flourishing Institution, and a practical and profitable centre. There was still something like £50 or £60 wanting, and Mr. Duckitt would be glad to receive contributions from the members towards the liquidation of this little debt. He was sure if they would take the trouble to call at the offices, No. 4, St. Nicholas' Buildings, Newcastle-upon-Tyne, they would be much pleased with the rooms, and members coming over from Sunderland or Hartlepool might find them very useful. He hoped they would take it seriously to heart, and get this £50 or £60 wiped off. He was also asked by the Secretary to call their attention to the fact that they had taken another room in connection with their new offices, which would give increased valuable accommodation for the reading room.

COUNCIL PROPOSALS—A WHITSUNTIDE VISIT TO THE FORTH BRIDGE, Etc.

He should now mention two or three items that came before the Council at its last meeting. There was first the notice of withdrawal of Mr. R. S. White from the Council. Mr. White, as many of them knew, had occupied the position of manager of Messrs. Sir W. G. Armstrong, Mitchell, & Co.'s Shipyard, Low Walker. He had now gone to take the management of the Fairfield Company at the request of the late Sir Wm. Pearce. The Council had appointed Mr. Thos. Millar to take his place.

The Council had also decided to arrange for the whole of the Institution to visit the Forth Bridge at Whitsuntide. He thought they would all agree with him that this was a great work and well worthy of a visit from an institution of this kind. They would, he was sure, all be benefited, and Whitsuntide had been selected as a convenient holiday for everybody. He did not think it could be more profitably spent than in a visit to the Forth Bridge. The visit would probably be arranged to take place on Tuesday, June 11th. He wished to call their special attention to this proposal. They had thought of going last year, but as only twenty-four members out of the Institution fell in with the proposal it was abandoned.

He ought to mention, although it was not intended to take any action upon it that night, it was the intention of the Council to suggest that the number of Vice-Presidents should be increased from six to nine, and three would retire each year instead of two as hitherto. This was merely for their consideration; the question would come up for decision at the May meeting. The intention of this alteration was to secure as Vice-Presidents of the Institution a larger number of gentlemen with local influence to aid the Institution. It was noticed at the last election that one connected with this neighbourhood, whose influence would have been valuable, was lost by the present restriction.

THE BALLOT FOR NEW MEMBERS.

The ballot for new members having been taken, the President appointed Messrs. J. Tweedy and J. P. Hall to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Cowan, M., 22, Clarendon Terrace, South Shields.
Reynolds, Charles H., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Low Walker.
Summers, James, 114, Grange Road West, Middlesbro'.

ASSOCIATES.

Tweedy, George, Gresham House, Bishopsgate Street, London.
Young, William M., Osborne Road, Newcastle-upon-Tyne.

GRADUATES.

Hilbert-de-Mattos, James, c/o J. Dickinson, Esq., Palmer's Hill Engine Works, Sunderland.
McRobie, Frank, Westmorland Terrace, Newcastle-upon-Tyne.

The adjourned discussion on Mr. Bergstrôm's paper "On the Structural Strength of Cargo Steamers" was then resumed; also the adjourned discussion on Mr. Sivewright's paper on "The Development of the Well-Deck Cargo Steamer," after which Mr. J. B. Dodds read a paper on "Corrosion and Pitting in Marine Boilers."

ADJOURNED DISCUSSION ON MR. G. BERGSTRÔM'S PAPER.

The **PRESIDENT** said he was afraid he had made a mistake at the last general meeting in Newcastle when he arranged to take the discussion on Mr. Sivewright's and Mr. Bergstrôm's papers together. He found practically nearly everyone spoke on Mr. Sivewright's paper. They would resume the discussion on these papers, but separately, and take Mr. Bergstrôm's first.

The **SECRETARY** intimated the reception and was asked to read communications from Mr. L. Piand, of Paris, and Mr. A. R. Liddell.

COMMUNICATION FROM MR. L. PIAUD ON MR. G. BERGSTRÔM'S PAPER "ON THE STRUCTURAL STRENGTH OF CARGO STEAMERS."

Mr. G. Bergstrôm's interesting paper "On the Structural Strength of Cargo Steamers," of which I have received a copy, has induced me to lay before the North-East Coast Institution the results of some calculations of the same kind which have been carried on at the Central Technical Office of Bureau Veritas, in order to ascertain the longitudinal strains to which vessels of different types are exposed at sea. I venture to hope these calculations may be of some interest to the Institution.

The method followed in that research was the same as that described by Mr. Bergstrôm. Each vessel was considered as resting in equilibrium —1st, in still water; 2nd, on the crest; and 3rd, in the hollow of a trochoidal wave whose length is exactly that of the ship, and whose depth, measured between crest and bottom, is equal to $\frac{1}{20}$th of its length.

The weight and displacement of every section of the vessel having been calculated, the curve of loads—*i.e.*, of the differences between weight and displacement—was drawn, then the shearing forces and bending moments were derived from it by integration. The latter were afterwards compared with the moments of resistance of different sections, so as to have an idea of the strains on various points of the vessel's length. This was at least done for vessels Nos. 1 and 8 (see table). As the most

To illustrate "Mr. I. Piaud's Communication on Mr. G. Bergstrôm's Paper."

FIG. I.

FIG. 1A.

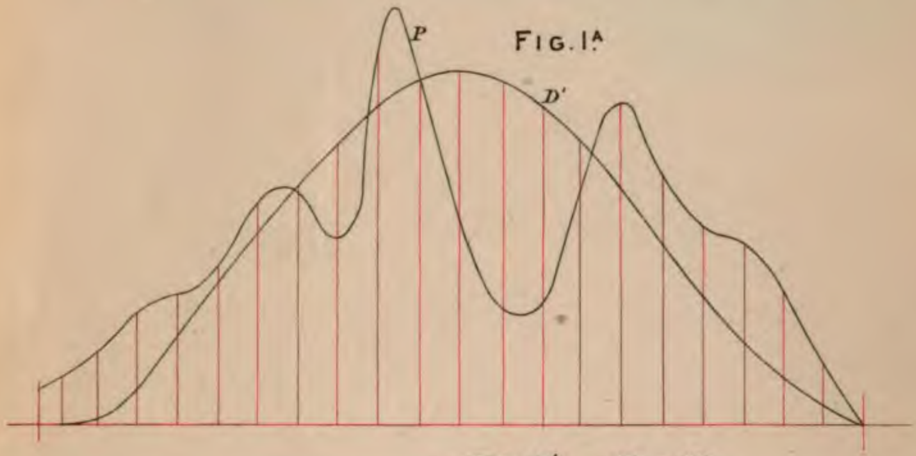

FIG. 1B.

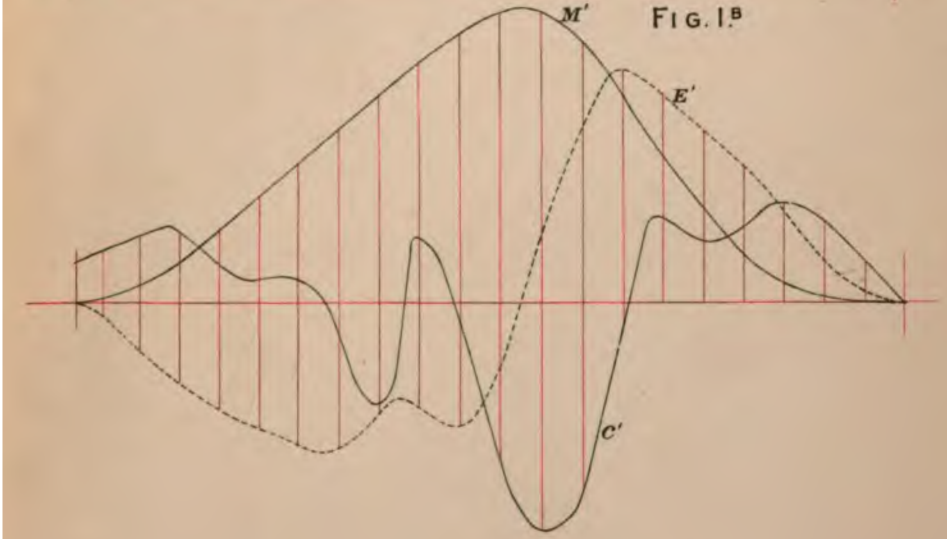

FIG. 1C.

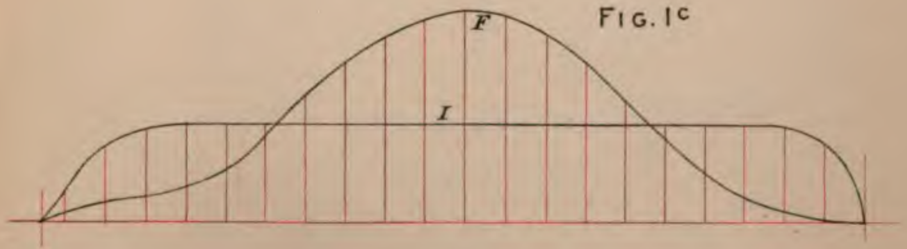

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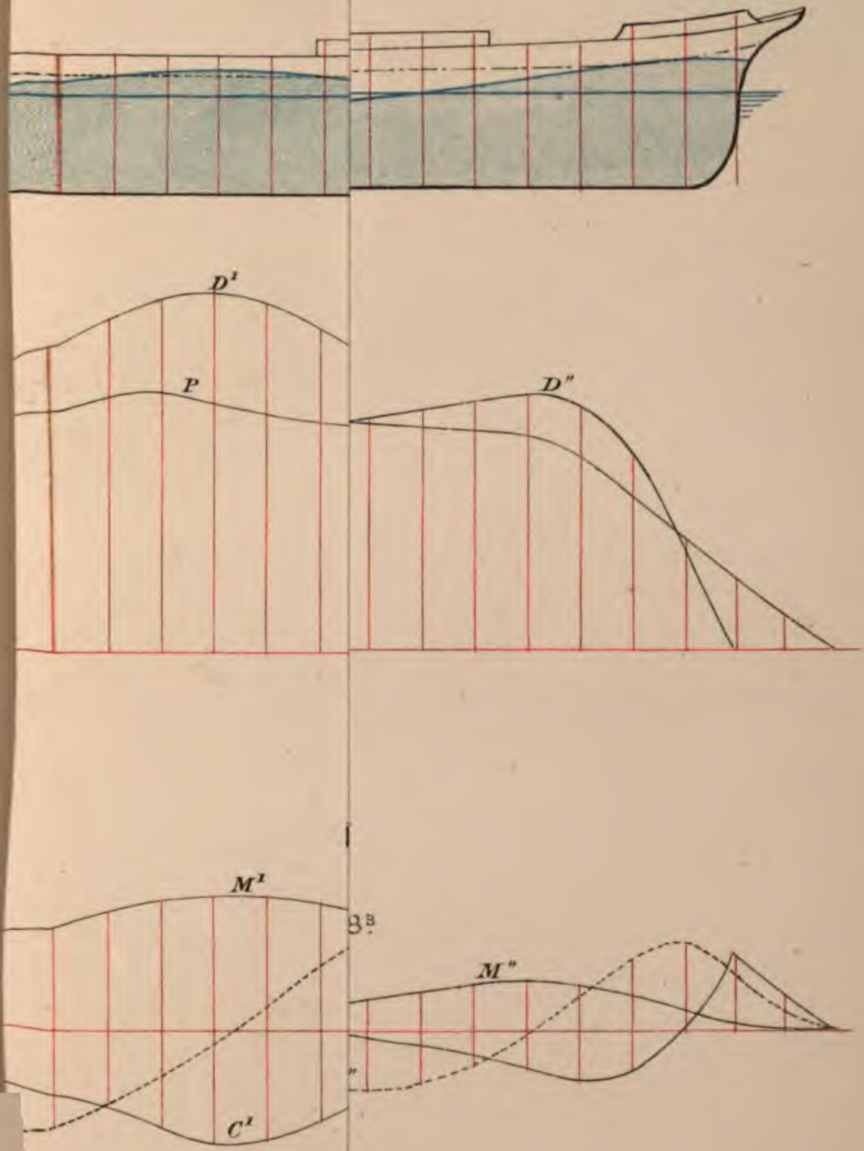
FIG. 7.



To illustrate "Mr L. Piaud's Communication on Mr G. Bergström's Paper."

FIG. 9.

FIG. 9.A

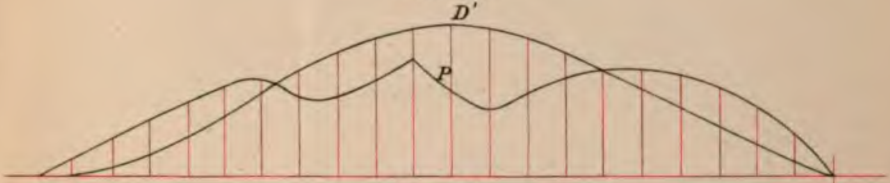


FIG. 9B.

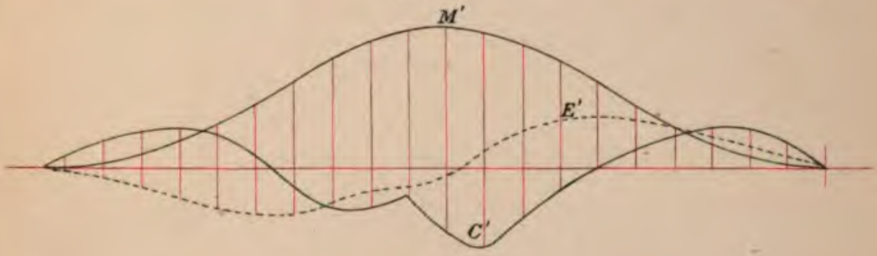


FIG. 9C.

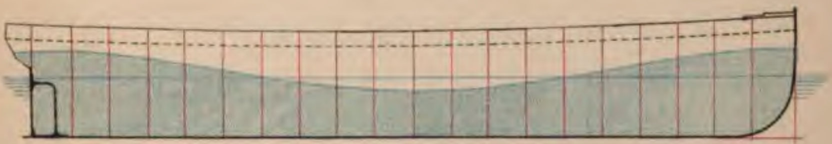


FIG. 9D.

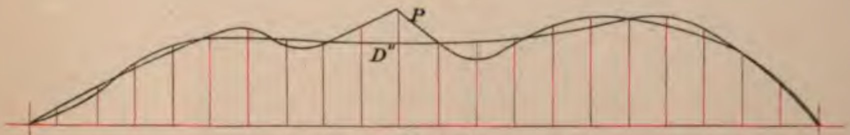
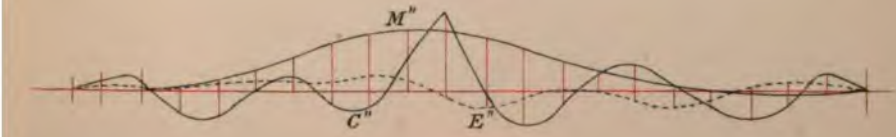


FIG. 9E.



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o Illustrate "Mr L. Piaud's Communication on Mr G. Bergström's Paper."

FIG. 10.

FIG. 10A.

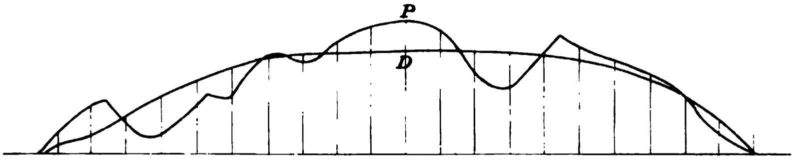
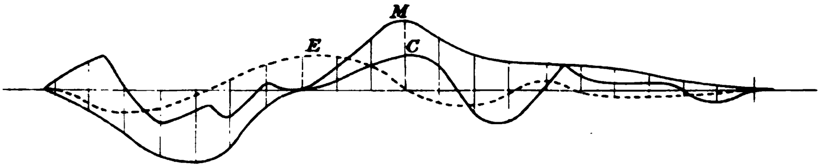


FIG. 10B.



ÔM'S PAPER.

	Des	nce ion.	Maximum Stress in Tons per Square Inch.		Range between the Maximum Tensile and Compressive Stresses in Tons per Square Inch.		Reference to Diagrams.
		nal ns.	Compressive Stress.	Tensile Stress.	At Deck.	At Keel.	
1	Spar deck st	369 369 912	Keel 0·629 Keel 3·283 Deck 2·451	Deck 0·646 Deck 3·460 Keel 2·324	5·911	5·607	Fig. 1, Plate XXIX. Fig. 2, Plate XXX.
2	The same, w weight.	369 912	Keel 3·486 Deck 2·794	Deck 3·683 Keel 2·660	6·477	6·146	
3	The same, w weight.	369 912	Keel 3·054 Deck 2·286	Deck 3·225 Keel 2·165	5·511	5·219	
4	The same, wi	369 912	Keel 2·578 Deck 2·038	Deck 2·724 Keel 1·930	4·762	4·508	
5	The same, w and draugh	369 912	Keel 3·289 Deck 1·600	Deck 3·473 Keel 1·517	5 073	4·806	
6	The same, w and draugh	369 912	Keel 3·418 Deck 2·521	Deck 3·645 Keel 2·387	6·166	5·835	
7	The same. in to an angl	02 766	Keel 4·426 Deck 2 864	Deck 4·045 Keel 3·130	6·909	7·556	
8	Transatlantic normal car	968 968 206	Keel 1·537 Keel 5·886 Deck 4·508	Deck 1·689 Deck 6·483 Keel 4·096	10·991	9·982	Figs. 3. 4, Pl. XXXI. Figs. 5, 6. Plates XXXI. & XXXII.
9	The same, wi	968 206	Keel 5·493 Deck 4·496	Deck 6·045 Keel 4·083	10·541	9·576	
10	The same, w weight.	968 206	Keel 5·690 Deck 4·502	Deck 6·267 Keel 4·089	10·769	9·779	
11	The same, w weight.	968 206	Keel 6·070 Deck 5·131	Deck 6·680 Keel 4·661	11·811	10·731	
12	Sailing vesse	137 422	Keel 2·597 Deck 0·463	Deck 3·454 Keel 0 349	3·918	2·946	Fig. 7, Pl. XXXII. Fig. 8, Pl. XXXII.
13	Steamer, wit normal car	944 238	Keel 2·038 Deck 0·209	Deck 1·956 Keel 0·222	2·165	2·260	Fig. 9, Pl. XXXIII.
14	River boat, w	141	Keel 1·784	Deck 2·857	...	...	Fig. 10, Pl. XXXIV.

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interesting result is to know where the maximum strains lie, and what their magnitude is, the midship section alone was considered in other cases.

The cargo was always supposed to be homogeneous.

Vessel No. 1, about which very complete information was in my possession, was examined under various circumstances, and gives a valuable series of results as to the changes which may take place in the working of a ship at sea, according to the state of her cargo. The effect of rolling may also be seen in the annexed table, under No. 7. For the latter purpose the moment of resistance of the midship section was calculated when assuming the vessel to be inclined to an angle of 15 degrees, and compared with the maximum bending moment, which was found not to vary from the upright position. The same vessel was also supposed to retain her original midship section and draught of water, and to have the finest possible shape at ends, and again the fullest form which may be met with in practice, the scantlings remaining the same in both cases.

The results laid down in the annexed table, and diagrams on Plates XXIX. to XXXIV., speak for themselves; but unfortunately they are not so numerous as to allow of a definite conclusion being drawn from them. Still, I hope they may be usefully collected and compared with the results of similar calculations on other types of vessels.

I would mention, as being worth notice, the values of the ratio—

$\frac{LD}{M}$ (length × displacement, divided by the maximum bending moment), which it has become customary to employ for checking the structural strength of a vessel. It will be seen from the table that this coefficient is nearly constant on a wave crest, and its value inferior to what it becomes in a wave hollow; it is smaller, which corresponds to a heavier hogging moment, for *steam vessels* with very fine lines and reduced cargo (cases Nos. 5, 9, and 10), as was to be anticipated owing to the extremities of the vessel being very little supported in that position.

The sagging moment in the wave hollow is a good deal less than the hogging moment on the crest. It is especially so in the case No. 13, referring to a steamer with little horse-power and very large cargo holds at both ends; and also in the case No. 12, from which it may be inferred that sailing vessels, owing to the absence of machinery, may be constructed with lighter scantlings in the bottom than steamers.

It is useless to mention the strains in still water, which are always very small.

L. PIAUD,
Inspector-General of Bureau Veritas.

Paris, February 13th, 1889.

Communication from Mr. Arthur R. Liddell.

Mr. Millar, at the last meeting, alluded to some experiments on strains undergone by vessels during launching and in a seaway, made some nine or ten years ago by Mr. Stromeyer of Lloyd's. I was present at some of these which were made during the launch of a vessel at Jarrow, and some details of them may be of interest to the meeting.

Wires about 10 or 12 feet long were fixed in a fore and aft direction in different parts of the vessel, on the floor, at the top sides, and about half-way up. They were attached to small clamps on the floors or frames, as the case might be, and stretched tight. About half-way along each wire was interposed a strong spring actuating a pointer on a circular graduated dial. The apparatus used was not self-registering, and the movements of the pointers had to be watched and noted down at each point during the vessel's launch, that is, at starting, when taking the water, when leaving the ways, etc. The system had not, I believe, been tried before; and owing to the ship going off somewhat sooner than Mr. Stromeyer expected he did not succeed in taking many observations, but enough was done to show that the measurement of actual strains was perfectly feasible, and the subject was afterwards allowed to drop, only because neither Lloyd's Committee nor the shipbuilders seemed to take any interest in it.

The same gentleman invented an ingenious little instrument, in appearance something like a microscope, for measuring local strains on individual plates of ships or boilers. It was then in its experimental stage (I believe it was subsequently further developed); but it was so far matured that the relative intensities of strains in different parts could be observed through it. With its principle I am unacquainted, but on applying it to a flat surface undergoing strain, one saw a succession of lines move across the glass, the number of which increased with the intensity of the strain. During a sea voyage it was found, for instance, that the strain on a shell plate just under a butt was greater than that on the same plate a space or two further along, and similar relative intensities were successfully noted at other parts.

Mr. Bergström has promised to return to this subject in a future paper, and as it is one of much importance and increasing interest to shipbuilders, I hope he will do so at an early date, and I should like to suggest that Mr. Stromeyer be then invited to attend and take part in the discussion.

Arthur R. Liddell.

Mr. **Bergstrôm**, in reply to the discussion, said, first as to Mr. Arnison's remarks, that gentleman said that: "Looking at the various diagrams, he could not help thinking that a set of tables showing the analysis of the paper would considerably increase the value of the same." He quite admitted that such a table was very useful as a comparison with other vessels, but as he had no similar calculations of other types to compare the results with, he could not see the necessity of such a table until the paper was completed or the straining on vessels of similar dimensions, but different types, were investigated. In the meantime a table of results of that part of his paper read at the meeting in January last would be found on page 146. Next, Mr. Arnison asked "Why was not the actual scantlings of the vessel used in the calculations?" This question was simply owing to a clerical error in the manuscript, where the words steel and iron had been reversed, and he was sorry he did not notice it in time. All the scantlings of the vessel used in the calculations were the actual steel scantlings with the exception of the bridge deck plating and the keel flats, which were of iron, but treated as steel in order to make it a steel vessel in every respect. The error would be put right in the Transactions.* A third question was whether the comparative safety was of iron or steel vessels. Certainly it was of the steel steamer treated in the paper, and he did not think the limit of safety as put at 10 tons per square inch for steel exaggerated. Mr. Arnison also asked about the allowance for rivet holes. This was done in the usual manner. In the case of tension—say on the upper deck gunwales—a deduction was made for the rivet holes in the uppermost part of the structure, treating the remainder as solid plate. The process was reversed in the case of compression. This was done for several sections along the vessel and corrected curves laid off. The corrections for rivet holes are hardly worth the trouble, and had it not been for the mere matter of form would not have been mentioned in the paper. In reply to Mr. Millar, he (Mr. Bergstrôm) intended to carry out the calculations in accordance with the heading of his paper comprising the principal types of cargo steamers. He hoped at the same time to be able to show the effect of a change from the upright to the inclined position.

The **President** said, he thought they were very much indebted to Mr. Bergstrôm for the great trouble he had taken in preparing this very interesting paper, and he hoped that Mr. Bergstrôm would continue the subject and bring it before the Institution at an early date. He thought they might further say it was a matter of very great interest to see it

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* The paper as printed is correct.—Editor.

excite so much attention as to draw forth the very valuable communication of Mr. Piaud, Inspector General of Bureau Veritas. He (the President) proposed a hearty vote of thanks to Mr. Bergström for his very valuable paper.

The vote was carried by acclamation.

ADJOURNED DISCUSSION ON MR. SIVEWRIGHT'S PAPER.

Mr. J. R. FOTHERGILL, West Hartlepool, re-opened the discussion. They were much indebted, he said, to Mr. Sivewright for his very able paper. Being an engineer, he (Mr. Fothergill) felt considerable diffidence in taking part in the discussion; however, it was not his intention to criticise the structural strength of steamers, nor yet did he propose to enter upon the important question of cubical capacity of the holds. He wished more particularly to confine his remarks to the extraordinary innovation taking place in the well-deck steamer proper. Mr. Sivewright pointed out, that in order to obviate the difficulty in trimming the early flush deck steamers, the long full poop was introduced (Fig. E, Plate XXIII.), but this added more capacity than was required, and therefore a compromise was effected by what is known as the raised quarter deck and covered in bridge type (Fig. F, Plate XXIII.) which constitutes the well-deck steamer proper. The Hartlepools had undoubtedly been the great champions and builders of this particular type of steamer. When the Board of Trade and Lloyd's tried to crush this steamer out of existence by assigning an absurdly large freeboard, was it not as conclusively proved to them that the well-decker was beyond all doubt not only the most suitable but the safest steamer afloat? One of the principal modes of comparison was to show, that a steamer built to the "Three-Deck Rule" (Lloyd's) had an infinitely more favourable freeboard assigned relative to the deadweight carried than had the well-decker, although the well-decker showed such exceptional immunity from loss as compared with a steamer built to the "Three-Deck Rule." The Board of Trade and Lloyd's accepted the evidence placed before them, and it might be in the recollection of many here present that Mr. Martell stated at the Hartlepools' meeting—"He believed the well-deck steamer to be the safest steamer afloat." The weighty evidence that was the turning point of the Load Line Committee, Board of Trade, and Lloyd's was from statistics compiled by Mr. Yeoman—who spoke at the last meeting—and he (Mr. Fothergill) said with his authority that those statistics were founded on the early type of well-deckers shown by Fig. F, Plate XXIII., *i.e.*, the raised quarter deck, covered in bridge ending a little forward of the stokehold bulkhead and the raised forecastle. Now, what he (Mr. Fothergill) wanted to know was this:—Why, after all this anxiety, worry, and trouble to prove the wonderful efficiency of the well-decker, they were now doing their best in the shortest possible time to obliterate it out of existence? First, they raised a short poop aft, then extended the bridge forward, so continued extending the bridge till they had only a "gap" left between the bridge and forecastle, and there was one steamer now building in which this "gap" was to be covered in by an awning deck. He was somewhat curious to know what she would be called, surely not a well-decker? The production of this new type of steamer appeared to him to be inconsistent with Mr. Sivewright's views of an ideal steamer, *i.e.*, a steamer that would have both holds of the same cubical capacity, fill herself with homogeneous cargo and be in trim, and Mr. Sivewright had told them the steamer he shows (Fig. F, Plate XXIII.) does this. Again, Mr. Sivewright had told them the full poop steamer gave too much capacity aft, and that the raised quarter deck just met the essential capacity necessary to safety and commercial success. Would Mr. Sivewright say how he was going to fill this covered in well and maintain the trim? Did not this covering in of the well add to the dead-weight and register tonnage? So far as he gathered from the paper, Mr. Sivewright's answer to this extraordinary incongruity was that the present so-called improved extended bridge type of well-deck steamer was designed to take the greatest possible advantage of the Load Line Committee's tables. As to the wisdom of such a course the future would tell. Well, he supposed in the general course of things they would go on improving, and as they had already improved the forward end by covering in the "gap" with an awning deck, which they might soon expect to find permanently closed in, they should have to turn their improving attention aft, and level up the raised quarter deck and so join poop and bridge; another small step and they had the flush deck steamer, which, it was asserted, had been shown to be incomparable for efficiency and safety to the well-decker proper. How was it the well-decker had proved such a safe steamer, wherein was her special virtues? Certainly not in having the well, but he should say—and he had had some experience in them—that the secret lay in the happy proportion of beam to depth of hold, and that they fairly filled themselves with homogeneous cargoes, carried dead-weight cargoes in the best possible position relative to the centre of gravity, and that they had no 'tween decks. Of course he alluded to the well-decker proper, for some of the so-called improved shallow draught well-deckers rolled unmercifully and caused considerable straining, and therefore must necessarily require stiffening and strengthening. Did Mr. Sivewright agree with him in this explanation? Would he explain as a naval architect why a flush deck steamer if properly proportioned in beam to depth, and capacity of holds arranged to give the desired trim, why she would not be as safe and commercially as efficient as the well-decker, and more particularly so as to the so-called improved type of well-decker? This occasion appeared to him to offer a fitting opportunity to draw the attention of the Institution to the grievous mistake they were making in the scientific and technical education of their young men. He would suggest that the President of this Institution represent to Professor Garnett, Principal of the Durham College of Science, Newcastle, that instead of establishing a Chair of Naval Architecture, a chair should be established to teach and show how to manipulate to the best commercial advantage, Lloyd's Rules, the Board of Trade requirements, and the Load Line Committee's tables.

Captain PETERSEN, Hartlepool, said, Mr. Sivewright, in his very interesting paper on "The Development of the Well-Deck Cargo Steamer," explained the reasons why such a class of vessel was introduced. He stated that a ship was wanted in which the cubical capacity of the after-hold was equal to the cubical capacity of the fore-hold, and that the raised quarter deck ship was expressly designed to meet this want. When they, however, remembered that the early built well-decker, of moderate size, had, as a rule, one hatch to her after-hold and two hatches to her fore-hold it was difficult to understand how such a division could have been desirable if dispatch in discharging was considered. Messrs. Herskind & Woods, West Hartlepool, the firm he had the honour to serve, managed a fleet of steamers, of which fifteen were well-deckers, built in West Hartlepool, Hartlepool, and Stockton, the first in 1871 and the last in 1888, and no doubt these ships fairly represented the practice of builders at the time they were built. In the earliest of these ships—the "Dania," built in 1871—the fore-hold had a cubical capacity 59 per cent. larger than her after-hold. In the "Cornelia," built in 1872, the fore-hold had a cubical capacity 54 per cent. larger than the after-hold, and in the "Hecla," built in 1874, the fore-hold had a cubical capacity 35 per cent. larger than her after-hold. From these figures it appeared that the division of the ship's cubical capacity in two equal holds was not the aim of the early well-deckers. These three boats had, when loaded with a homogeneous cargo, and in trim, room unoccupied in their fore-holds for not above 10 tons of cargo, and were, from an owner's point of view, as near perfection in this respect as could reasonably be expected. In the later built ships—the "Hilda," built in 1880—the fore-hold had a cubical capacity 9 per cent. larger than her after-hold, and in the "Brenda," built in 1881, the fore-hold had a cubical capacity 6 per cent. larger than her after-hold. But these two boats had, when loaded with a homogeneous cargo, and in trim, room unoccupied in their after-holds for about 40 tons of cargo. From these figures it appeared that although a steamer's cubical capacity was divided in two equal holds, it did not therefore necessarily follow that she would be in trim when filled with a homogeneous cargo. Mr. Sivewright's next argument in favour of well-deckers was sea-worthiness, or the immunity from shifting their cargoes, enjoyed by them, and to impress this more strongly upon them, he gave an illustration (Fig. D, Plate XXII.). Now, the tendency to shift, for instance a grain cargo in bulk must necessarily be the same in all single deck ships, whether flush or well-deck, provided always, of course, that their dimensions are equally stable. In a double deck steamer the bulk cargo of grain was carried under precisely the same circumstances as in a single deck steamer, either flush or well-deck. Shifting boards and grain feeders of 2 per cent. capacity were fitted in all of them, as per the Grain Act, and as the Board of Trade when fixing this 2 per cent. capacity naturally had a margin of safety they might assume that a grain cargo in bulk might settle about 1 per cent., and with a ship safely loaded there was little, if any, danger in this. As for the bag cargo carried in a ship's 'tween deck, he need only remind them that hundreds of bag cargoes were brought annually from the East in all types of ships, but he was not aware that any of them had come to grief through their cargoes shifting. A bag cargo did not, as a rule, shift in a ship properly and safely loaded. In connection with this Mr. Sivewright says there is good reason to suppose that a large number of 'tween deck steamers were lost through no other cause than the shifting of their cargoes; but authorities on the subject had not yet agreed upon a reason why those steamers were lost. Some thought their loss due to the act of God, others thought the Board of Trade had neglected their duty; some blamed the ships and others the stevedores, and there were even people asserting that owners were not in all cases free from blame. His opinion was that those steamers were not lost because they were 'tween deck steamers. In comparisons between the different types of steamers to show their relative sea-worthiness no account had, as far as he knew, been taken of ships lost through preventible causes. Assuming, for instance, a steamer was lost, and it was afterwards proved that her loss was due to being grossly overladen, or assuming another steamer lost, narrow and deep, and loaded with barley, for instance, and it was proved her loss was due to want of stability, then he considered both losses preventible. Surely the type of ship had nothing to do with these losses, and he submitted that such cases should be excluded from comparisons for sea-worthiness, if such comparisons are to be relied upon. The reason of the success of the well-deck cargo steamer was, he thought, very concisely stated by Mr. Martell at the West Hartlepool meeting last year, when he said, "the well-deck cargo steamer had solved the problem of carrying a ton of cargo a given distance at the least cost." The well-deck steamer was cheaper to build, she was cheaper to work with grain cargoes in bulk than a 'tween deck steamer, and she had certainly proved herself—when of moderate dimensions—as seaworthy as any other type of ship, and for these reasons was deservedly in favour with owners. As for the large well-deckers carrying, say 4,000 tons dead-weight or more, it seemed to him that they must in time develop into spar or awning deck ships if they were to carry iron ore or other heavy cargoes, as the want of a 'tween deck was very much felt in them when so loaded. It was, as they were all aware, a factor in sea-worthiness that the weight a ship carried should be placed in such a position as to ensure as easy working as possible when in heavy seaways, and he would leave it for their consideration whether any strength in the structure could completely compensate for a lack in this respect. A good many large sailing ships were lost years ago because their cargoes were improperly placed, and the ships on account thereof too stiff. What he wanted to explain was, that a steamer when loaded so as to make her too stiff in a seaway—as the large well-deckers were apt to be when loaded with iron or ore—was unseaworthy as well as if she were too tender, and no strength in the structure could completely compensate for this. Besides this the great depth of their after-holds prevented them from carrying with safety all case and barrel goods, in fact any cargo that could not stand the great pressure the bottom tiers were exposed to.

Mr. Geo. N. Arnison, Jun., did not know whether the information that he could add to the discussion would be considered so valuable as that of the previous speakers, but in regard to the historical part of the subject of the development of the well-decker, although Mr. Sivewright's paper was extremely interesting and instructive, yet, neither in it nor in the subsequent contributions to the discussion, had any mention been made of two different forms of well-deck steamers. The first to which he would call attention were known as raised fore deckers. He did not know exactly how many of these vessels were constructed, but three had been built on the river Wear about seventeen years ago by Messrs. Osbourne, Graham, & Co., North Hylton. A number were also constructed at Hull, by Messrs. Humphry, Pearson, & Co., and probably there were others.

Mr. **Sivewright**—About fifteen altogether.

Mr. **Geo. N. Arnison**, Jun.—He thought in connection with a paper of such a high character, dealing in most respects so fully with the development of the well-decker, that it was only fitting that it should be recorded that the raised fore decker had been in vogue. Probably some description of it would not be out of place (Fig. N, Plate XXXV.). This type of vessel differed from the ordinary long full poop and topgallant forecastle class of vessel, as shown in Fig. E, Plate XXIII., as the main deck from the fore end of the long poop front (slightly forward of amidships), was raised two feet or thereabouts above the ordinary main deck line, and at this raised line was carried forward to the stem, the ordinary topgallant forecastle being erected above the raised fore deck. At all events, this was the arrangement of the vessels constructed under his personal observation at North Hylton. Possibly in other vessels, the main deck at the extreme fore end under the forecastle was dropped to the normal line. Owing to the break occurring at such a crucial point, as about amidships, special compensation was required by the Committee of the Underwriters' Registry for iron vessels, with which these vessels were solely classed. The main sheerstrake was locally doubled, with one plate 20 or 24 feet long. The fore main deck projected abaft the poop front 6 feet at the centre and 12 or 14 feet at the side, and the fore and after main decks, both of iron, were united together by a number of girders. These were the main features, but probably some other member would be able to add further *data*, more especially as to vessels of this type built elsewhere. Well-decked steamers had also been constructed, at all events on the river Tyne if not elsewhere, in which in addition to having a raised quarter deck, hurricane or bridge house, and topgallant forecastle, as shown on Fig. F, Plate XXIII., there was also on the raised quarter deck an ordinary full poop. These vessels were specially designed with a view to being engaged in the cotton and similar trades, and in considering the present subject, should not be overlooked, more especially as they were liable to have a deficiency of stability. He (Mr. Arnison) had taken out the centre of gravity and the transverse metacentre of one of those vessels, loaded with cotton, and found that the height of the metacentre above the centre of gravity was nearly *nil*—and even with the whole of the ballast tanks full, there was no great metacentric height. Previous speakers had made considerable reference to what are called improved well-deckers, but he (Mr. Arnison) did not think this portion of the subject had been exhausted. In Sunderland, the previous week, a vessel had been launched which had the poop extended to the forecastle, or, as he preferred to call it, with a continuous fore awning deck, from the after end of the engine room to the stem. This was in reality annihilating the well-deck altogether, as they could scarcely consider a vessel deserving of the name of a well-decker when there was only a shallow well on the quarter deck. It was difficult to understand why shipbuilders and shipowners were building such a type of vessel, unless it were to obtain advantage of a lessened freeboard. It should, however, be remembered in obtaining this doubtful benefit, they were adding considerably to the registered tonnage of the vessel; and, further, that with very few, if with any, cargoes, they could completely utilize the additional enclosed space. One of the greatest benefits obtained in the well-decked steamer proper had not been distinctly mentioned, although doubtless it might be considered to be inferred in Mr. Sivewright's paper. When one of these vessels shipped seas over the forecastle head, or on the beam abaft the end of the forecastle, the power of the waves was exhausted by coming into contact with the bridge or hurricane house front, etc. The existence of the forward well was thus a decided advantage. On the contrary, in steamers, *e.g.*, with spar and awning decks, the head seas had, comparatively speaking, an unbroken course, and not unfrequently the decks were swept of all boats, gear, etc., and even sometimes of permanent fittings Experience of this character, on the North Atlantic, had led the owners of large mail steamers to imitate to some extent the well-decker. Until the R.M.S. "City of Berlin" was built, the Inman liners were commonly flush decked. The R.M.S. "City of Chester" and the R.M.S. "City of Richmond," constructed a year prior to the first-mentioned vessel, had originally no topgallant forecastle, although the "City of Berlin" had. It was only in 1882 that topgallant forecastles were added to the older vessels, although experience had long previously shown their necessity. Most, if not all, of the White Star liners were built with raised forecastles, provided with deep breakwaters at their ends, on which the fury of the head seas could be spent. A further imitation of well-deckers in the latter vessels, as also in the R.M.S. "City of Rome" and more recently-built steamers, was the provision of a turtle back aft, in reality a modified poop. Now, no doubt none of these mail steamers came within the designation of well-deckers proper, but it is evident in their design some of the good points of that formerly much abused class of North-East coasters were either designedly or undesignedly appropriated. After careful reflection it did appear to him (Mr. Arnison) that the present tendency to dispense with the fore well was a retrograde step, and he for one should certainly not advise a shipowner to have one of the latest so-called well-deckers. There was only one other part of Mr. Sivewright's valuable paper he would refer to, and that was as to the use of Z sections for combined frames and reverse frames. Evidently by its adoption there was a saving in manual or machine riveting, and as all such saving of labour tended to cheapen the production of vessels, its extended application appeared to be highly advisable.

Mr. J. Johnson said, it was not his intention to take part in the discussion on Mr. Sivewright's paper, but, in the absence of Mr. Joseph L. Thompson, Jun., who was unable to be present owing to another engagement, he had been requested to explain the drawing, Fig. P, Plate XXXV. The filling in of the well forward had been criticised during the discussion; Messrs. J. L. Thompson & Sons having built several vessels of that type, the reports received from the owners and captains were most satisfactory, and no complaints had been made against the sea-going qualities of these vessels. There was, however, in the modern well-decker, the after well which was a serious objection on account of the quantities of water shipped during severe weather, and in this design exhibited (Fig. P, Plate XXXV.) an improvement was suggested to overcome these objections. The main deck was continued aft instead of forward and covered in with a long full poop. The main deck forward was raised in way of the main and fore-holds as shown. For stowage purposes the main hatch possessed many advantages, which with the extended bridge as hitherto was very difficult to obtain. The objection to the well forward was chiefly on account of its depth, this would now only be half the depth. Another advantage was that with any kind of cargo there would be no difficulty whatever in trimming the vessel. He thought Mr. Sivewright had placed too much importance on the permanent iron shifting boards in giving additional longitudinal strength; as these bulkheads were not continued through the hatchways they could only give local support. He would also ask Mr. Sivewright if he did not find any difference in sagging between ships built with ordinary bar keels and centre through keelsons. Messrs. Thompson had also made a series of tests of the kind mentioned by Mr. Sivewright, and their experience showed that ships fitted with a centre through keelsons were more rigid than if built with ordinary bar keels.

Mr. Sivewright, in reply to the discussion upon his paper, said, with reference to Mr. Wigham Richardson's remarks, he quite agreed with him when he stated that a ship ought to be considered as a girder, the sides of the vessel being really the girders it depended upon the depth of these sides how much a ship could stand the wear and tear of carrying heavy cargoes.

The breaking of the continuous line of main deck stringer plates in way of the raised quarter deck did not weaken the girders or sides of the vessel, but to prevent any local weakness in the iron deck at this point extra local stiffening was arranged for. He gathered from the discussion that considerable importance was placed upon the fitting of intermediate decks; at the same time he thought shipbuilders as a rule were too ready to accept the idea that the only way to strengthen ships was by fitting intermediate decks.

He maintained it was possible to build raised quarter deck vessels of large dimensions without intermediate decks, providing the sides of the vessels were made strong enough and well backed up by web-frames and intercostal stringers and with the holds divided by a sufficient number of bulkheads. Of course large vessels of this design might not be quite suitable for fragile general cargoes, but would be admirably adapted for deadweight, bulk, and bale cargoes. The contention of North-East Coast shipowners was, that if intermediate decks were not necessary for their trading and the strength of the structure could be maintained when dispensing with these, it would be to their advantage to do so, and he thought it had been amply proved that such an arrangement could be carried out.

The immunity from foundering of raised quarter deck vessels was due, in a great measure, to the large amount of reserve buoyancy that these vessels possessed, and this was got by the addition of the topgallant forecastle, bridge, and raised quarter deck. By having these erections the height of platform above loadline was increased, and was of great benefit to the seamen in working the vessel. As regards stability, the length of the righting lever was also increased by these erections. Whenever a flush deck steamer was so inclined that the upper deck touched the water, she then began to lose her righting qualities, but with the well-deck steamer under the same conditions there remained the reserve range of stability, due to the addition of the topgallant forecastle, and other erections.

Mr. Richardson appears to consider the fore well to be of no importance to raised quarter vessels. It has always been the contention of shipowners and those who command these vessels that the well was of the greatest use, and this was experienced when the vessel shipped heavy seas forward, these being confined to the fore well, expended their fury upon the front of the bridge.

Several members had spoken in favour of the flush deck type of vessel, but if this class is intended to be loaded down so that the dead-weight approaches somewhat near the cubic capacity of the holds (as it is in the raised quarter deck type of ship), to make these vessels safe at sea, he thought it would be generally admitted by captains that the addition of erections at each end and amidships would be necessary to enable these vessels to complete their voyages without serious deck damage.

He was sure that Mr. Fothergill and Captain Petersen would agree when he stated that the design of a steamer was not altogether left to the shipbuilder, and that many circumstances arose from time to time that influenced these designs one way or another. There can be no doubt that to get the most successful cargo steamer they must have one with low capital, good earning power, and not to overlook in the design to combine these qualities with the greatest safety to the ship and crew. He contended that these features were admirably carried out in the old form of well-deck steamer. In this type the dead-weight carrying capacity approached nearer to the cubic capacity of the vessel than any other design, and this was one of the secrets of its success.

The introduction of the long extended bridge type was not due, in a shipbuilder's opinion, to any advantage that this class of vessel would have over others as regards sea-worthiness, but in a great measure to the action of the Board of Trade authorities. The great increase of freeboard they required for the old well-deck type at that time prevented it from being built, and owners wanting to build ships resembling this type were induced by the favourable freeboard granted to the long extended bridge design to favour this class, but it ought to be clearly understood that whenever they got a cargo vessel approaching to the design of the flush or double deck type the same troubles would be experienced that the original well-deck type of ship was intended to obviate.

They could not have a better illustration, bearing out his remarks, than the action of the firm with whom Captain Petersen and Mr. Fothergill are connected. For a number of years they traded with well-deck steamers, they then went in for double deck steamers, and he noticed that during the last four years they had entirely abandoned the double deck type, and all their new vessels built, and now building, were of the well-deck design.

He did not agree with Captain Petersen when he stated that the large well-deckers must eventually develop into spar or awning deck ships. They must bear in mind that the trade of the world was a dead-weight bulk trade: that is, some kind of grain, coal, or cargoes of this nature, and not necessarily requiring an intermediate deck.

Several of the speakers had argued that the reason why well-deckers were built was that they were cheaper to construct than double deck ships. Of course there could be no denying this, but if this type of vessel did all the work required in the dead-weight trade, then why should shipowners be asked to build double deck vessels which would be unsuitable for their trading ?

The design of the raised main deck vessel, as mentioned by Mr. Arnison, was not a successful type of the well-deck cargo boat. There were only a few of this type built and several of these were lost, and this loss was thought to be caused in a measure through want of height of platform, or in other words, too little stability. This class of vessel approached too near the deeply laden flush deck type of ship.

He quite agreed with Mr. Arnison when he stated that the filling in of the fore well in the long extended bridge type of vessel, making the vessel awning deck forward, was a retrograde step, that is if the ship was *loaded deeper* through this filling in, for with other faults they would then have the old complaint of expense in having to bag a large portion of the grain cargoes from the Black Sea; he thought it would also only be a question of time when shipowners would have to consider the advisability of putting a topgallant forecastle and another bridge on the top of these semi-awning deck vessels for the better protection of the vital openings of the ship.

In reply to Mr. Johnson, if the iron grain divisions could be carried in one continuous line fore and aft this would certainly give a very strong central support to the structure of the vessel, but on account of the hatchway openings the increase of strength of the divisions to an extent was local, but he thought that Mr. Johnson would agree with him that although this was so, yet the divisions as fitted were of considerable advantage to the structure. The centre through plate keels were certainly stronger in every way than the ordinary bar keel. In sighting lately a number of large well-deck steamers, and especially one that had an iron cargo, with bunkers, of 4,300 tons all told on board, the depth moulded was right to within a fraction of an inch, and he considered this was due in a great measure to the many special features that had been lately introduced into this design of vessel.

The statistics supplied by Mr. Yeoman very forcibly proved how small the loss of life is in steamers, considering the enormous amount of mileage these vessels steamed in the year, and more especially when collisions and strandings due to fog or stress of weather are taken into consideration. The only way he (Mr. Sivewright) could suggest to keep the flush double deck type of ship sea-worthy would be for the Board of Trade to rigorously insist that no bulk grain should be carried in 'tween decks, and if some of these vessels were of good enough proportions to have a forecastle, bridge, and poop fitted, these erections would certainly be of great assistance to them, but if the proportions were so bad as not to allow of these additions, the only remedy then would be not to load them so deep, and thus admit of more height of platform and consequently greater stability. Mr. Yeoman may rely upon shipbuilders when building large single deck vessels of the raised quarter deck type that every care will be taken in making them strong enough to do their work, and this can be done without the fitting of an intermediate deck; and, as Mr. Macoll states, should these vessels get very large it would be an easy matter to put a tier of strong beams in the holds without laid deck to assist the strength of the structure.

Mr. Scholefield appeared to consider that the use of long plates in the construction of vessels was not altogether advantageous from an underwriter's point of view, but it ought to be taken into consideration that if these long plates were damaged they could be butted in the middle if necessary, and then would not be worse than the old style of plating with short plates. It ought also to be looked at from another point of view, viz., the enormous amount of strength gained by having a smaller number of butts in the structure. The difference in using plates averaging in length 24 feet instead of 10 feet after, making a liberal allowance for short plates at ends, is something like a reduction of 40 per cent. in the butts of the vessel—a great advantage, as these butts are all breaking points, supposing the vessel to be stranded or straining at sea.

The writer, in reading his paper before this Institution, endeavoured to specially bring to the notice of the members the benefit in strength to be gained by the more general adoption of the web-frame and cellular bottom principle, and he is convinced that if this system of construction was more encouraged by underwriters very many more steamers would be salved from stranding than in the past. Some very special cases of salvage of vessels constructed on this principle had come under his notice lately, such as the floating of the large steamer "Beresford," loaded with railway iron, and stranded for fourteen days on Hasbro' Sands, the S.S. "Vulcan" from the Comino reef upon which the ill-fated "Sultan" sank, also the salving of the S.S. "Merida" from the coast of Ceylon, now in graving dock undergoing repairs, and of which vessel several members of this Institution have had the opportunity of inspecting. The way this latter vessel has stood the enormous amount of battering and straining on the rocks for a considerable time was a conclusive proof that long plates and the web-frame and cellular bottom principle were very far in advance of any other form of structure, and was also a very practical testimonial of the superiority of steel over iron for shipbuilding purposes.

The PRESIDENT said, he was sure he only expressed their feelings and sentiments when he said they were all very deeply indebted to Mr. Sivewright for his very valuable paper, and that they would accord to him a very hearty and cordial vote of thanks. They had not only had a most valuable paper; but they had had, perhaps, the most interesting discussion on well-deck and cargo steamers that had ever taken place in any institution. He was quite sure this discussion would make the Transactions of this Institution much more valuable even than they had been. He moved that they accord to Mr. Sivewright a very hearty vote of thanks.

The vote was heartily accorded.

CORROSION AND PITTING IN MARINE BOILERS.

By J. B. DODDS.

[Read before the Institution on March 13th, 1889.]

The question of boiler corrosion and pitting is one that has had the writer's professional attention and consideration for some few years; and although he is somewhat conversant with the many theories and practical explanations so ably propounded in papers read before the various scientific bodies of this country, yet it appeared to him that the chemistry of corrosion as investigated by himself would be of interest to this Institution.

It was not his intention to propound any startling theories, but to lay before the members the simple and plain facts he has observed, and the deductions he has drawn therefrom.

On examination of corroding boilers, those parts seriously affected are generally found devoid of the usual hard protective, "sulphate of lime" scale, and in exceptional cases the whole of the boiler is perfectly free from this scale, the various parts being covered with a red, or even a black coating of a soft matter, frequently slimy in character. Much of this matter is found on the upper portions of the boiler in the form of a froth, while the rest is deposited on the tubes, combustion chambers, or settles to the bottom of the boiler like mud.

Attention is particularly drawn to the chemical composition of this deposit; the following analyses may be taken as fair averages of the many samples the writer has examined and analysed:—

	Deposited at bottom of Boiler. Per cent.	From top of Boiler. Per cent.
Ferric oxide	65·00	72·9
Calcic sulphate	9·02	1·58
Calcic oxide	·75	1·38
Magnesic oxide	10·12	8·14
Zinc oxide	·75	1·35
Sand, etc.	1·70	1·2
Oily organic acid, combined with the ferric, calcic, and magnesic oxides	10·66	10·75
Free uncombined oil	2·00	1·25
Water	—	1·45
Total	100·00	100·00

In some cases this oily combined acid has amounted to 20 and even 25 per cent.

On examining these deposits one is struck with the curious fact that they contain a very large percentage of magnesic oxide in an insoluble form, and also with the fact that they contain a very considerable amount of oily organic acid, and that this organic acid is in combination with the ferric, calcic, and magnesic oxides. The presence of this insoluble magnesic oxide compound at first sight appears unaccountable, and causes us to speculate as to where it comes from, because sea water only contains magnesia as either sulphate or chloride, both of which salts, especially the chloride, are exceedingly soluble, and are not, as sulphate or chloride, capable of forming an insoluble deposit. Indeed, in one gallon of sea water only the 98·7 grains of calcic sulphate and the 2·8 grains of calcic carbonate are capable of forming permanent insoluble deposits on boiling and evaporating. All the other constituents are very soluble, and simple boiling and evaporation, to the extent carried on in a steam boiler, would only make the solution stronger without causing their deposition in an insoluble form—that is, supposing no other influences acted on them at the same time. It may be asked, might not the river waters with which the boilers are filled when in port furnish this magnesia? But river waters do not contain magnesia salts as a rule, but are surface waters containing principally calcic sulphate; therefore this magnesic oxide of the deposits must be derived from the chloride and sulphate of the sea water.

There is also the other fact noticeable in the analyses of these deposits, and that is the very considerable percentage of "oily organic acid" present in combination with the ferric, calcic, and magnesic oxides, and this organic acid is derived from the mineral oil used as "cylinder oil" in the cylinders. It is generally stated that these oils are hydrocarbons, therefore not capable of saponification, and that they do not affect metallic surfaces. This is correct as applied to these oils in their natural state, then alkalies do not affect them or form soaps, nor is copper or other metals tarnished or corroded, even after being immersed in them for a considerable or indefinite length of time; but it is incorrect as applied to these oils, when exposed to the influences and conditions existing in the high-pressure cylinder of an engine working at such a pressure that the temperature is higher than the "vapourising point" of the "cylinder oil" which may be in use. All these oils are capable of oxidation, otherwise they would be incombustible; and placed under sufficiently favourable conditions for oxidation, such as very extended surfaces exposed to the action of steam of sufficiently high-pressure, and therefore temperature, to reduce a portion of the oil to a vapourous state—and these are the conditions existing in engine cylinders, particularly in the high-pressure cylinder of a triple engine—under these conditions these oils will become in part decomposed and broken up, producing compounds different from the original oil put into the cylinder. These compounds pass forward with the steam, and gradually work their way through the condenser into the boiler, and so introduced into the boiler are capable of combining with bases such as ferric oxide, calcic oxide, or magnesic oxide, as is proved by the constituents of the deposits already mentioned.

Oil merchants and manufacturers will state that their particular oils have a "vapourising point" of over 600 degs. Fah.; it has even been seriously contended that the "vapourising point," or that point when vapours become apparent, is at a higher temperature than is the flash point. The writer has examined very many of the standard cylinder oils, and can say that the majority of them, as supplied to ships, vapourise or show vapour when heated to under rather than over 280 degs. Fah., and flash at under rather than over 450 degs. Fah.

Seeing that 160 lbs. pressure is not now considered an extraordinary pressure, and that the temperature of the steam at this pressure is 363 degs. Fah., it is not difficult to imagine that much vapour is given off from such oils when used at such temperature, and as this giving off of vapour indicates the decomposition or change of the oil, the amount of such decomposition may be estimated therefrom.

Having pointed out these two peculiarities, let us take into consideration what it is that takes place in a steam boiler supposing the surfaces of the metal to be unprotected by scale or by artificial means. The salts of the sea water, especially the magnesic chloride, causes the water to act chemically on the exposed metallic surfaces. This chemical action takes place at *all* temperatures, and in water of all specific gravities, but is greater at a high temperature than at a low one, and also greater the higher the specific gravity or more degrees the water indicates on the salinometer. The result of this chemical action is the oxidation of the exposed surfaces of iron, but more especially of steel. This oxidation or chemical action at the same time produces electricity, as chemical action always does. When this oxidation takes place in a cold solution, the electric tension exhibited is slight, even though the chemical action be considerable. Though this tension does appear slight so far as instruments show it, yet in fact the amount of electricity produced is proportionate to the amount of chemical action, but as both the metal and the water are conductors and remaining in contact, the greater part of the opposite electricities produced recombine and neutralise each other as fast as they are separated. But if this chemical action or oxidation takes place at a high temperature, as in a steam boiler, this recombination does not take place to the same extent, and the salts of the sea water become electrolysed or decomposed by the electricity, their bases combining with the "oily organic acid" produce the deposits found in the corroding boiler. As these bases of the sea water combine and are neutralised by these "oily organic acids," there is liberated an equivalent amount of the acid of the sea water salt, which helps to still further increase the corrosion.

These reactions take a considerable amount of time to state, but in fact they all take place nearly instantaneously, and this, the writer considers, is the reason why corrosion is attributed to electric action, whereas really the electric action in a steam boiler is due to the chemical action of the water on the metal of the boiler.

A voltaic couple which may consist of, say a plate of zinc and a plate of copper immersed in a bath of dilute sulphuric acid, the two plates being connected outside the liquid by a wire, chemical action is set up, and electricity produced in exact proportion to that action. The chemical action causes the electricity not the electricity the chemical action. The same state of things exists in a steam boiler, there is corrosion or oxidation of the iron or steel exposed surfaces by the sea water, instead of the corrosion of the zinc plate by the dilute sulphuric acid. The sea water acting in its degree as the exciting liquid to produce chemical action and so electricity.

There are two ways of stopping this corrosion, one by rendering the water non-exciting, and the other by taking advantage of a law or fact observed in electricity, which is—that when two elements or metals of dissimilar characters are immersed in a liquid capable of chemically acting on one or both of them, and are at the same time connected together by means of a metallic connection, that element or metal which is most acted on by the exciting medium, becomes the positive or corroded element, while the other becomes the negative or inactive element, and so escapes all corrosion so long as they are in metallic contact.

When it is wished to stay corrosion by taking advantage of this electrical fact, the usual method is to employ metallic zinc, being careful to bring it into intimate metallic contact with the metal of the boiler. This will, if sufficient zinc be used, have a beneficial effect; still too much is generally expected from the zinc; engineers expect the effect of these zinc plates, say four of them weighing in all about 56 lbs. and placed in different parts of the boiler, which will weigh about 30 tons, to influence the whole and every part of the boiler, and to continue to influence it for a period of time. Even if these plates were most elaborately connected in strict metallic contact with the metal of the boiler in its different parts, it is too much to expect from such a quantity of zinc, there being too great a disproportion between the weight of 30 tons and 56 lbs., therefore the areas of its influence must be circumscribed, more especially after being in use a few days, when its surface becomes coated and protected against a great proportion of the corrosion it ought to undergo to enable it to keep its place as the most readily acted-on metal, and absorb to itself the chemical action or corrosion which would otherwise attack the iron or steel of the boiler. This idea that the areas of influence of the protective plates are circumscribed to some extent accounts for the fact that a boiler shows signs of corrosion sometimes in one place and then in another; in other words it shows these signs over areas where the protective influence of the zinc has either been destroyed, or too much diminished to be effective.

56 lbs. of zinc represent ·083 per cent. of the weight of a 30-ton boiler: if from four to five times this amount were used in the first instance, and supplemented from time to time, as it was corroded and rendered ineffective, it would be found that corrosion would be stayed, though there would be considerably more than a proportionate quantity of zinc consumed in a given time than when the smaller quantity was employed. The reason for this larger consumption of zinc being that though zinc in proper metallic contact absorbs all corrosion to itself, it does not destroy or prevent the chemical action or the resulting electricity being formed in the boiler, it rather increases it. As has already been stated the action of the zinc is simply that being the most readily acted-on metal it becomes the positive or corroded element instead of the iron, as would be the case were the zinc not present and in metallic contact. This being the case it may be unnecessary to point out the advisability of the zinc used being good and as pure as possible. Any foreign metals the zinc may contain will injure its efficiency as a protector to the metal of the boiler, as part of its power will be wasted in becoming positive to them instead of to the boiler.

It would certainly seem that the most logical method of preventing corrosion is to make the water non-exciting or incapable of acting chemically on the iron or steel of the boiler; thus the cause is at once attacked, whereas the other method only deals with the effect, and there is moreover avoidance of the great difficulty in making and maintaining the metallic contacts, owing to corrosion at the point of juncture, or the breaking of the contacts from other causes, and such imperfections can only be remedied when the boilers are opened. In those methods which aim at destroying the corrosive or exciting power of the sea water, the protective agent is added either at the condenser or hot-well from time to time, and in greater or less quantities as desired. There are several ways of making or causing the sea water to be non-exciting, and there are many compounds offered as meeting all the requirements, but care should be taken not to put into boilers any compound which contains a constituent that, of itself, is capable of combination with iron, or which contains a constituent that can by any means be made to furnish compounds capable of such combination, because it should be a *sine qua non* that the protective agent should be in itself harmless. Lime preparations added to the water are beneficial, their action being to keep the surfaces of the boiler always coated and thus protected from corrosive action. This subject has occupied so much of the writer's professional attention that it has caused him to take more than an ordinary interest in the solution of the problem, apart from any commercial consideration of the question, although he felt it would be a great advantage if some reduction could be made in the present costly application of zinc, and the writer is of opinion that a basic solution of zinc would effect this economy, but, after all, he assumes that the vitality of the boiler is the first consideration.

The great advantages in the use of such anti-corrosive or anti-exciting compounds is that they can be introduced in small quantities at stated intervals. They render the water non-exciting, and diffuse themselves through all parts of the boiler, thus protecting all parts equally.

In treating of corrosion, mention of that special kind generally known as pitting has been omitted. This pitting is occasioned by the same causes as induce the more general corrosion, but these causes are intensified and accelerated by two other influences, which tend to concentrate the effects of such corrosion by rendering it very local instead of general. These influences are rust or iron scale, and variations of temperature. Rust or iron scale is frequently, indeed generally, in the the form of magnetic oxide of iron, and when the metal of the boiler, especially if it be steel, is acted on chemically by the sea water, and whilst in intimate contact with this oxide, such chemical action induces electricity, the oxide and the metal in its very immediate neighbourhood constitute a voltaic couple, the metallic iron or steel being the most readily acted on becomes the corroded or positive element, while the oxide becomes the inactive or negative one; this couple induces a current of electricity having only a very local influence, thus concentrating the action on that limited portion of the iron or steel which has become the positive or corroded element through the influence of the oxide or scale, instead of allowing that action to expend itself more generally over a larger area.

Variation of temperature affects more particularly the question of the very serious and dangerous pitting observable on the sides of the furnaces. In cases where two portions of even the same plate of iron or steel are subjected to unequal temperatures when immersed in a liquid capable of chemically acting on them, these two portions become virtually two different metals so far as molecular arrangement is concerned, and are capable of forming a voltaic couple; the more highly heated portion being the most readily chemically acted on by the sea water becomes the positive or corroded element, while the less highly heated portion, being also the less liable to the chemical action, is the negative or inactive one. Thus, when through any physical or structural cause, one part of the metal becomes more highly heated than another part—and portions of the furnaces and combustion chambers are very liable to this, especially along the fire-line—this more highly heated portion becomes positive to the less highly heated portion, and thus concentrates on itself all the corroding or chemical action which would have diffused itself more generally over the whole surface had the temperatures been equal.

To counteract or stay this pitting is much more difficult than it is to stay the general corrosion. In the case of general corrosion there is a general cause which may be met by a general cure, but in the case of pitting there are several causes, each perhaps similar, but yet each requiring to be separately neutralised and overcome. Each case of pitting being due to a local and not a general cause, in any endeavour to effect a cure by means of metallic zinc it will be necessary to remove this cause and bring the part affected into intimate metallic contact with the metallic zinc. Bringing the zinc into contact with these parts will very greatly increase the consumption of zinc, seeing that these parts are so prone to chemical action. Supposing the causes, such as rust or iron scale, and the variations of temperature to be removed, this increased use of zinc will be effective. But though it may be possible to remove the rust, it is not so possible to do away with the variations of temperature; therefore the best method of effecting a cure of this pitting would be to strike directly at the cause by rendering the water non-exciting. By this means the rust and the variations of temperature are rendered innocuous.

In conclusion, the writer would point out that prevention is better than cure, and that if it is desired to keep a boiler in good order certain precautions must be taken. Firstly, great care must be taken in the selection of cylinder oils, and only use such as have a vapourising point at a higher temperature than the temperature of steam at the pressure at which the boiler is worked, and do not take the statement given of the vapourising points of these oils for granted, even though it may be a certain brand or make, but see that each particular lot as supplied is equal to the sample and bears out all the statements made respecting it and which influenced its purchase. Such supervision will always give a good return for the trouble, because whether it is cylinder oils or any other goods that are sold and which are *not* subjected to this supervision it may be taken for granted that the lowest quality accepted without serious complaint or rebate in price will eventually become about the highest quality that will be supplied.

Secondly, work the boiler with the greatest amount of regularity practically possible on board ship, and endeavour to keep the specific gravities of the water as regular as possible. Samples of these waters might be taken at stated times during the voyage, and of deposits whenever opportunity offers; these samples to be kept for examination when necessary. The taking of these samples answers two good purposes: one is, that if the boiler should happen to show signs of corrosion, these samples will enable the cause of such corrosion to be traced. The other purpose is that by taking samples systematically and for a certain purpose, the attention is thereby drawn to the boiler and a certain interest created, which induces regularity in working and treatment generally, and all means which have this effect are most valuable, and cause a very material reduction in the wear and tear of the boiler.

The PRESIDENT remarked that they were very much indebted to Mr. Dodds for calling their attention to this subject of the corrosion and pitting in marine boilers. It was one they had all more or less to do with, and it would afford a subject of very valuable discussion. Most of them had seen the extraordinary difficulties that arose from the pitting of marine boilers, and they might or might not have hit upon the right cause, but at any rate they were quite sure of this that such advice as he gave at the end of his paper would always be valuable. It was always wise to see they bought what they were supposed to buy; and nothing could be more important in matters of this kind than very careful observation and continuous inspection of samples of water from boilers at sea. By such circumspection they might get a valuable lesson as to the pitting of marine boilers. The meeting was now at a close. They were very much indebted to their Hartlepool friends for having given themselves the trouble to come so far to meet with their *confrères* there that night. They were very glad to see them, and also for the very valuable paper which their friend (Mr. Sivewright) had been good enough to submit.

The meeting then adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIFTH SESSION, 1888-89.

PROCEEDINGS.

EIGHTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, APRIL 8th, 1889.

H. F. SWAN, ESQ., VICE-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting held in Sunderland, on March 13th, 1889, which were approved by the members present, and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Messrs. B. G. Nichol and R. L. Weighton to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Buchanan, Charles, 14, Humbledon View, Sunderland.
Dickinson, R. E., Messrs. Palmer's Iron and Shipbuilding Co., Jarrow.
Eiles, Robert, Messrs. Eiles & Dryden, 4, Quayside, Newcastle-on-Tyne.
Robinson, William, 9, Waterville Road, North Shields.
Rogers, Herbert M., Lloyd's Registry, Newcastle-on-Tyne.
Newton, Richard, Park Square, West Hartlepool.
Wotherspoon, R., Board of Trade Offices, West Hartlepool.

ALTERATIONS IN THE CONSTITUTION AND BYE-LAWS.

The SECRETARY, in the absence of the President, gave notice that at the Closing Business Meeting to be held in Newcastle-upon-Tyne on May 13th, the President, on behalf of the Council, will move that the following alterations shall be made in the Articles of Constitution and the Bye-Laws:—

CONSTITUTION.

"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."

"IX.—The Officers of the Institution shall be elected from and by members, and shall consist of one President, the Past-Presidents, *nine* Vice-Presidents, fifteen Councilmen, and an Honorary Treasurer."

"X.—The President and Treasurer shall be elected annually. *Three* Vice-Presidents and five Councilmen shall be elected annually. The retiring Vice-Presidents and Councilmen shall be those who have served three years from their last election."

BYE-LAW.

"6.—All subscriptions shall be payable in advance, and shall become due on the 1st of June 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 June following."

NOTE.—*The proposed alterations are printed in italic.*

THE COUNCIL.

The SECRETARY intimated that, in accordance with Article X. of the Constitution, the following gentlemen would retire from the Council:—President—F. C. Marshall, Esq.; Vice-Presidents—Messrs. Wigham Richardson and Alex. Taylor; Councilmen—Messrs. J. P. Hall, C. W. Hutchinson, A. Laing, M. Sandison, and J. Tweedy; Hon. Treasurer—Mr. B. G. Nichol.

The VICE-PRESIDENT, on behalf of the Council, nominated the following gentlemen from whom to fill up the vacancies by ballot:—President—F. C. Marshall, Esq.; Vice-Presidents—Messrs. Raylton Dixon, William Gray, J. P. Hall, C. W. Hutchinson, Arthur Laing, Robert Thompson, and John Tweedy; Councilmen (five vacancies)—Messrs. Henry Clark, John Gravell, Johan Johnson, L. Rusden, G. W. Sivewright, J. C. Stirzaker, and Alex. Taylor; Hon. Treasurer—Mr. B. G. Nichol.

NOTE.—*If alteration to Article IX. of the Constitution is agreed to, five Vice-Presidents will be elected.*

The **Secretary** said he had received a letter from Mr. Raylton Dixon requesting that his name might be withdrawn. It would therefore be necessary to nominate another gentleman.

Mr. B. G. **Nichol** nominated Mr. John Dickinson, engineer, Sunderland, for a Vice-President.

There was no other nomination.

EXCURSION TO FORTH BRIDGE.

The **Vice-President** said, he had been asked to draw special attention to this important subject. It was expected that the Forth Bridge would be finished in August next, so that the proposed excursion was really the last opportunity that such an Institution as this would have of visiting the works in progress; of course to practical men, seeing the work in progress and the pieces being put together was of much more interest than merely seeing the finished structure. He might say that, last autumn it was his good fortune to see the works, and he must say he was struck, when he got within two or three miles of the place, at seeing this stupendous erection towering in the air. He had, moreover, the opportunity of visiting the workshops and the bridge itself, and found them most interesting. It was necessary to arrange the trip of the Institution economically, to have 200 passengers at least guaranteed to the railway company, and it was desirable that members should, as early as possible, send in to the Secretary intimation whether or not they could attend, or that those who wished to go should send in their names. They would also see there was an Associated Conversazione to be held in the Durham College of Science on April 29th, which he hoped would be well attended. He would also draw their attention to the fact that the Closing Meeting of this session would be held on Monday, May 13th.

The discussion on Mr. J. B. Dodds's paper on "Corrosion and Pitting in Marine Boilers" was proceeded with, after which a paper on "The Proper Capacity of Air Pumps," by Mr. J. H. Hamilton, was read.

DISCUSSION ON MR. J. B. DODDS'S PAPER ON "CORROSION AND PITTING IN MARINE BOILERS."

The SECRETARY said he had received a communication from Mr. Fothergill (who was very sorry he could not attend the meeting) upon Mr. Dodds's paper. If it was the wish of the meeting he would be pleased to read it.

The VICE-PRESIDENT thought it would be well to hear it; Mr. Fothergill had taken a great deal of interest in the subject.

COMMUNICATION FROM MR. J. R. FOTHERGILL, WEST HARTLEPOOL, ON MR. DODDS'S PAPER.

DEAR MR. DUCKITT,—I regret I find it impossible to attend the meeting on Monday night, as it was my intention to have taken part in the discussion on Mr. Dodds's paper, but with the President's permission I will ask you to read the following comments:—

I think there is much reason to congratulate ourselves on this particular paper in that it may be called a new departure as compared with the usual papers read before the various technical institutions on this most important and interesting subject. Here we have the practical views of an analytical chemist, who has not only analysed the various deposits and waters from boilers, but has himself gone through the boilers, and there investigated the destructive action at work. The practical engineer, from his lack of thorough knowledge of chemistry, is prone to misconception and forms and retains erroneous views, and becomes prejudiced, and thus it is, I think, this very able paper of Mr. Dodds's of special value. Mr. Dodds describes not only the decomposition and new combinations of the salts, but warns us to be on our guard as to the quality of the many "cylinder oils" now in the market. The firm I represent has had many samples of these oils analysed, and I may say it is the exception to find an oil that will stand 400 degs. Fah. without giving off vapour. Many oil merchants represent the vapourising point higher than the flash point. It appears to me the vapourising point must be lower than the flash point, for what is it that flashes, but the vapour, and I think there is no doubt these oils directly or indirectly have much to do with corrosion. Now as to the use of zinc. I must confess I once had a strong feeling that the use of zinc was far from effecting all that was said of it, and I therefore entirely disused it in two steamers, but the boilers being in very good condition it was sometime before I became convinced beyond all doubt as to its value. I then tried it in metallic contact in various ways, and also by suspending it in the boilers in trays, and I found that whether in metallic contact or simply suspended in the water, if plenty of zinc was used, and that good zinc, the results in both cases were equally as efficient. Of course the quantity of zinc required depends on the condition of the boiler. The analysis of many samples of boiler water shows zinc in solution, and I am of the opinion the prevention of corrosion is principally due to zinc in solution in the water making the water as described by Mr. Dodds non-exciting. It is a well known fact hot brine dissolves zinc. I should like to ask Mr. Dodds whether he does not think it is probable the zinc as generally used in a boiler, for it must be borne in mind that in far the larger majority of cases zinc is only suspended in trays, which is certainly not in metallic contact, does not act by non-exciting the water, and not by electrically protecting the material of the boiler? I should imagine the use of zinc to electrically protect the boiler would necessitate a large quantity in actual metallic contact, but zinc in a boiler soon oxidizes, and would not this soon destroy the electrical efficiency? To my mind the most simple and practical method to prevent corrosion is to make the water non-exciting, and if, as Mr. Dodds suggests a basic solution of zinc can be made so that measured quantities can be added to the feed water, say every day or every "watch," we should not only reduce the cost of the use of metallic zinc, but we should get very much better results. For sometime past I have had a careful record kept of zinc used in various boilers in different trades. Two steel boilers supplying steam to engines indicating about 850 horse-power when new required to prevent corrosion 8 to 10 lbs. of good zinc per 24 steaming hours, and when in good condition, free from corrosion, about 4 lbs. per 24 steaming hours is sufficient. This steamer is in the Indian trade, but these quantities may be taken as the maximum and minimum for steel boilers. There is one point I note Mr. Dodds does not allude to, that is the air in the water. It is a well known fact water absorbs free air, and thus oxygen is carried into the boilers: does not this assist or propagate corrosion? Will Mr. Dodd give us his opinion?

J. R. FOTHERGILL.

The VICE-PRESIDENT—That is an interesting letter and raises two or three important points.

Captain McNAB—It ought to have been kept back as it will put a damper upon the discussion.

The VICE PRESIDENT—On the contrary; it raises points that should give it a start. That suggestion of using zinc in solution instead of the metallic form is a very interesting one, and somebody might give them an idea as to whether the question of £ s. d. comes into play, or the relative cost of the one with the other.

Mr. J. C. SPENCE said, that as the subject-matter of this paper was involved in some doubt and obscurity, they were greatly indebted to the writer for bringing before them the results of his special investigations, his analyses, and the conclusions he drew from them. But their sense of gratitude did not require them to accept his arguments without criticism, and his (Mr. Spence's) criticism commenced at his first sentence, thus: He says—"The question of boiler corrosion and pitting is one that," etc. Now he considered that corrosion and pitting were not one question but two quite distinct questions. Their mode of action was different in every particular. By corrosion he meant the slow, gradual, and comparatively uniform wasting away of the heating surface (furnaces, tubes, etc.) of boilers. This he believed to be inevitable, and to take place on both sides of the heating surface, perhaps more on the fire side than the water side. On the other hand, pitting only occurred in exceptional cases; its action was not slow and uniform, but rapid and most fortuitous in its distribution. It occurred, so far as his experience went, only on the water side of heating surfaces. Seeing that in all these particulars the action of pitting was strongly contrasted with the action of corrosion he could not agree with the author that pitting was due to the same causes, as corrosion only intensified and accelerated by rust and heat. Or, if it was admitted that this was so, the question still remained, why did the rust and heat, which were in general uniformly diffused, occasionally have this effect? Why should one furnace out of three which were working in the same boiler, under identical conditions, using the same oil, subject to the same variations of temperature, be destroyed, while the other two were left untouched? Why should the action be intensified in one instance and not in the other? In his experience the one characteristic that was uniform in relation to pitting was the want of uniformity with which it occurred. Out of a set of furnaces, working under identical conditions, one would be pitted and the others quite free from pitting. He had had to renew three fires out of a set of four, the fourth not having a mark upon it. He had seen a few tubes in a new boiler destroyed in a very short time, all the remainder lasting for years without a sign of pitting. If the author could tell them why the causes which generally acted uniformly were occasionally intensified and concentrated he would have solved this problem, which was now without a solution. It was no solution to say that pitting was a special case of corrosion. This was equivalent to saying the abnormal was a special case of the normal. Let them now consider the author's arguments in relation to oils. He said that oils with a vapourising point of 280 degs. would vapourise and decompose at 363 degs., the temperature of steam at a pressure of 160 lbs.; but the vapourising point meant the vapourising point at atmospheric pressure, and this point would rise with every increase of pressure. In the absence of experiment it would be safer to assume that, if at atmospheric pressure the vapourising point of an oil was higher than the boiling point of water, then at a pressure of 160 lbs. the vapourising point of the oil would still be higher than the boiling point of water, than to assume, like the author, that this point remained constant for all pressures. The presence of oily organic acids proved that the oils had been partly decomposed, but it appeared from the author's own arguments that it was more likely that this decomposition took place in the boiler than in the cylinder. On page 196 he showed that the salts of sea water were decomposed or electrolysed by feeble currents of electricity, generated by the action of the water on the plates. Now, if these electrical currents were capable of decomposing the salts of the sea, they were surely capable of decomposing the much less stable components of mineral oils. He should, therefore, conclude that the author was not warranted in tracing corrosion to the decomposition of oils, but that, by his own showing, the decomposition of the oil was the consequence of the corrosion of the boiler; a conclusion which was, he believed, in accordance with general experience, that pitting could not be traced to nor avoided by the use of any special oils. He was sorry to say his criticism was only negative. He could not contribute any suggestion which appeared even to himself satisfactorily to account for pitting, and he had serious doubts whether corrosion was preventible—that was, whether a time would ever arrive when an old boiler would not be a worn-out boiler in the heating surface; the shell, with proper care, seems capable of lasting for ever. He would like to have heard the author's views about rendering the water non-exciting. If this could be carried out on a practical scale it promised to stop both pitting and corrosion, at least on the water side of plates.

Mr. J. P. **Hall** thought the Institution should give Mr. Dodds its best thanks for his very important paper. The question of boiler management and protection was certainly one which required a great amount of study and thought. The knowledge that the practical men present had ought to be given up to the Institution as largely as possible. He thought that from the paper they gathered two or three lessons—(1) the necessity of keeping internal parts clean; (2) the advantage of keeping the surface covered and secure against the attack of the chemical action; and (3) the advantages of using fresh water. The practice he had hitherto advocated and adopted as far as possible with new boilers was to have them thoroughly cleaned at the outset, to clear away all dirt and rust to the bare iron, and then coat them with lime mixed with a little Portland cement, and afterwards to fit sheet zinc plates in metallic contact, not simply hanging them in the spaces, but a better result was got, he thought, from attaching the zinc sheets to the boiler plate itself by studs, leaving a space of about three-quarters of an inch. He had recently got splendid results from a boiler 13 feet 3 inches diameter and 10 feet long by the application of about 2½ cwt. of zinc. That, he thought, a fair quantity to put into a boiler of that size, and distribute it throughout the space uniformly. This boiler has three furnaces, with a heating surface of about 1,500 square feet, and represented practically about 20 tons of water. He thought about 2½ or 2¾ cwts. a fair allowance to keep a boiler of these dimensions free from any attacks chemically. He found, also, the use of soda on the voyage a very important feature. With a clean boiler at the outset, zinc plates fitted, and from 4 to 6 lbs. of soda used in 24 hours, he had found, after a voyage of two months, the whole of the internal parts almost perfection, and he went in and surveyed it with a great deal of pleasure, coming out as white as a miller. There were no signs of oxidation or decay, bearing out what Mr. Dodds had described in his paper. On page 201, Mr. Dodds says that "Prevention is better than cure." This, he thought, they would all admit. They should prevent serious decay also if they ceased to use oil as a lubricant in the cylinders. Oil, to his mind, did more harm than good, and often played havoc with the boilers, especially the oils usually supplied to ships. The results which had been obtained by many who had ceased to use oil in cylinders were such as to satisfy him that it could be done without. One of the largest and most successful firms on the Clyde never now used a drop of oil on the cylinders, even at the outset, and if they took example from their practice it would materially help to solve the question. It was certainly a very important one. The oil evaporated before it reached the cylinder. He had noticed many times both in small and large engines the oil applied had decomposed even before it reached the cylinder, and going into the boiler in a condensed state damaged it without having done any good to the cylinder. Gentlemen with more practical every-day sea experience than he (Mr. Hall) had might give them their views, which would be of very great service to the Institution.

The VICE-PRESIDENT—I take it to be in your experience that treating the boiler with metallic zinc and soda kept it free from any sign of either pitting or corrosion?

Mr. HALL—Yes; there was no sign whatever in the case I referred to, and I could give half-a-dozen other instances.

Mr. B. G. NICHOL said he would like, at the outset, to endorse the expressions used by Mr. Fothergill in the opening remarks of his communication with reference to the author of the paper. He (Mr. Nichol) thought it to be an exceedingly valuable one, and if it were possible to introduce some solution of zinc which could by any means be made to assume a position analogous to a thin coating of lime on the interior surface of the boilers, the whole question of boiler pitting, and probably of boiler corrosion, would be solved. As to the action of zinc, he said that at Portsmouth some years ago an extensive series of experiments were carried out, and it was found that wherever these zinc blocks were attached to the boilers the effect of pitting, as distinguished from corrosion, was absolutely annihilated within a radius of 3 feet from each block; but, unfortunately, when they put zinc blocks into boilers its usefulness was very short-lived, the blocks not lasting during an ordinary six weeks' voyage. The zinc of commerce was so mixed with iron nodules that internal action was set up and the mass rapidly wasted away. The method of neutralising the water with other agents was the most logical way of accomplishing the desired purpose, and if some such method could be carried out successfully it would prove a great boon to steam users. With regard to oil, notwithstanding the very carefully thought out remarks of his friend, Mr. Spence, he was quite of opinion that the excessive use of oil in the cylinders had a most damaging effect on the boilers. Where this practice prevailed it was quite impossible to have a white coating of lime throughout the interior of the boilers. He knew of a set of tubes completely ruined in two short voyages by the excessive use of oil, and to prevent the repetition of such an occurrence the cylinder lubricators were cut off the cylinders of all the vessels of which he (Mr. Nichol) had control, and probably the gentleman who succeeded him in the superintendence and who was now in the room, would be able to say whether the cylinders were in good condition, in what condition he found the boilers, and whether the discontinuance of oil was beneficial or otherwise. Then there was another point raised in Mr. Fothergill's communication which was of considerable importance. He had a great amount of trouble in getting the white scale over the interior surface of a pair of boilers, and found ultimately that by some means or other a considerable quantity of air got into the boilers, and as air of the same temperature and pressure as the steam was considerably heavier, it formed an air cushion between the steam and water. Small cocks were inserted just above the water level by which the air which accumulated was removed, and in a short time the interior of the boilers were coated with the thin white covering they were always very anxious to obtain.

Mr. J. F. WALLIKER (Lloyd's) said, that a great part of his business consisted in examining for corrosion and pitting, and all that concerned the condition of boilers. During the last seven years his observations led him to conclude that about 75 per cent. of the boilers trading from the Tyne used zinc, and 25 per cent. patent composition or nothing at all. His opinion about the use of zinc was this, that in ocean-going steamers, not subject to very bad water, water contaminated by sewage, and other deteriorating matter, the use of zinc was not in any degree necessary, and was only a safeguard against careless or incompetent engineers. Mr. Spence said corrosion as distinguished from pitting took place in the tops of furnaces. As far as he had seen, they had never had any corrosion there, and he believed corrosion took place in tubes owing to the fact that tubes were not kept clean, the corrosion taking place under the scale. He thought tubes should be cleaned as frequently as furnaces, and after much observation his opinion was that if tubes were cleaned as freely as furnaces they would last out the boiler. Mr. Spence said that one furnace in a boiler pitted and others did not, but he (Mr. Walliker) believed very often this was owing to local causes, and in some cases owing to the over-heating caused by the firebricks on the bridge or fire lying against it, but generally of course from defective circulation. He knew of one instance of pitting in the tubes with three weeks' running. The water was fed through a great length of internal copper pipe, and this was undoubtedly the whole of the cause of the pitting which occurred only along the line of the weld. Referring back to the question of the utility of zinc, the chief engineer of one of their largest fleets told him he had taken three triple expansion engines from England on a run to Australia, one of the most trying runs any vessel's boilers might be put to, and never used anything but ordinary sea water. He occasionally skimmed the boilers, and when within three days off Melbourne, when the density rose over $\frac{3}{32}$ he used fresh water condensed from the donkey boiler. This course could be easily followed, a proper attention to the waste from leaky glands, etc., being all that was necessary. He did not use zinc, and found his boilers in a perfect condition, with a beautiful enamel on when opened up. He quite agreed with Mr. Hall that very little cylinder oil should be used, but he believed that a little oil was necessary provided that it was of a good quality.

Mr. T. Putnam said, that in taking part in the discussion of Mr. Dodds's paper he did so with all due deference to the opinions Mr. Dodds had expressed, but he thought exception might be taken to some of his theories. Take, for instance, the theory of the decomposition of sodium chloride by electrical action. If this theory held good where pitting and corrosion occurred one would naturally expect to find free hydrochloric acid in quantity, or, at least, distinct traces of it in the water. He did not think this was the case. In fact, in some samples of boiler water he had had through his hands, one sample, he thought, taken after thirty days' steaming, a second sample taken some four days later from the same boiler, not only contained no hydrochloric acid, but the increase of the sodium chloride between the taking of the first and second samples was some ten grains to the gallon. This, he thought, was a negative proof of the action of decomposed sodium chloride on corrosion as advanced by Mr. Dodds. With regard to the action of impure oils, it was a very fertile source of pitting, more especially if fatty oils were mixed with the supposed pure mineral oils. Here decomposition in the cylinders was not necessary. They could be carried mechanically with steam into the condensers, from thence to the boiler, very likely with additions from the pumps. When fatty oils got into the water in the boilers there was not the slightest doubt where they adhered to the boiler pitting would occur and to a very great extent. These fatty oils were broken up into fatty acids that attacked the metal and dissolved it, forming fatty metallic compounds as instantaneously decomposed as they were formed, liberating free acid which again attacked the boiler, and would in time work entirely through the plate. This had actually come under his observation in the case of some steam pipes where the pipes were eaten through. He thought the presence of free oxygen had a great deal to do with pitting as mentioned by one gentleman, and he submitted this, in addition to defective circulation; and also the probable effect of sodium chloride in solution at the temperature and pressure obtained in boiler, might have a great deal more to do with pitting and corrosion than some of the theories Mr. Dodds had advanced.

Mr. P. Salmon (Lloyd's) said, the writer of the paper, after having stated his own experience with regard to boiler corrosion from a chemical point of view, concluded by drawing attention to two precautions: firstly, that "great care should be taken in the selection of cylinder oils," and secondly, that the "boiler should be worked with the greatest amount of regularity possible on board ship, and the specific gravities of the water should be kept as regular as possible." He would not make any remarks upon the selection of oils, and, as to the other, he was not sure whether he quite understood the writer. In these days of high pressures engineers had almost done away with surface blowing, and many who still used surface pipes fixed them in such a manner as to render them practically useless in blowing or discharging the oily refuse kept on the surface by the boiling water. A surface pipe, to be advantageous, should be very flexible and fitted with a float so that the mouth of the pipe will always be close to the surface, and the blowing should be done frequently, but only for very short periods of time. If more attention was paid to this than is at present given much of the corrosive element would be got rid of, independent of the oil used, and less would be heard of the red or even black coating of soft slimy matter now found in many boilers, and, what is quite as bad, collapsing of furnaces would be minimised. Several cases had been brought under his notice where a vessel, after having been for some time at sea, had called at a port, remained there sufficiently long to allow the water to cool down in the boilers; the heaviest particles of oil would immediately sink and lodge on the furnace tops, and this port not being the vessel's ultimate destination, on the steam being again raised the furnaces very often caved in.

Mr. D. **Andrew** said, he could not agree with some of the speakers that it was possible to run marine engines without using oil in the cylinders. That was the result of his experience at sea, extending over a period of twelve years; and he never worked with more than 80 or 90 lbs. pressure, but at that pressure he found it utterly impossible to run without using oil in the cylinders. He did not say it was necessary to use large quantities; a very small quantity would do all that was required. He had often seen the result of using a large quantity of mineral oil. It had a very bad effect on the high pressure cylinder, softening the cylinder and causing it to wear rapidly. As a rule sufficient care was not exercised in ascertaining what oil is used as cylinder oil, owners and superintendents being in the habit of accepting what is offered without analysing the mixture to find what it really did contain. In fact, all kinds of cheap rubbish was sold as cylinder oil. He thought if more attention was paid to the quality of the oils and the quantity used in cylinders less would be heard about corrosion and pitting in boilers.

Mr. R. L. Weighton had nothing of any importance to contribute to the discussion, but he would like to ask Mr. Dodds one or two questions. There was one point which he thought was not very clearly put. He (Mr. Dodds) said there were two methods of dealing with corrosion. The first was by rendering the water what he (Mr. Weighton) should say innocuous, by introducing an element which the water attacks instead of the boiler, such as solid slabs of zinc. The second method consisted in rendering the water non-exciting. Would he make clear what he meant on page 200 when he spoke of the use of a basic solution of zinc? As the matter was put on page 200 he understood it to mean that the solution rendered the water non-exciting; was it not rather that it rendered it innocuous—was it not analogous to the case of the introduction of solid zinc? If a solution were introduced it would be the positive element and the acid attacked it instead of the iron, just as it would the solid zinc. In speaking of preparations of lime for rendering the water non-exciting, to what preparations did Mr. Dodds refer, and what preparations would he recommend for use?

Mr. Dodds said he should prefer to have his reply postponed till next meeting, so that he might consider the questions asked.

The Vice-President, at the close of the discussion, remarked that, as far as he could gather, if all that the speakers said could be substantiated a cure was arrived at. He thought there was a consensus of opinion that it was objectionable to have any oil in the boiler, and some of the gentlemen believed that there was no necessity for using oil in the cylinders; and if that could be established it eliminated one difficulty, for it could not get into the boilers from that source. Mr. Hall had told them that with a very small amount of metallic zinc and a constant application of soda he had been able to arrive at a very satisfactory result in boilers both as regarded pitting and corrosion. If these experiences could be relied on it seemed they had got to the bottom of the difficulty. Before passing on to the next paper (although Mr. Dodds had yet to reply) he thought that at this stage they might at any rate pass a vote of thanks to Mr. Dodds for his paper.

The proposal was carried by acclamation.

ON THE PROPER CAPACITY OF AIR PUMPS.

By J. H. HAMILTON, B.Sc.

[Read before the Institution on April 8th, 1889.]

A person not informed of the facts might think that the air pump, dating, as it does, from the days of Watt, should now have settled down to fixed proportions which such a mass of accumulated experience would indicate as the best.

If he were told that with jet condensation the capacity of the air pump may vary from $\frac{1}{4}$ to less than $\frac{1}{10}$th of the cylinder capacity, he would probably suggest that the special conditions under which air pumps work must vary in a similar way; but if further informed that two engineers designing air pumps to work under exactly the same conditions will often assign to them very different proportions, there is no escape from the difficulty unless he comes to the conclusion that either or both of the engineers does not know his business, or that within the limits of variation it does not matter much what size the air pump be made.

If he adopts the former conclusion he belongs to a class which is but too numerous, and probably will not give any further attention to the subject. In any case we have nothing more to do with him.

If, on the contrary, he possesses a scientific mind he will not be content to get out of the difficulty in this way, and on investigation will find that each of the engineers can justify his practice by reference to the results obtained with pumps made in accordance with it.

One will proudly show a vacuum of 27½ inches; the other may be able to record 28 inches, and it is possible that the latter may be the man who supplies the smaller pump; but, again, other results taken from their practice may reverse these figures. Here, then, is a confirmation of what he previously suspected, viz., that such a variation in the size of the pumps as is to be found in these cases does not much affect the vacuum.

This fact will require explanation, and our enquiring friend will seek one in the text books, manuals, and treatises on the steam engine.

In all, he will meet with the statement that the usual practice is to make the capacity of the air pumps between such and such fractions of the cylinder capacity "only that and nothing more" in the majority, but in one or two he may find a calculation for determining what the capacity of the pump ought to be, and as the result will not agree with practice, it will be necessary to assume that air pumps are very inefficient and to multiply the result by a factor, perhaps 2 or 3.

In none will he find a detailed account of scientific facts upon which to build a rational theory of the action of the air pump, nor any attempt to show how the vacuum depends on the capacity of the pump and the conditions under which it works. If he have the inclination and leisure he will inform himself of these facts, and it is the writer's object in what follows to state such of them as are essential to a correct understanding of the problem and to endeavour to exhibit their application to its solution.

The function of the air pump is to remove from the condenser water resulting from the condensation of steam, and when jet condensation is used the condensing water in addition, together with such permanent gases as may be liberated therein.

The permanent gases are introduced mainly by the water carrying them in solution, and generally consist of oxygen, nitrogen, and carbonic acid gases; that is, of the chief constituents of the atmosphere; but since carbonic acid is more soluble than oxygen and the latter than nitrogen, the proportions of the dissolved gases, even if they are absorbed from the atmosphere, as in the case of rain water, are different from those which obtain in the atmosphere. However, as all these gases behave like perfect gases within the temperature and pressure limits to which the following calculations apply, it is not necessary to know in what proportions they are present if only the total volume dissolved in the water is given.

Though differing in proportional composition from ordinary air, it will be convenient for shortness to refer to the mixture of gases as air. Besides the water and air there is aqueous vapour mixed intimately with the air. It is not necessary for the air pump to remove the vapour, for it cannot accumulate in the condenser like the water and air, but, nevertheless, its presence affects the working of the pump, as will be seen further on.

The pressure in the condenser and the height of the barometer determine what vacuum is possible, for the vacuum is the difference between these quantities, and as the height of the barometer and the vacuum are generally given in inches of mercury, it will be convenient to express all pressures in terms of that unit. It was shown by Dalton that for mixed gases and vapours (such as air and aqueous vapour) which had not any chemical effect on one another that the total pressure of the mixture contained in a closed vessel was the sum of the pressures which each constituent would exert if all the others could be removed from the vessel. This law of partial pressures has been amply proved, and it shows us that the total pressure in the condenser is the sum of the pressure of the aqueous vapour and that of the air.

Of these the pressure of the aqueous vapour depends solely and entirely on its temperature, and is independent of the air pressure, which in its turn only depends on the weight of the air in the condenser and on its temperature.

Thus the vapour pressure is entirely independent of the action of the air pump, while the air pressure, depending as it does on the weight of air in the condenser, is directly affected by it. To take a numerical example, suppose the height of the barometer to be 30 inches and the atmospheric temperature 59 degs. Fah., the condenser temperature 102 degs. Fah., then the vapour pressure will be 2 inches and if the air pressure be ½ inch, the total condenser pressure will be 2½ inches, and the vacuum 27½ inches. The volume of a given weight of air under these conditions will be $\frac{30}{\frac{1}{2}} \times \frac{461 + 102}{461 + 59} = 65$ times as great as it would be under atmospheric pressure and temperature, and the air pump must be capable of removing whatever air may be introduced per stroke when expanded to this volume.

The quantity of air introduced into the condenser per revolution of the engine depends on the volume of water which passes in during the same time, and on the amount of air dissolved in that water, and also, of course, on air leakage, but as this is very slight indeed when the engine is in good order, the air so introduced will be neglected for the purposes of the calculations which follow.

The volume of water introduced into the surface condenser is very slight, but a considerable amount makes its appearance in the jet condenser. As the latter was the earliest form, and is still more largely used for land engines, and since it is the practice of many marine engine builders to make the air pump so that it will work with jet condensation, this paper will be mainly devoted to the consideration of air pumps for this type of condenser.

One of the variable quantities for which provision must be made is the volume of gases dissolved in different kinds of water.

The following information on this point is obtained from Watt's *Dictionary of Chemistry*, in which the detailed analyses of a large variety of waters are given. Spring water may contain from 2 per cent. to 10 per cent. of its volume of dissolved gases, but the higher figure is due chiefly to carbonic acid, which is found in such quantities in mineral springs.

Three samples of spring water gave dissolved gases 2·46, 1·81, and 7·14 per cent., the mean being 3·803 per cent. by volume.

Nine samples of Welsh and Cumberland river and lake water gave total dissolved gases varying from 2·04 to 2·94 per cent., the mean of the nine being 2·32 per cent. of the volume of the water.

The remarkably small variation in the percentage of dissolved gases in the above nine samples would indicate that in clear river or lake water uncontaminated with sewage, etc., 2·32 per cent. by volume represents very nearly the quantity of gases dissolved.

The case is different when we take the analysis of samples from such rivers as the Thames at and below London. The dissolved oxygen diminishes, but the carbonic acid increases in a much larger proportion as the water becomes more impure.

Thus when a large proportion of the London sewage was discharged into the Thames, the volume of the dissolved gas increased from 5·2 per cent. at Kingston to 7·43 per cent. at Erith.

For such water as that a mean value of 6·3 per cent. by volume of dissolved gases would be probably not far wrong.

Ten samples of water, mostly from Continental rivers and lakes, gave total percentages of dissolved gases varying from 2·2 to 5·8 per cent., the mean value being 3·69 per cent.

The volume of dissolved gases varies least in rain water, as might be expected, and it amounts to 2·5 per cent.

For most kinds of clear fresh water, then, 4 per cent. by volume of dissolved gases would be an ample allowance; but since some waters contain up to 10 per cent., the value 5 per cent. would be a fair mean, and this figure will be used in the following calculations.

The percentage contained in sea water is said to vary from 1 to 4 per cent.; but accurate analyses of samples from different localities do not seem to have been made.

It is probable, however, that 5 per cent. is the greatest quantity in ordinary sea water.

The above figures all refer to the volumes dissolved under ordinary atmospheric conditions of pressure and temperature.

For such gases, however, as oxygen, nitrogen, and carbonic acid, the weight of gas dissolved is proportional to the pressure, and decreases as the temperature rises; thus when the injection water enters, the condenser being broken up into spray and having every facility for giving up its dissolved gases, it will only retain the proportion which it could take into solution under the temperature and air pressure conditions existing in the condenser.

The curve AB, Fig. 8, Plate XXXIX., represents the solubility of air at atmospheric pressure in water at different temperatures. The curve is carried on to C, representing a temperature of 112 degs. Fah. If 5 per cent. be dissolved at D, representing 59 degs. Fah., then 5 per cent. $\times \frac{1{\cdot}5}{1{\cdot}8} = 4{\cdot}17$ per cent. would be dissolved if the temperature were 103 degs. Fah.

But if the air pressure in the condenser be ½ inch, and the atmospheric 30 inches, the fraction of the air which will remain in solution will be $\frac{4{\cdot}17}{5} \cdot \frac{\frac{1}{2}}{30} = {\cdot}014$.

This is such a small fraction that for practical calculations it may be assumed that the whole of the air separates from the water in the condenser.

Thus for every cubic foot of water which has to be removed from the condenser there are $\frac{5}{100} \cdot \frac{461 + \text{T deg.}}{461 + 59 \text{ deg.}} \cdot \frac{30}{\text{P}}$ cubic feet of air, where it is assumed, as before, that the temperature of the atmosphere is 59 degs. and its pressure 30 inches of mercury, T being the condenser temperature and P the pressure of the air in the condenser in inches of mercury. If T be 102 degs. as before, and $\text{P} = \frac{1}{2}$ inch, then for each cubic foot of water $\frac{65}{20} = 3\frac{1}{4}$ cubic feet of air would have to be removed.

In most types of air pump the air pressure is still further reduced in the barrel of the pump; but we can conceive a type of pump in which the air and vapour pressures will be the same as in the condenser.

Such a pump is shown in Figs. 1 and 2, Plate XXXVI.

The passage A, leading from the condenser, is closed by a flap valve, which readily yields to the pressure of the water that accumulates in the passage during the delivery stroke. The water flows into the pump at the bottom of the valve, while towards the end of the stroke of the piston the vapour and air pass in through the upper corners of the valve opening.

As the pressure of the water in the passage is supposed to be sufficient to open the valve, the distribution of air and vapour pressure above the water level in the pump is the same as in the condenser.

The top of the valve must be at such a level that, on the return stroke, the water surface rises above it before the air above the water has increased much in pressure, otherwise some of the air would be liable to leak back.

As the piston comes back the vapour above the water condenses, so that its pressure is constant; but the pressure of the air increases under the isothermal compression till it is in excess of the air pressure above the delivery valve by an amount depending on the pressure required to lift the valve with the head of water above it, and at this point the discharge commences.

Water takes a considerable time to absorb air unless the latter is violently shaken up with it, and the absorption of air due to the increasing pressure as the surface of the water rises will be very slight, if any. If there is any solution at all it will take place at the surface, and as the water at the surface is discharged through the delivery valve there will be no disengagement of air from the water when the latter descends in following the piston. All the air that is in the pump enters directly from the condenser.

It is usual to express the capacity of an air pump as a fraction of that of the low-pressure cylinder, and to calculate the capacity of this pump so as to maintain a given vacuum it is necessary to make some assumption as to the quantity of steam in the low-pressure cylinder.

To be on the safe side assume that if the expansion curve were carried to the end of the indicator card it would show a terminal pressure of 10 lbs. per square inch absolute. Further, there may be 10 per cent. of the steam condensed in the cylinder, which will re-evaporate during the exhaust. The loss from clearance may amount to 3 per cent., so that if V be the volume swept by the low-pressure piston per stroke, the volume $2 \cdot \frac{113}{100} V$ of steam at 10 lbs. pressure absolute would require to be condensed per revolution. The specific volume of the steam at this pressure is about 2300, so that the volume of condensed steam will be $\frac{2 \cdot 26\, V}{2{,}300} = \cdot 000983\, V$.

The total heat of this steam will be 1,140 thermal units per lb., and if the condensing water rises in temperature from 59 to 102 degs. the volume of injection water will be 24 times as great as that of the condensed steam. The volume of water to be removed per revolution will thus be 25 × ·000983 V = ·0246 V, and if the air pressure in the condenser be $\frac{1}{2}$ inch and barometer 30 inches as before, the volume of air will be $3\frac{1}{4}$ times that of the water.

Thus the pump must be capable of removing a volume of water and air equal to 4·25 × ·0246 V = ·1045 V; that is to say, since the pump is double-acting, its capacity must be $\frac{1}{10}$th of that of the cylinder.

In most air pumps, however, the suction valves are covered with water, and the pressure of the air in the condenser must be higher than in the pump before any can be transferred from one to the other. Such would be the case for pumps like those shown in Figs. 3 and 4, Plates XXXVII. and XXXVIII. As the same reasoning applies with slight modifications to each, it will be better to take the common form, shown in Fig. 4, as a case to work out. Suppose the bucket full down and immersed in the water which covers the foot valve. The whole space between the bucket and foot valves is filled with water, and when the bucket begins to ascend there would be a perfect vacuum below the bucket valves if it were not for the evaporation of the hot water and the fact that the water enters through the foot valve.

Unless the speed of the pump is very low, the water will not enter the pump as fast as the bucket rises, as the difference in pressure between the condenser and the pump will not be sufficient to produce the acceleration required.

Suppose, for instance, that a pump with 2 feet stroke is running at 60 double strokes per minute, and that the effective area through the valves is the same as that of the cross section of the passage from the condenser, both being one-fourth of the area of the bucket. The acceleration of the bucket at the commencement of its upstroke will be (when upstroke corresponds to forward stroke of engine and $\frac{\text{crank}}{\text{connecting rod}} = \frac{1}{5}$) 47·5 feet per second, and the acceleration of the water through the passage and valves would be 47·5 × 4 = 190 feet per second; that is, nearly = 6 g, if the water were to follow up the bucket.

Thus, if the passage between the condenser and air pump were a foot long, the pressure required to put the water in the passage in motion, with an acceleration of 6 g, would be equal to that of a column of water 6 feet high, which corresponds to 5·4 inches of mercury. To this would have to be added the pressure required to force the water through the valves, and that required to put the water below the valves in motion, and the sum of these pressures would represent the difference which would have to exist between the pressure in the condenser and that in the air pump, in order that the water should commence to enter as fast as the bucket rises.

This pressure difference is much greater than any which generally occurs in practice, so that the conclusion is inevitable that as soon as the bucket begins to rise it leaves a continually increasing space between it and the water below. This space fills with vapour, and the pressure of the vapour depends on the rate of evaporation in relation to the rate at which the space between the bucket and the water increases. But the rate of evaporation is itself a function of the difference between the actual vapour pressure and the pressure corresponding to the temperature of the water; it is very rapid if this difference is large, and is very slow when this difference is small.

The vapour pressure below the bucket then is less than that corresponding to the temperature of the water; but, having regard to the agitation to which the water is subjected, and the extensive evaporating surfaces exposed by the ribs of the bucket and wall of the pump, and also bearing in mind that the evaporation of one cubic inch of water suffices to fill a cylinder 30 inches diameter × 30 inches long with saturated vapour at a pressure of ·2 inches of mercury, it would seem that the pressure of the vapour below the bucket will not be much short of that due to the temperature.

The water which accumulated in the passage from the condenser during the down stroke of the bucket has meanwhile been flowing slowly through the valves into the pump, and if the pressure difference be sufficient, so much will have passed into the pump that the level of the water in the passage falls till it touches the top of the passage, where the latter enters the pump, as represented in Fig. 4, Plate XXXVIII.

The momentum of the water passing through the valves helps to keep them open, and air and vapour pass along the top of the passage, mixing with the water, which has still some onward motion, the vapour being condensed and the air bubbling up through the water above the valves.

This air carries up some vapour with it, and the agitation increases the evaporation, so that when the bucket has arrived near the top of its stroke, at which point it is moving very slowly, the vapour pressure cannot be much less than that due to the temperature.

If the water were at rest, the condition that the air should pass up through it would be that the pressure of the air below should be greater than that of the air in the barrel of the pump by an amount equal to the pressure due to the column of water through which it has to pass.

Just before the air first begins to pass through the valves there is a water current in the upward direction, owing to the greater air pressure in the condenser; but immediately the level of the water falls below that of the top of the passage and the air passes along, the pressure below the foot valve becomes almost equal to that in the condenser, and the water comes gradually to rest, since the head of water above the valves checks the flow. A reverse current, downwards through the valves sets in, and the valves close, preventing further entrance of air. From this it would result that the last portion of the air will have entered about the time when the water is at rest, and the pressure of the air in the barrel of the pump will be less than that of the air in the condenser by an amount due to the head of water above the valves.

The capacity of a pump required to give any vacuum which may be fixed on will, on the assumption that the action is somewhat as above-described, be as follows. For the sake of comparison, the temperatures will be taken the same as before, viz.:—

Temperature of injection water ... 59 degs. Fah.
,, ,, discharge to hot well 102 ,,
Barometer ... ... 29·5 inches.
Air dissolved in water at 59 degs. and 30 inches pressure
= 5 per cent. by volume.

Then the volume of water to be removed per revolution will be as before, ·0246 V, where V is the volume swept out by the low-pressure piston per stroke. If p be the pressure of the air (in inches of mercury) in the barrel of the pump when the bucket is full up, then the volume between the surface of the water and the bucket should be

$$\cdot 0246\,V \times \frac{5}{100} \times \frac{461 + 102^\circ}{461 + 59^\circ} \times \frac{30}{p} = \cdot 04\,\frac{V}{p}.$$

Thus the capacity of the pump should be $\left\{\cdot 0246 + \frac{\cdot 04}{p}\right\} V.$

To find the vacuum in the condenser corresponding to this capacity, the height of the water over the foot valve when the bucket is full up must be known. This height is the sum of the height due to clearance and that due to the quantity of water which enters at each stroke.

The former may be taken at 6 inches for a medium sized pump, and the latter will depend on the diameter of the pump in relation to that of the low-pressure cylinder. If the diameter of the pump be one-half of that of the low-pressure cylinder, the water which enters at each stroke will raise the level by ·0246 × 4 S, where S is the stroke of low-pressure piston. If S be 4 feet this becomes ·0246 × 16 = ·3936 feet = 4·72 inches. The total height of the water will then be 10·72 inches, giving a pressure equivalent to ·78 inch of mercury, or say $\frac{3}{4}$ inch.

The absolute pressure in the condenser will then be 2 inches vapour pressure + $(\frac{3}{4} + p)$ inches of air pressure, and the vacuum will be = height of barometer $- (2 + \frac{3}{4} + p)$.

The curve in Fig. 9, Plate XXXIX., shows the way in which the vacuum is related to the capacity of the pump, as calculated from the above formula. The barometric pressure is assumed in this case to be 29·5 inches, and the abscissæ represent pump capacity as a fraction of the cylinder capacity. Thus when the pump is ·04 or $\frac{1}{25}$th of the cylinder capacity, the vacuum is 24·15 inches, which increases to 26·52 inches when the capacity of the pump becomes $\frac{1}{5}$th of that of the cylinder.

The capacity is supposed to be varied by keeping the diameter the same and varying the stroke, so that the depth of water over the valves is the same in all cases. If, however, the ratio of diameter to stroke be constant for the different sizes the larger sized pumps would give slightly better vacua relatively to the smaller sizes.

There is, however, in addition to this a good reason for not reducing the diameter too much, for in such a pump as that shown in Fig. 4, Plate XXXVIII., the area through the foot valves cannot be made more than a certain fraction of the bucket area, and this fraction decreases generally as the diameter decreases; but even assuming it constant for different diameters, it is evident that the pressure required to force the water through the valves will be greater for the smaller diameter than for the larger.

Suppose the air pump, considered above, were to run at 60 double strokes per minute, and that the effective area of the foot valves is $\frac{1}{4}$th of the bucket area, then the mean speed of the water would have to be $\frac{4{\cdot}72 \text{ inches} \times 4 \times 120}{60 \times 12} = 3{\cdot}15$ feet per second, and it would require a pressure of ·135 inch of mercury to produce this velocity. If the velocity be doubled by reducing the area, the pressure would be ·54 inch in addition to the pressure required to balance the water column and overcome friction.

The fluid friction will vary approximately as the square of the velocity, and ·8 inch would probably not be too much difference of pressure to allow for forcing the water through the valves with a velocity of 6·3 feet per second, and ·2 with a velocity of 3·15 feet per second.

In the former case if the difference in the level of the water in the condenser and in the air pump be equivalent to a pressure of ·75 inch, then the air pressure in the condenser must not be less than ·75 + ·8 = 1·55 inches, making, with the vapour pressure of 2 inches, a total absolute pressure of 3·55 inches. If the pressure in the condenser falls below this the pump will not take a full charge of water, and will draw no air, with the result that the air pressure will slowly increase until it is sufficient to force the water through the valves at a greater rate than that at which it accumulates in the condenser. The water level in the latter will thus gradually fall, and air will begin to pass into the pump as well as the water. As soon as the pump commences to draw air the air pressure in the condenser will begin to fall, and will keep on falling till the reduced air pressure is not sufficient to force the proper charge of water through the valves while the bucket makes its upstroke. The water and air will then accumulate in the condenser as before, and the cycle of changes will be repeated.

This explains the observed fact that in many condensers the vacuum slowly diminishes till a minimum value is reached, and then begins gradually to rise till a maximum value is attained, and then begins to fall again. The variation may amount to ½ inch or more, or it may be less, but it has a regular and definite period when the engine is working regularly.

If the air pump is much too large for the work which it has to do, as is the case with pumps fitted to surface condensers, and having proportions suitable for working with jet condensation, it may happen that when the vacuum is at maximum value as above described the pumps will not take a charge of either water or air for several strokes.

This is easily explained when it is considered that the pressure required to raise the valves is greater than that required to keep them open when once off their seats.

Suppose the pressure in the condenser to be at its greatest, the valves open at each upstroke, and the pump draws water and air. The quantity of the former is insignificant, and as the pump is large a few strokes will probably reduce the pressure in the condenser to that just required to lift the valves. The next will be the last effective stroke, for the air in the condenser when the following stroke occurs will not have sufficient pressure to open the valves, and a few idle strokes may take place before sufficient air pressure has accumulated to open the valves again.

The maximum attainable vacuum would in this case not be increased by increasing the size of the pump, but would be limited by the pressure required to lift the valves. If this pressure be p, then the maximum vacuum would be height of barometer — vapour pressure — p.

Vertical air pump without foot valves. In the preceding case the operations taking place above the bucket were not considered, as the vacuum depends only on the action below the bucket. It is true that if there were any leakage from the atmosphere into the space above the bucket the pump would require more power to drive it, but such leakage would not affect the vacuum so long as the bucket valves remain well covered with water.

The case is entirely different when the foot valve is omitted, since in such a pump the vacuum depends chiefly on the perfection of the vacuum in the space between the bucket and delivery valves. If every joint between this space and the atmosphere is well covered with water there will not be any air leakage, and the attainable vacuum can be found in much the same way as before.

Suppose the bucket fall up as shown in Fig. 5, Plate XXXVIII. If water is to pass the bucket valves the level of the water inside the barrel will have to be considerably above the bottom of the barrel.

As air passes into the barrel during the latter part of the upstroke the level of the water in the condenser will not be much above the bottom of the barrel. The difference of head A B represents the excess of the air pressure in the condenser over that in the barrel of the pump. Leaving inertia effects out of account for the moment, it is evident that as the bucket comes down the air below it will be compressed unless its pressure is sufficient to lift the bucket valves against the pressure of the water above them. By the time it has acquired this pressure the surface of the water inside the barrel will be lowered by an amount representing the increase of the air pressure, as indicated by the line at C. After this the level may tend to rise slightly, since the air pressure required to open the bucket valves is greater than that required to force the air through the water after the valves are open, but on the other hand it is not to be forgotten that as the air passes into the upper part of the pump the pressure in that part rises from that due to the vapour pressure to the sum of the air and vapour pressures. The relative effects due to each of these forces will depend on the size of the pump and other special conditions.

If the pump is to take a charge of water as well as air the level of the water in the barrel must be more or less above the level of the top of the bucket when the latter is full down.

Just as the last portion of air is about to pass the valves and the water below touching them, the difference between the air pressure in the air pump and that in the condenser is represented by the difference in level of the water above the bucket and that in the condenser.

Now if the water were not to yield to the pressure of the descending bucket on its upper surface (in other words, if it were to act as if there were a foot valve), this difference in level would be the sum of (1) height of water above bucket due to clearance; (2) height by which the water charge would raise the level; (3) height of top of bucket when full down above water in condenser. Comparing this with the difference in pressure which was found to exist in the case of a pump with a foot valve, viz., height of water above foot valve due to clearance + height due to entrance of water charge, we see that in the case of the pump without a foot valve the loss of pressure between the condenser and pump would be greater than the loss in the case of a pump with a foot valve by the height of the water above the bucket due to clearance between it and the delivery valve. (This is on the assumption that, for the pump without a foot valve, the difference in level between the water in the condenser and the top of the bucket when full down is the same as the height of the water above the foot valve due to clearance in the pump provided with a foot valve.)

It would follow that the attainable vacuum would be less by this amount when a pump without a foot valve is used instead of an otherwise exactly similar pump with a foot valve.

The loss of pressure will be greater when allowance is made for the yielding of the water below the bucket.

The determination of the extra height of water in the barrel which would be necessary in order that a full water charge should pass the bucket valves is rather complicated, and could not be solved except in special cases. The following, however, is a convenient way of considering the action.

Let the downward velocity of the water below the bucket be u and that of the water above the bucket be U. When the two surfaces of water come in contact after impact, both the water above and that below will move downwards with a common velocity (less than U and greater than u) depending on the relative mass of water above and below the bucket. This velocity will be less as the mass below the bucket is increased, and would be practically constant were it not for the resistance in passing the valves and the decreasing difference in level of the water in the condenser and in the pump. The bucket is, however, moving downwards with a velocity which is greater at first but gradually diminishes as it approaches its lowest position, so that some time before it arrives at the bottom of its stroke it will be moving with the same velocity as the water, after which no water will pass up through the valves, and the latter will close.

The amount of water which passes the valves between the time of impact and that at which the bucket has the same velocity as the water will represent the water charge per stroke.

It may be observed that in this case, as well as in that of the pump with foot valve, the water charge will be in excess of that due to accumulation of condensed steam and condensing water, since, while air only is passing up through the valves, some water will leak back.

Such a calculation as indicated above, with its necessary corrections for friction, change of direction of flow, and effects due to the striking of the water by the ribs, boss, etc., of the bucket, would, of course, be out of the question for general practical purposes; but we may note that some results of the preceding are:—(1) The effective capacity of an air pump without foot valves is reduced by the volume of water which fills a length of the pump equal to the extra height at which the level of the water in the barrel must stand in order to provide for the yielding of this water under the impact of the bucket and the water above it; (2) this yielding may be reduced by increasing the mass of the water which is set in motion by the impact, and also by increasing the velocity of any portion of this water relatively to the velocity at the plane of impact, or, more concisely, by increasing Σmv where m is the mass of the portion which is moving with the velocity v.

Thus a good construction would be to reduce the diameter of the chamber into which the lower end of the pump projects so that the level of the water in that chamber would rise at a greater rate.

Other effects due to inertia and oscillation of the water cannot be considered here.

The speed of the pump is an important factor, and the period of free oscillation of the water would affect its working to some extent, but it is probable the vacuum, as calculated on the above principles, would not be very far wrong. In pumps working in connection with surface condensers the quantity of water to be removed at each stroke is insignificant, and if the bottom of the bucket valve strikes the water a few inches from its lowest position enough water will probably be passed.

The working of pumps of marine engines must be affected by the rolling and pitching of the vessel; drawing a large charge of water sometimes and none at others.

The common horizontal double-acting pump, with the suction valves below, is said to be not very efficient, and this is probably the case. One of its disadvantages is that the height of the water over the foot valves is greater than for vertical pumps, and the loss of air pressure between the condenser and the pump will be greater in consequence. Suppose that at the end of the suction stroke the height of the water over the valves was 13·6 inches in excess of that over the foot valve of the vertical pump (Fig. 4, Plate XXXVIII.), with the same discharging capacity the vacuum maintained by the horizontal pump would be less than that given by the vertical one by 1 inch.

This would not probably represent the whole difference between results from the two types, for the horizontal pump is more liable to leakage as usually made, and the fall of the water on to the foot valves, when the latter are about to open, is another defect.

However, it possesses this defect in a less marked degree than the pump shown in Fig. 7, Plate XXXVII., while the latter, being altogether a unique example of bad design, forms a good illustration of what an air pump ought not to be like.

When the plunger is drawn out the water above and around it falls on to the foot valves, which ought to be just opening at this time. It will require a greater difference of pressure to lift them against this impact, and, as in the ordinary horizontal pump, the static head will be large too. The stuffing box affords a tolerably easy means of access for air, and any calculation would in all probability give results considerably wide of the mark on account of leakage from it.

Before leaving the subject of the capacity of air pumps working with jet condensation, it may be of interest to consider how a change in the working conditions affects the attainable vacuum.

If the temperature of the condenser be altered, as would be the case if the point of cut-off of the steam be changed without altering the quantity of injection water, the vacuum would be altered by an amount equivalent to the difference in the vapour tensions, due to the initial and changed temperatures. If the cut-off be earlier the temperature will be lowered and the vacuum increased, and if later, the temperature will be raised and the vacuum diminished.

If the temperature of the injection be varied without altering its quantity, there will be a similar consequent variation in the temperature of the condenser.

If the quantity only of the injection be increased, more water and air will have to be removed, and the vacuum would be lowered in consequence of the increased air pressure in the condenser, and it would be raised owing to the reduced temperature of the discharge; the change in the vacuum would thus be the difference in these effects.

Engines built for tropical countries may have to work with the injection water at 100 degs. Fah. or more. As such cases occur sometimes in practice, the following example is worked out for a single-acting vertical pump with foot valves:—

Suppose the temperature of injection water to be 100 degs. Fah., the temperature of discharge = 120 degs. Fah., the quantity of air dissolved being 4 per cent. by volume at 100 degs. Fah., and the atmospheric pressure 30 inches. Let us assume as before that the volume of water resulting from the condensation of steam is ·000,983 V per revolution, V being the volume swept by the low-pressure piston per stroke. The temperature of the condensing water rises by 20 degs., so that the water required is 52·5 times that of the condensed steam. The volume of water to be removed per stroke is $53{\cdot}5 \times {\cdot}000983\ V = {\cdot}0526\ V$.

Now this will fill the pump to a greater depth than in the former case, and the loss of air pressure between the condenser and the barrel of the pump will in consequence be greater. Suppose it is 1 inch instead of ·75 inch.

If p be the air pressure in the barrel of the pump, then the latter should have a capacity above the water level of

$$\cdot0526V \times \frac{4}{100} \times \frac{461 + 120}{461 + 100} \times \frac{30}{p} = \cdot0644\,\frac{V}{p}.$$

Let k be the capacity of the pump expressed as a fraction of that of the cylinder. Then

$$kV = \cdot0526V + \cdot0644\,\frac{V}{p};$$

whence

$$p = \frac{\cdot0644}{k - \cdot0526}.$$

The vapour pressure corresponding to 120 degs. is 3·42 inches, and the pressure in the condenser will be 3·42 inches + 1 inch + p inch and the vacuum, with the barometer at 30 inches, $30 - (3{\cdot}42 + 1 + p)$. Putting $k = {\cdot}08, {\cdot}12, {\cdot}16, {\cdot}2, {\cdot}24$ in succession we shall find the corresponding values of p to be 2·35, ·955, ·6, ·43, ·35, and the vacua 23·23, 24·62, 24·98, 25·15, 25·23. The result is shown graphically by the curve, Fig. 10, Plate XXXIX.

To obtain the above results in practice the area through the valves would have to be made larger in proportion to the larger volume of water to be dealt with.

If the injection be clean spring water the vacuum attainable ought to be greater than the above, but if on the other hand it be turbid river water the vacuum would perhaps be less, since in the former case the dissolved gas would probably not amount to more than 3 per cent. by volume, while in the latter it might reach 8 per cent.

It will thus be seen that in addition to the numerous observations which are necessary to give complete information as to the working of any air pump the percentage volume of dissolved gases would have to be known. It is, however, not a difficult matter to find this volume with an accuracy sufficient for all practical purposes.

It is more difficult to reconcile theory and practice when the surface condenser and the capacity of its attendant air pump are to be discussed than it is in the case of jet condensation.

The practice of most engineers seems to be to make the air pump large enough to act properly with jet condensation, but smaller than the usual size of pump fitted to jet condensers.

In such a case it may be interesting to note what vacuum should be obtained when working with jet condensation. Thus if the temperatures, etc., are the same as those used in the calculation of the curve in Fig. 9, Plate XXXIX., it will appear on reference to that curve that ·08, or $\frac{1}{12\cdot5}$, (a common proportion), might be expected to give a vacuum of 26 inches, always supposing the valves were large enough in area for working with jet condensation. A much smaller pump would doubtless give as good results when working with surface condensation if an automatic arrangement be employed to prevent the feed pump drawing air, and if the joints and piston rod glands are tight.

If, however, the feed pump worked by the engine draws direct from the hot well, or from the air separating vessel, it seems inevitable that some air must be drawn in. This air being agitated and thoroughly mixed with the water on its passage to and from the feed pump will be dissolved more or less. Some which does not dissolve will find its way into the air vessel, on the feed delivery, and some may pass along with the water without dissolving. Whether this last action takes place or not depends a good deal on the design of the feed discharge passages into and out of the air vessel, and of course also on the quantity of air; for if this is excessive the water level in the air vessel will be kept near the top of the outlet pipe, and portions of air must pass out occasionally as the water oscillates about.

It is possible, however, for some air to pass in bubbles along the pipe and be carried past the air vessels, for the following reasons:—Air bubbles rise upwards through water, because their specific density is small. The velocity with which they rise depends on the difference between their density and that of the water.

When the air and water are subjected to, say, a pressure of 160 lbs. per square inch, the difference in their density is much less than when under atmospheric pressure. It will result that the upward velocity of the bubbles will be less under these conditions, and it may happen that the horizontal currents will carry the bubbles along so fast that they will not have time to rise above the level of the top of the outlet pipes before arriving at its mouth.

Attention should be paid to this fact in designing air vessels, as it is better for all the undissolved air to be liberated in them.

As an example of how air in the feed water will affect the vacuum, suppose the water going along the pipes to the boilers to contain the maximum quantity of dissolved air possible under the temperature and pressure conditions existing in the pipes. This would be, at a temperature of 102 degs., and under atmospheric pressure 1·52 per cent. by volume, but if the pressure be 165 lbs. per square inch, or an absolute pressure of 12 atmospheres, the quantity would be 18·24 per cent. by volume after the air is reduced to atmospheric pressure. If the air pressure in the air pump be $\frac{1}{60}$th of an atmosphere the above would expand to 1094·4 per cent., or the volume of the air would be about 11 times the volume of the condensed steam. If the volume of the condensed steam be taken as ·000983V, the air pump would have to remove a volume = ·0118V per revolution; that is to say, its capacity should be about $\frac{1}{90}$th of that of the low-pressure cylinder.

It is not suggested that this is an accurate representation of what occurs generally, but serves to show how a small quantity of air introduced by the feed pump affects the vacuum.

If the feed arrangements preclude the possibility of any air being introduced except such as may be taken into solution in the hot well (and this would be a very small quantity, probably not more than ½ per cent. by volume at atmospheric pressure) the only manner in which air can find its way into the condenser would be by leakage.

It is possible that the decomposition of the cylinder lubricant may evolve some permanent gases, but there does not seem to be any information on this point. If the air pump does not maintain a good vacuum when made of sufficient size and having sufficient area through the valves, the result must be due to leakage into the pumps or into the condenser and parts in communication with the latter. It is of course impossible to predict what will be the loss by leakage, but it may not be without interest to glance at the various places in which it may occur.

In the pumps shown in Figs. 1 and 2, Plate XXXVI., the discharge valves and the joints of their seats are well covered with water, so that there will be no air leakage at these places.

There is a possibility of leakage at the end cover, but these joints are easily made tight. Leakage at the gland would be nearly sure to take place unless a water seal is used. The vertical single-acting pumps shown in Figs. 3 and 4, Plates XXXVII. and XXXVIII., are in the same way liable to leakage at the joints between the condenser and pump and at the lower doors, but these joints are likewise easily made tight.

In the pump shown in Fig. 4, Plate XXXVIII., however, there is a chance of leakage at the joint A. The air would pass down between the liner and outer casing and into the space below the foot valves. It is also likely that there would be leakage at the joint B into the space above the bucket, and although this would not affect the vacuum it ought to be avoided as increasing the work which the pump has to do. Both of these defects might be remedied by making the retaining lip C an extension of the cast iron casing, as shown by dotted lines, instead of casting it on the delivery valve seating, or if it is necessary to give stiffness to the latter the cast iron extension may be used in addition.

A similar provision is of much more importance when the pump is without foot valves, as any leakage into the space above the bucket affects the vacuum. The water should also have access to the rod below the stuffing box, as there is a danger, that if the joints between the cover and the valve guard, and between valve guard and valve seating are water tight, there will be an air leakage from the stuffing box between the surface of the rod and the various parts it passes through.

An air pump in which there does not seem to have been provision made for this purpose, and in which the retaining lip was cast on the delivery valve seat, kept a tolerably good vacuum, 26 inches at full speed, 88 revolutions, but when running at 40 revolutions the vacuum fell to 16 inches, a result no doubt due chiefly to leakage, though as we have seen, the speed may independently of that be a factor in determining the efficiency of such an air pump.

If the speed of the engine be varied without varying the point of cut-off or throttling, so as to give the same steam lines on the indicator card, and if the temperature of the discharge from air pump be kept the same, then the leakage per unit time being supposed to diminish as the difference between the atmospheric and internal pressures is decreased, the loss by leakage should be at one-half full speed slightly less than twice as much as for full speed; that is, if the pressure in the condenser or pump be raised by ½ inch by leakage when the engine is going full speed, then the pressure would be raised by very nearly 1 inch when going one-half full speed.

Such a set of conditions, however, is not likely to be fulfilled, as the steam has usually to be throttled or cut-off earlier to reduce the speed. Now, in this case the leakage at the low speed may be greater than above indicated, for the steam line on the low-pressure card will fall below the atmospheric line sooner; and if any of the leakage takes place at the low-pressure piston rod gland, the leakage into the cylinder will begin at an earlier point in the stroke, and be more rapid also, since the steam line falls more quickly. The loss by leakage in such a case would be more than twice as much at one-half as it would be at full speed.

The depreciation of the vacuum by lowering the speed is then generally a sign of leakage if the fall is due to an increased pressure of air.

It must be kept in mind that in the case of an injection condenser, when the speed of the engine is lowered without altering the injection valve opening, that the flow of injection water being approximately constant and the terminal pressure of the steam lower, while the volume passed into the condenser per unit of time is also diminished, the temperature of the discharge, and consequently vapour pressure, will be less than at full speed, and this will tend to increase the vacuum.

On the other hand, the quantity of water and air to be removed per stroke of the pump will be greater, and the air pressure will rise on this account and lower the vacuum.

Such effects must, of course, be allowed for before it is determined whether the fall in the vacuum is due to leakage or not.

Similarly, if the speed of an engine exhausting into a surface condenser be reduced, the temperature of the discharge will be altered, for not only is the terminal pressure of the steam lower, but in passing over the tubes it remains longer in contact with them; so that, even if the quantity of water passing through the tubes were reduced in the same proportion as the weight of steam to be condensed, the temperature of the vapour would be lower, and a better vacuum would be obtained.

In most cases, however, the quantity of circulating water will not diminish in proportion to the speed, even when the circulating pump is driven by the main engine, for, if the inlet to the circulating pump be throttled, it will not take a full charge at the high speed, though it may at the low. This would further increase the vacuum by lowering the temperature, and consequently the vapour pressure.

In well-constructed engines there does not appear to be much loss by leakage, and constructors who have most confidence in their work and in those who are to have the care of it might reduce the size of air pumps working in connection with surface condensers, since they are unnecessarily large as generally made.

It is believed that if the leakage be slight the smaller limit to the usual practice (viz., one-tenth to one-eighteenth of the low-pressure cylinder capacity), would give good results

In calculating the vacuum by the method above given a high terminal steam pressure was assumed, with a view to render the capacity of the air pump suitable to the maximum work which it has to do, but a more usual terminal pressure, at least in compound and triple engines, would be 4 to 5 lbs. absolute, and a condenser temperature of 80 degs. Fah., with injection at 55 degs. Fah., is not uncommon. The air dissolved is also not likely to be more than 3 per cent. for spring water. The curve (Fig. 11, Plate XXXIX.), represents the results of calculations made with these data to represent ordinary working conditions.

Now in fixing on the best capacity for an air pump, one of the factors to be taken into account is the power required to drive it, for if this be increased so that the extra power would only balance the gain in power resulting from a better vacuum, due to a larger pump, it would not be any advantage to increase the size of the pump.

Figs. 12 and 13, Plate XXXIX., are theoretical cards from the spaces above and below the bucket of a vertical single-acting air pump with foot valves. They are constructed in accordance with the assumptions made about the action of such a pump. As the bucket descends the air below it is compressed but the pressure above it is constant till that air begins to pass through the valves. This part of the stroke is represented by the AB in Fig. 12, and by GH in Fig. 13. The discharge of air and water through the bucket valves occupies the remainder of the stroke, and is represented by the lines BC and HKLM, there being a sudden rise of pressure at KL owing to the valves striking the water below.

On the upstroke the air is compressed above the bucket as shown by the line CD. (The large scale necessary to show the lower part of the cards clearly prevents the upper part being represented.) The pressure below the bucket is constant till the air begins to enter, and this part of the stroke is represented by the line EF. During the remainder of the stroke the pressure rises slightly as indicated by the FG.

These cards are for a pump with a capacity of $\frac{1}{6\cdot25}$ of that of the cylinder, and the accented letters mark corresponding points in the cards of a pump of one-half that size or $\frac{1}{12\cdot5}$ of the cylinder capacity. The difference in the areas of the cards is shown by the dotted shade lines.

It will be seen that the total power (exclusive of friction) required to drive one pump differs but slightly from that required to drive the other. The friction of the large pump would, of course, be greater than that of the small pump, probably twice as great, if the capacity is altered by altering the stroke.

For a pump working under the conditions set forth in Fig. 11, Plate XXXIX., the increase in vacuum gained by making the capacity of the pump = $\frac{1}{6\cdot25}$ instead of $\frac{1}{12\cdot5}$ would be ¼ inch, and if the back pressure on the piston be lowered by the same amount the gain in power would be equal to ¼ inch × 12·5 = 3·1 inch pressure acting on the bucket of the smaller pump during both strokes. If then the loss of power by increase of friction, etc., is not greater than this there would be a gain of power to the engine by increasing the size of the pump, but that gain would be so trifling that it need not be considered if there be no other reason for making the pump larger.

If the conditions be such as described in Fig. 9, Plate XXXIX., the gain of power would be greater, for the vacuum would in this case be increased by ½ inch instead of ¼ inch.

Lastly, under such conditions as those from which the curve in Fig. 10, Plate XXXIX., is plotted, the gain in the vacuum would be 1¾ inches by increasing the size of the pump from $\frac{1}{12\cdot5}$ to $\frac{1}{6\cdot25}$ of the cylinder capacity, and it would probably be better in this case to increase the size of the pump still more.

One of the advantages to be gained by making the pump large in all cases is the provision this course affords for maintaining a good vacuum, even when there is leakage into the pump, condenser, pipes, or cylinder.

One of the disadvantages is that if the capacity be increased by increasing the length of the stroke the bucket strikes the water when moving with a greater velocity, and the strain on the bucket and valves is greater both near the lower and upper end of the stroke. If the capacity be increased by increasing the diameter only, the bucket will strike the water with less velocity, since in this case the water charge of the pump fills the barrel to a less height, so that the pressure intensity is less than in the case of the smaller pump; but it is more difficult to make the parts strong enough to stand a given pressure per square inch on account of their larger diameter. If both the stroke and diameter be increased, then the effect will be intermediate between those described.

Air pumps attached to surface condensers have an advantage in this respect, for in many cases the water charge will only fill the barrel to a height of ¼ inch to ½ inch, while with jet condensation this may become 5 inches, more or less.

From this it would follow that a bucket speed which would be disastrous to a pump of the latter kind might be quite safe for one of the former, but would not be safe if it had to work with jet condensation.

The question of the strength of the working parts is, however, beyond the scope of this paper except in so far as it limits the bucket speed, for in the theory here advanced there is an assumption all through that the speed is kept within moderate limits, otherwise it might require some modification.

As an example take the assumption that during the upstroke of such as those shown in Figs. 3, 4 and 5, Plates XXXVII. and XXXVIII., the evaporation proceeds at such a rate that the vapour pressure is not much short of that due to the temperature. It is evident that this will be more nearly correct for low speeds than for high ones, but the actual error can only be found by taking cards off the pumps at work. It is not sufficient to know the rate of evaporation from a free still surface when the vapour pressure is less than that due to the temperature by a given amount, for the agitation of the water introduces an unknown factor.

The correctness of other assumptions can likewise only be tested by comparing the results of trials with those which could be predicted by the foregoing; and with this object in view, the writer has consulted all the published reports of steam engine trials which he could find, but owing to the fact that these trials were directed towards testing the engines as heat engines, some data—essential for arriving at a knowledge of the action of the air pump—were omitted.

This will not be a matter for surprise if the tabulated list of requisite data given at the end of this paper be read through, as such a collection would only be brought together if a complete test of air pump performance was aimed at. Such tests may have been made, but the writer is not acquainted with any, and he regrets that in consequence he has had to abandon his original intention of comparing predicted with actual results, and so determining with what degree of accuracy the preceding methods are applicable to practical work.

Although such rigid tests cannot here be applied, it is hoped that the facts stated and the conclusions arrived at will help to explain the anomalies to be found in current practice. Thus it has been shown that under ordinary conditions if the capacity of the air pump be considerably less than usual, the bad results will be marked. If, on the other hand, the proportions vary between the usual limits, the results will vary too, but in ordinary cases the variation in results will be slight, though under some circumstances pumps with nearly the minimum usual capacity will give appreciably worse results than if they had been made with the largest capacity. If the capacity be increased beyond the limits common in practice the result will not be appreciably better.

The variation in dissolved gases in the temperatures of the injection water and of the discharge in the terminal pressure of the steam, and the quantity evaporated during exhaust, all have an influence on the results achieved by the air pump.

As the working conditions are seldom known with accuracy beforehand, the practical engineer will make the air pump of such a size that it will maintain a good vacuum under the most disadvantageous circumstances in which it is likely to be placed.

If the conditions be such extreme ones as those which are assumed in the calculation of the curve in Fig. 10, Plate XXXIX., he will be justified in making the pump one-fourth of the cylinder capacity, but if it is certain that the most adverse conditions will be those from which Fig. 11, Plate XXXIX., is obtained, there is nothing to be gained by making the pump more than one-eighth of the cylinder capacity.

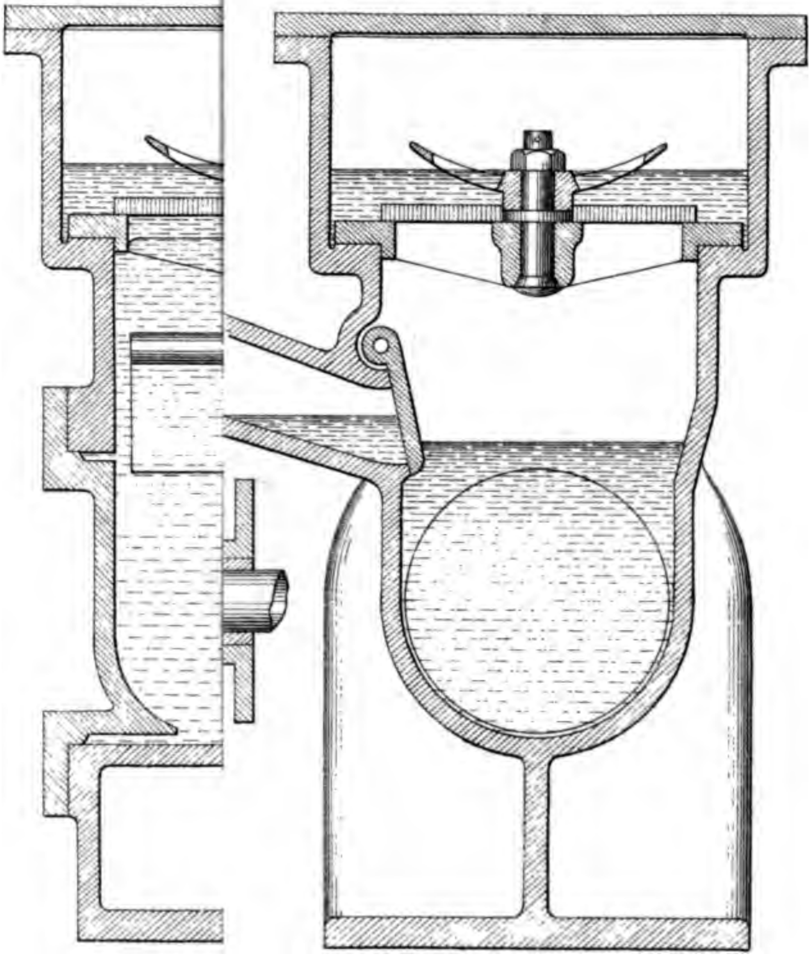
If the preceding methods and results shall give some assistance to any who may have to design air pumps to work under special conditions, or if they give rise to a discussion which shall prove a valuable addition to the present scanty literature of the subject, the object of this paper will have been attained. It is granted that there is no great economy to be expected from improvements in the common type of air pump. If any improvement can be realised, it will be very slight, and negligible in comparison with those effected by modern developments of the steam engine. Nevertheless, to the true engineer nothing which concerns his work can be a matter of indifference, and with the writer's belief that there are many such in this Institution comes the conviction that they will not look upon the time which they have spent on the consideration of this question as thrown away.

Data required to give full information on any air pump performance :—

1.—Drawings of pump, valves, and passages, and showing indicator connections.
2.—Particulars of low-pressure cylinder.
3.—Cards from low-pressure cylinder during trial, and
4.—Cards from lower and upper ends of pump, to correspond.
5.—Speed of engine.
6.—Air dissolved in water.
7.—Height of barometer.
8.—Vacuum.
9.—Temperature of condenser.
10.—Temperature of injection, when jet condenser.
11.—Temperature of discharge.
12.—Quantity of discharge (if possible).

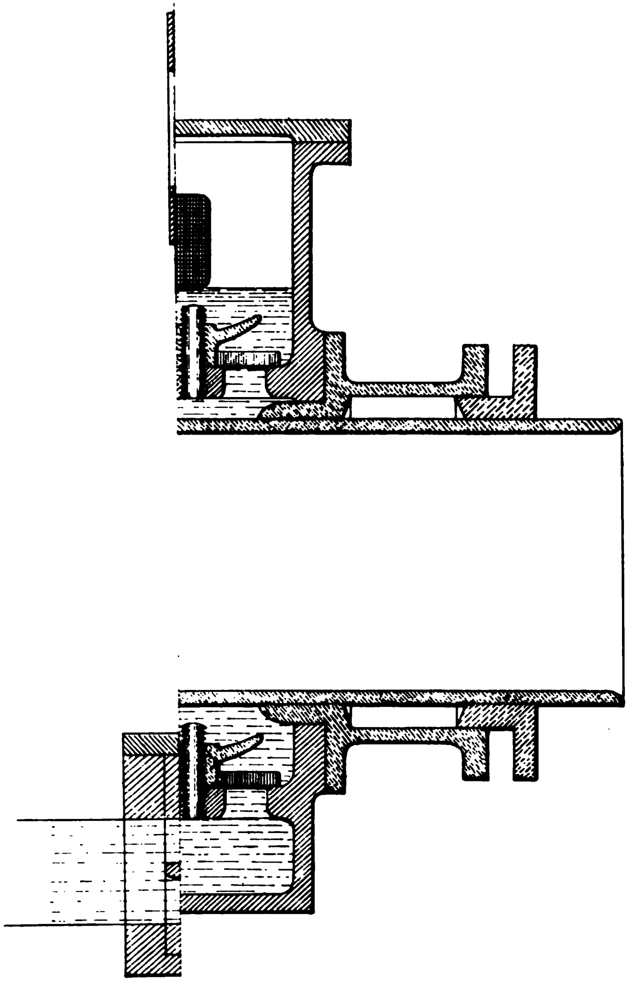
"Air Pumps."

FIG. 2.



Vol V Plate XXVII

ir Pumps."



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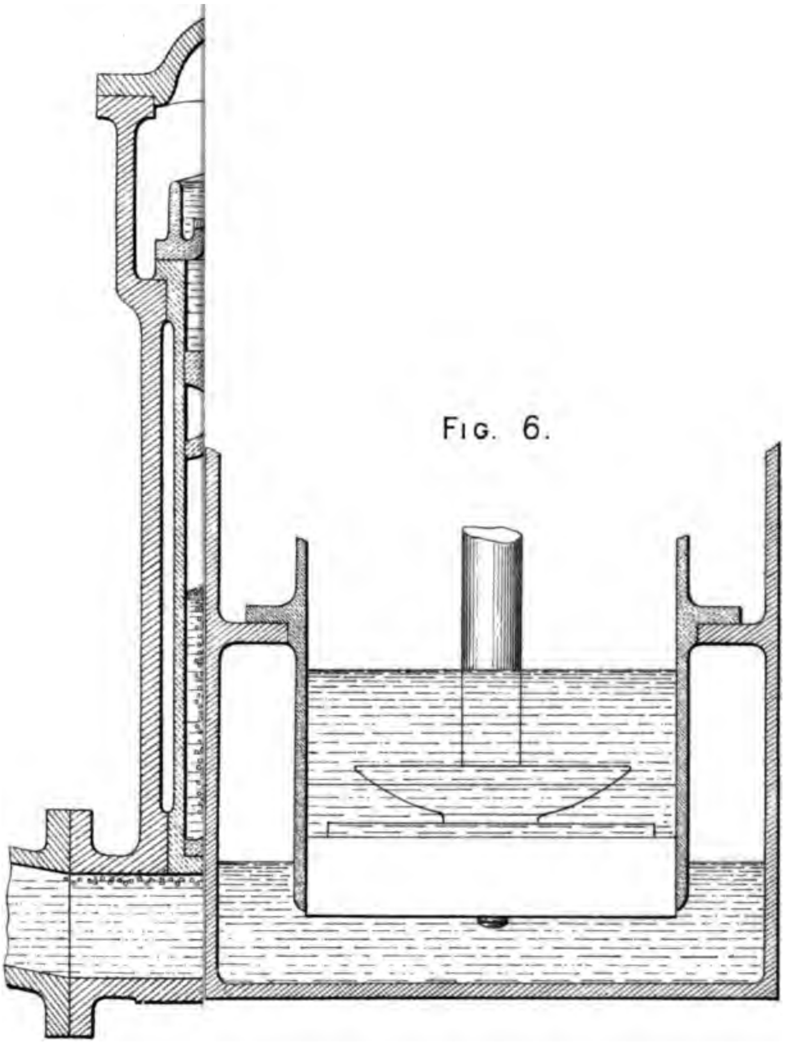
of Air Pumps."

FIG. 6.



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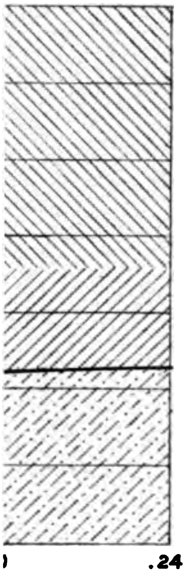
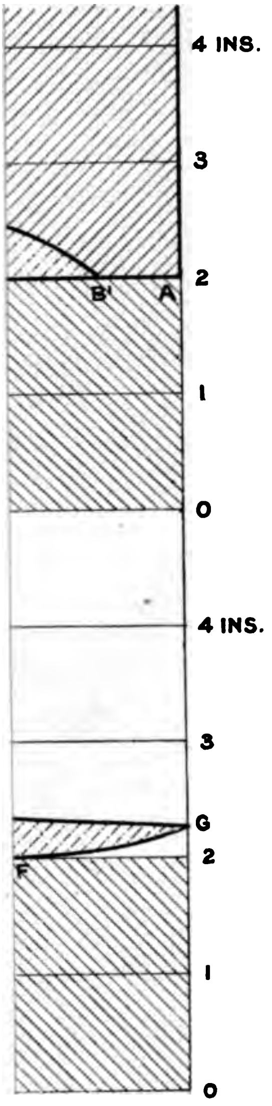
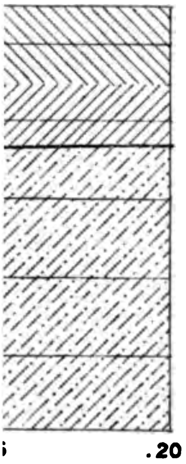






2° F.

3Sᴿ.

If possible the above observations to be made at different speeds so as to estimate leakage.

NOTE.—It would be better to check the vacuum gauge by taking cards off the condenser, using the same spring in the indicator as when taking cards off the pump.

The VICE-PRESIDENT, in deferring the discussion till the next meeting, said he was sure they were very much obliged to Mr. Hamilton for such an exhaustive paper.

This concluded the business of the meeting.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIFTH SESSION, 1888–89.

PROCEEDINGS.

CLOSING BUSINESS MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, MAY 13TH, 1889.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting held in Newcastle-upon-Tyne, on April 8th, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. H. Charlton and S. Tatham to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Allan, David Thompson, Messrs. Black & Hawthorn, Gateshead-on-Tyne.
Crawford, John P., 1, St. Vincent Street, Sunderland.
Eltringham, J., Messrs. J. T. Eltringham & Co., South Shields.
Garthwaite, John R., Messrs. R. Ropner & Son, Shipbuilders, Stockton-on-Tees.
Lindfors, Hugo, 16, Alexandersgatan, Helsingfors, Finland.
Smith, C. Hubert, Board of Trade, South Shields.
Whitehead, Francis, Messrs. Blyth Dry Dock Co., Blyth.

ASSOCIATE.

Jobson, W. J., Messrs. Robert Stephenson & Co., Engineers, South Street, Newcastle-on-Tyne.

GRADUATE.

White, Ernest T., 3, Belle Vue Terrace, Gateshead-on-Tyne.

Mr. J. B. Dodds replied to the remarks made on his paper on "Corrosion and Pitting in Marine Boilers."

The discussion upon Mr. J. H. Hamilton's paper "On the Proper Capacity of Air Pumps," was then proceeded with.

This was followed by the closing business of the session.

MR. DODDS'S REPLY TO THE DISCUSSION ON "CORROSION AND PITTING IN MARINE BOILERS."

Mr. **Dodds**, in reply to the discussion on his paper, entitled "Corrosion and Pitting in Marine Boilers," said, the discussion had raised the question as to the manner of action of zinc on the boiler when in metallic contact, as against its action when simply suspended in the boiler, such contact not being specially provided for. In his opinion zinc acted in two ways under these different conditions; when in metallic contact it acted by becoming the positive or corroded metal, protecting all such parts of the boiler as were within the radius of its influence; when not in metallic contact it acted as a non-excitant on such portions of the water as were in its immediate neighbourhood, but this action of zinc, in its metallic condition, would necessarily be small, as metallic zinc cannot diffuse itself sufficiently to act as a general non-excitant. As to the presence of air in the boilers causing corrosion, he considered, as air was always present, it was a constant quantity and could not therefore be blamed for exceptional cases of corrosion. The use or disuse of cylinder oils was perhaps more a mechanical than a chemical question, and depended much on the quality of the oil used, a bad oil, with a low vapourising point and poor body at the temperature of the cylinder, would certainly be injurious, but a good oil, of high vapourising point, and good body, at say 370° Fah., would, by its lubricating power, ease the working of the cylinder, and so effect a proportionate saving in power and in wear and tear.

In reply to Mr. Spence, he must differ from him in so far as Mr. Spence considered the questions of corrosion and pitting as different questions; this can hardly be the case, seeing that the same cause, viz., the chemical action of the water on the metallic surfaces occasioned both forms of deterioration. In the absence of local influences this deterioration was general, and may then be classed as corrosion; but when local influences intervened, this chemical action of the water on the metallic surfaces of the boiler became localised, and the full force of such action was concentrated on certain small portions or sections of the boiler which have become positive to the remaining and greater portion of the boiler, thus causing serious local damage or deterioration—this form of deterioration may be classed as pitting. These local influences were occasioned by the presence of rust and of differences of temperature between one part of the boiler and another, and these differences were much more frequent than Mr. Spence would suggest, and it is on those parts of the boiler most likely to be subject to such influences, especially that of temperature, that pitting is most frequently observed. In the case mentioned by Mr. Spence of a set of furnaces which were said to be working under identically the same conditions, one was pitted and the others were free from pitting; from this it was only possible to prove that the one furnace which was pitted was not really working under identical conditions, there must have been a difference, perhaps unobservable and unavoidable, but it must have existed to cause one furnace to pit and the others to be free from pitting. Then as to oils and their vapourising points, it may be pointed out that the vapourising point of an oil does not indicate quite the same thing as the vapourising point of water. In the case of oils, the giving off of vapour indicates that the oil is being decomposed and changed, if such vapour be condensed it does not condense to an oil having any one of the properties observable in the original oil:—When water is vapourised and condensed it condenses to water again, no physical or chemical change having taken place, therefore the same law cannot be applied under such dissimilar conditions:—And if the decomposition which produces the oily organic matters, that are found combined with the bases in the deposits, took place in the boiler and not in the cylinder, then one would expect to find the free unchanged oil in larger quantities than the changed or combined oil. This is not the case; there being only a small proportion of free oil found, therefore it would seem logical to argue that only very little unchanged oil passed from the cylinders, only such as had undergone change having passed forward to the boiler in quantity. He could not accept the assertion that mineral oils are more unstable under electrical influences than are the salts of sea water; indeed his experience was exactly the opposite to that.

He noticed that Mr. Putnam took exception to his theories whilst he really did not mean to advance any, but only to state observed facts. Mr. Putnam said—"Take for instance the theory of the decomposition of sodium chloride;" in the paper there was no mention of such decomposition. What the writer stated was that as the deposits from corroding boilers contain a considerable percentage of magnesic oxide in combination with oily organic matters, that the presence of this magnesic oxide indicates that the magnesic salts of the sea water had been decomposed (page 196), but this is not stated as a theory but as a demonstrated fact, because the very *soluble* magnesia salts of sea water could not otherwise enter into the composition of an *insoluble* desposit. The amount of hydrochloric acid liberated from those salts by the action of this oily matter would be small relatively to the bulk of the water, and it would be almost instantaneously neutralised by action on the metallic surface. In the case of the samples of water examined by Mr. Putnam, it was surprising there should have been any increase of sodium chloride per gallon, as no such increase is warranted or possible under the circumstances, as steam boilers possess no power to create sodium chloride, therefore the data which showed such increase must be erroneous and unreliable. With regard to oils, the oils used in the cylinders at the time the deposits given were produced, were not impure oils, but standard brands of mineral oils. Animal and vegetable oils are well known to be injurious, but it can be still further stated that *mineral* oils, under favourable conditions, may become conducive of corrosion by being oxidised when in a vapourous form in the cylinder of a high pressure engine, forming acid compounds capable of combination with bases.

Mr. Salmon had asked "what was meant by regularity in working the boilers, and as to caving in of furnace"? Simply that the supply of water to the boilers should be uniform and as nearly as possible always the same. It would seem to be attributing a great deal to the oils to blame them for the collapsing of the furnaces. In the first place, oils are lighter than water and unless combined with other substances will not settle or sink, and the quantity present could not produce such disastrous results as to collapse a furnace, it would rather appear as if the supply of water to the boiler had been irregular. But this was rather an engineer's than a chemist's question; only from a chemical point of view, and considering the quantity of oils used, so great an effect could hardly be expected.

The PRESIDENT said they had heard Mr. Dodds's reply to the various criticisms upon his paper at their last meeting, and he was sure they were very much indebted to him for the trouble he had taken in bringing the subject before them. He asked them to accord Mr. Dodds a hearty vote of thanks for his valuable contribution to the records of the Institution.

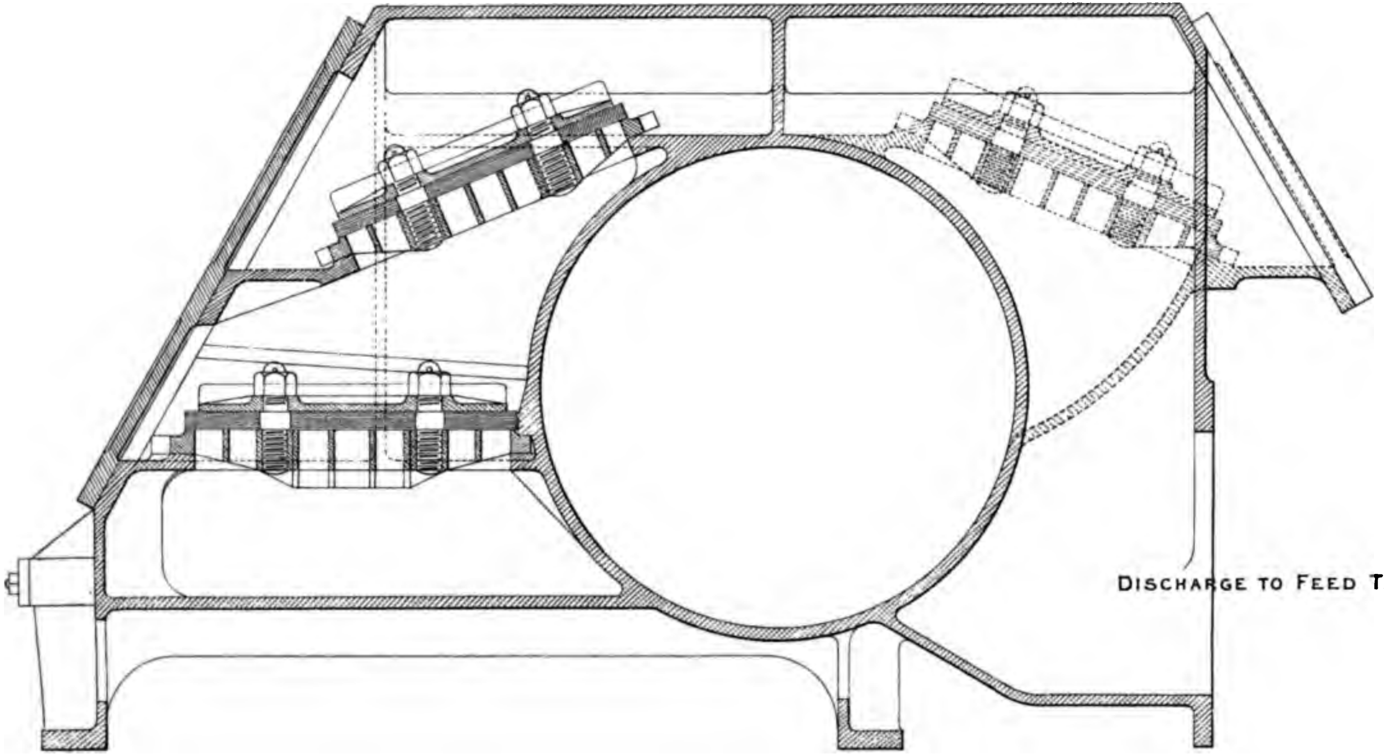
The vote was carried by acclamation.

CONSTITUENT PARTS OF ONE GALLON OF SEA WATER, SP. GR. AT 60° FAH., 1·027.

Water	67,488	Grains.
Sodic Chloride	1,960	„
Potassic Chloride	54	„
Magnesic Chloride	236	„
Magnesic Sulphate	161	„
Calcic Sulphate	98	„
Calcic Carbonate	3	„
	70,000	„

DISCUSSION ON MR. HAMILTON'S PAPER "ON THE PROPER CAPACITY OF AIR PUMPS."

Mr. R. L. **Weighton** thought they were very much indebted, to say the least, to Mr. Hamilton for bringing this paper before them. It certainly required a great deal of thought, and a great deal of working out. While he said that, he hoped he was at liberty to criticise some points adversely. On page 239 Mr. Hamilton said, "it is hoped that the facts stated, and the conclusions arrived at, will help to explain the anomalies to be found in current practice." This was just the point on which he thought the paper was defective. His difficulty—and he thought the difficulty of most engineers—was to explain the anomalies current in practice with air pumps, and more especially with horizontal double-acting air pumps. So far as the vertical single-acting air pump was concerned, the paper fairly explained the phenomena found in practice with jet condensation. In passing, however, from jet condensation to surface condensation there seemed to be some confusion in the writer's mind. In dealing with jet condensation the air in solution in the condensing water is alone dealt with as the possible source of a bad vacuum, and with which the air pump is concerned. The amount of this air is assumed to be 5 per cent. When, however, surface condensation is approached, it is admitted that this source of bad vacua is reduced from 5 per cent. to 1 per cent.; but leakage of air at glands, etc., is taken account of as explaining the fact that the vacuum generally attained with surface condensation is not by any means so much better than that obtained under jet condensation as the theory advanced would lead us to expect. Now, the confusion here consists in taking account of air leakage through glands, etc., in the case of surface condensation, and in ignoring such leakage in the case of jet condensation. Such leakage exists in both cases, and should be taken into account in both. It is, however, when the question of the horizontal double-acting air pump is approached that all theories hitherto advanced fail to account for observed phenomena in practical work. The writer of the paper points out—and very properly so—that the vacuum in the case of the vertical pump is very largely dependent, in any given case, upon the depth of water over the foot valves—the less the depth over the foot valves the better the vacuum—and he gave a drawing (Figs. 1 and 2, Plate XXXVI.) of what he (Mr. Weighton) presumed to be a typical horizontal pump, in which pump the foot valve is entirely uncovered

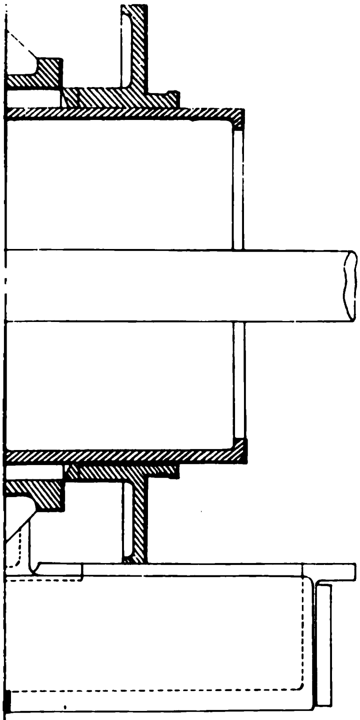


SCALE 1½′ - ONE FOOT

Andrew Reid Sons & Co Lithos Newcastle

on's paper.

Vol V Plate XII.



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during a great part of the stroke. The vacuum with such a pump ought, according to theory, to be very nearly perfect. As a matter of fact, he (Mr. Weighton) had designed a pump similar to this, in so far as the foot valve was uncovered during most of the stroke, and the vacuum was just about what is currently realised with horizontal pumps. (See Plate XL., for a sketch of this pump.) The depth of water over the foot valve certainly does not determine the vacuum attainable in such pumps. In fact it does not appear to have very much influence upon the vacuum. Hence he (Mr. Weighton) held that the explanation given in the paper of the anomalies they found in practice was not sufficient. He thought as regarded the size of pump for any given vacuum, the writer showed very distinctly how, within certain limits, size had nothing to do with it, or very little. They would observe from Diagram 10, Plate XXXIX, the increase of size raised the vacuum very little. Assuming these calculations to be correct, it would be seen from inspection of Diagram 10 that the gain in vacuum by increasing the pump five times is barely 10 per cent., a gain which will certainly not compensate for the increased power required to operate the enlarged pump.

The PRESIDENT said, the question of the capacity and efficiency of air pumps was a very important one, and he thought they would show their appreciation of the industry of the author by taking part in the discussion, and introducing any illustration they could call to mind. He might say that he had one case specially in mind, a double-action pump converted into a single-acting pump, where, though the capacity was reduced to one-half, the vacuum was very much better with the single than the double-acting pump. This was something like what was done:—A bucket was made; but instead of this bucket being made solid, working in a cylinder, it was made with valves hung as shown in the sketch (Plate XLI.). One set of delivery valves were closed at one end of the pump, and those at the other allowed to act; the one set of suction valves were closed and the other allowed to act, and so the pump was made practically single-acting and reduced to half its capacity, but the vacuum was very much better. In fact, he thought they got something like three inches better vacuum. The secret of that was simply this—the water drawn in through this valve was lying on the bottom of the air pump, and when the bucket went back into it, it had no resistance to overcome, for the inertia of the valves was overcome by the movement of the bucket and discharged perfectly free, and there was an absolute vacuum left through the pump, there being no resistance on the valves.

There was no further discussion.

MR. HAMILTON'S REPLY.

Mr. **Hamilton**, in replying, said he regretted there had not been a fuller discussion, as doubtless there were defects in matter or treatment which a good discussion would have brought to light; but it was difficult to make up a criticism on such a paper as this without the aid of the diagrams. He thought that Mr. Weighton did not quite catch the main idea of his paper, which was to show in a general way, irrespective of special constructions, how the vacuum ought to depend on the capacity of the air pump, and to draw the attention of members to the laws which govern the pressure in the condenser. His excuse for bringing such simple and elementary matter before them must be the fact that even the best writers on the steam engine gave either no information at all on this subject or else their treatment of it was inaccurate and very incomplete.

With regard to Mr. Weighton's objection that he had not taken leakage into account, in the case of jet condensation as well as in that of surface condensation, they would find that he had assumed leakage to be the cause of a bad vacuum, when a good one might be expected from other considerations; and a reference to page 236 would show that he intended the remarks to apply to jet as well as to surface condensers.

The depreciation of the vacuum would, however, be greater in the latter case, for, since the air pump would be much smaller than the pump on the jet condenser, while the leakage per unit time for the same sized engine would be presumably the same, it would follow that the lowering of the vacuum would be much more marked in the surface condenser.

Mr. Weighton seemed to think that, according to the theory advanced in the paper, the vacuum should be much less for the jet than for the surface condenser; but with the usual pump capacities, and the same condenser temperature, the vacuum should not differ by more than ½ or ¾ inch, and this would be partly due to the difference in depth of water over the valves.

His remarks on the bad results attained with horizontal double-acting pumps evidently referred to those used in marine work with surface condensers, and in most cases running at a comparatively high speed, for the most widely used double-acting horizontal pump—viz., the kind which was applied to many horizontal stationary engines with jet condensers—did not give results so very much worse than vertical pumps; and in such cases as he (Mr. Hamilton) was acquainted with, the difference in the vacuum could be nearly accounted for by the extra height of water over the valves. But the interesting example adduced by Mr. Weighton showed that this was not the case, for the pump represented in Plate XL., which, as he (Mr. Weighton) pointed out, resembled that shown in Figs. 1 and 2, Plate XXXVI., in that, the suction valve was not under water during the whole stroke. There were, however, very important differences between these two pumps, one of which was that the bucket of the latter was always completely immersed in water, while in the former the upper portion was uncovered during the greater part of the stroke—in fact almost to the end of the delivery stroke, for they should always bear in mind that with a regular discharge of water the quantity discharged at each stroke would be extremely small, say about $\frac{1}{100}$th of the pump capacity. As it would be very unlikely that with ordinary workmanship the bucket should be quite air-tight, the result would be that the vacuum would be spoiled by leakage past it. On referring to Plate XL., it would be seen also that the highest point at which air could escape was a little below the level of the top of the barrel, and if the surface of the water rose gradually and evenly, without breaking up or oscillation, the air would be nearly all discharged first, and during the last $\frac{1}{100}$th of the stroke water would be discharged. But the water did not move in this way in such a pump as this when running at a high speed. There would be violent agitation of the water, the surface would be greatly broken up, especially if the delivery passages were irregular in form, and the consequence would be that the whole of the air in the pump barrel would certainly not be discharged, but some would remain and be compressed up to the discharging pressure, and thus, even though the bucket were quite air-tight, the pump could not maintain the full vacuum. Supposing the volume of trapped air at the end of the delivery stroke were $\frac{1}{16}$th of the pump capacity, and that the discharging pressure were 32 inches, then the pressure in the barrel of the pump when the bucket had got to the other end of its stroke would be $\frac{32}{16} = 2$ inches greater, and consequently the vacuum 2 inches worse than if all the air had been discharged.

If the pump had been drawing from a jet condenser, the water current towards the delivery valves would probably have helped to carry some of the air out with them; but with such a very small discharge as occurs with surface condensation there could not be any appreciable currents.

This arrangement of delivery valves was another point in which the pump differed from that shown in Figs. 1 and 2, Plate XXXVI, in which it was intended that the motion of the surface of the water should be simply a rising and falling one, and the action similar to that of a vertical pump. The delivery valve was placed at the highest point, and spread over the whole extent of the water surface; and there were no irregularities or pockets in the space below the valve, so that the oscillation of the surface would be reduced to a minimum, and there would be much less danger of trapped air. At the same time the pump would not be suitable for very high speed, but would do for moderately high speed if the area of the water surface were increased in proportion to that of the bucket, so as to reduce the working speed of this water surface.

It would also be better, if possible, to increase the head of water over the barrel by raising the suction and delivery valves, making the vertical part of the same diameter throughout from the delivery valve down to the barrel, and thus getting sufficient pressure to produce the horizontal acceleration of the water in the barrel. The flap valve would also have to be replaced by a rubber valve or rubber-faced valve.

The principle of making the working speed of the water surface moderate was used in the Porter-Allen high speed engine, and the bucket in this case was replaced by a plunger with a shell-shaped end passing into a mass of water in a rectangular box, so that it was a single-acting pump. A somewhat similar pump to this might be used for very high speeds.

Passing on to Mr. Weighton's remark that the theory did not account for the usual practice as to the capacity of pumps working with surface condensers, he was prepared to admit that it was so, unless, it were assumed that the pump was made so large that if occasion required it could keep a tolerably good vacuum with jet condensation.

That, when everything was in good order, the pumps usually fitted to marine engines were unnecessarily large when working with jet condensation, he thought was illustrated by the air pump cards shown in Figs. A and B, page 253, for which and for other information he was indebted both to Mr. Alexander Taylor, the designer, and Messrs. Douglas and Grant, the makers of the engines, which were among the earliest built on the triple compound principle. The capacity of this pump was $\frac{1}{14{\cdot}25}$th of that of the low-pressure cylinder, and they would see that, although three strokes were shown, there was only one discharge, because only one rises above the atmospheric line.

The President—Your inference is that neither of the dotted lines discharge at all?

AIR PUMP INDICATOR CARDS.

S.Y. ISA.

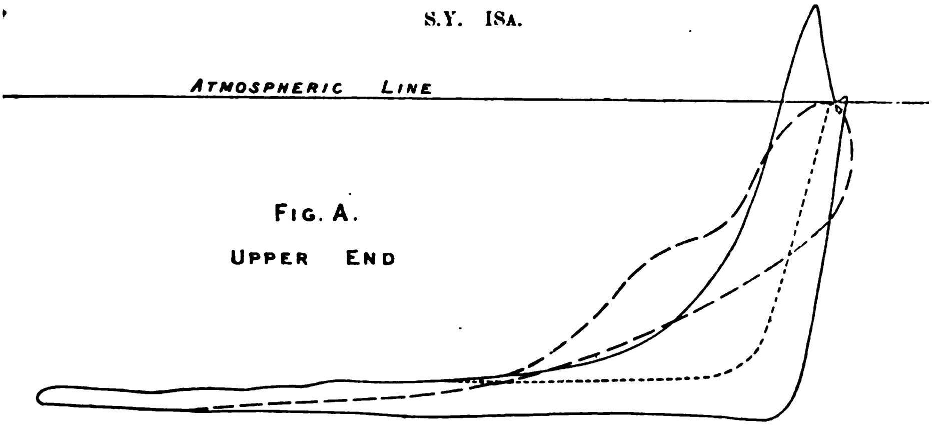

Fig. A.

Upper End

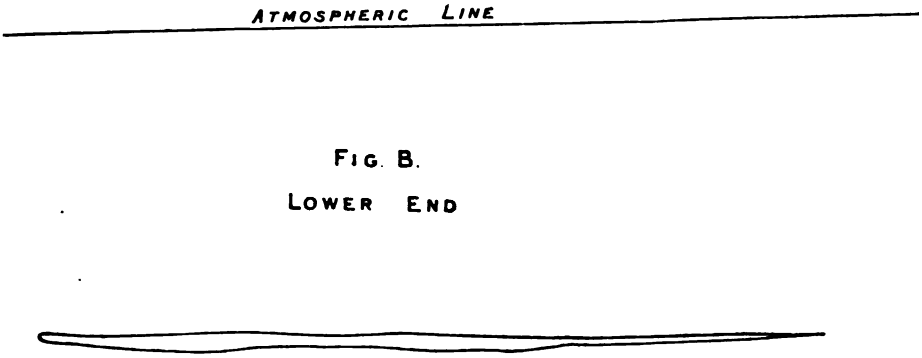

Fig. B.

Lower End

Scale $1/8$

Mr. HAMILTON—Yes, because if there was a discharge the line would rise above the atmospheric line; and he thought this showed that the pump was unnecessarily large, for if it had been about one-third of the size there would probably be a discharge every stroke, and the vacuum would doubtless be just as good. There was, however, not much objection to making the pump large, for the difference in power required to drive it would not be very great, as the power depended in the first instance on the volume of water and air delivered, and as this was independent of the size of the pump the difference in power would be due to difference in friction, etc.

The case cited by the President, in which an improvement in the vacuum followed the conversion of a double-acting pump into a single-acting one, suggested to him (Mr. Hamilton) the liability of horizontal pumps to form air traps which was a point he did not get into his paper, and he thought this hypothesis would explain the result completely, while the fact that the improvement was apparently not affected by reducing the capacity to three-eighths of its former value emphasised the above remarks on the capacity of pumps on surface condensers.

They would see (Plate XLI.) that though the delivery valves were placed well up in this case, yet the passages leading to them were very irregular and there would probably be some air trapped.

Calling the trunk or the suction end the front end, it would be evident that as the bucket moves forward the inertia of the water increases the pressure on the front and decreases the pressure on the back of the bucket, so that when the level of the water is the same on each side of the bucket the valves would probably open and the water begin to pass through them.

As the quantity that passed through at each stroke would be very small with surface condensation, the level of the water would be about the same on each side of the bucket when the latter was full forward. Supposing that the total clearance at the suction end was equal to the volume opened out by the backward movement of the bucket and trunk, also that when the bucket was full forward the level of the water in the barrel was up to the centre line, and that the water in front of the bucket occupied one-half of the clearance space; then, when the bucket was full back, the air in front would have expanded three times. If the volume of air trapped on the delivery side were the same as before the pump was made single-acting, say $\frac{1}{16}$th of the volume opened out behind the bucket on the forward stroke, the air pressure in the pump at the commencement of the suction stroke would be $\frac{32}{16} = 2$ inches (supposing that the quantity of air which enters from the condenser is so slight that the increase of pressure due to this cause can be neglected), and the air pressure in the front end, at the end of the suction stroke will be $\frac{2}{3}$ inch; thus there would be a gain of $2 - \frac{2}{3} = 1\frac{1}{3}$ inches by making the pump single-acting. But there would also be less depth of water over the suction valves, say $4\frac{1}{2}$ inches $= \frac{1}{3}$ inch mercury; thus the gain in vacuum would be $1\frac{2}{3}$ inches. If the volume of the trapped air had been $\frac{1}{7}$th instead of $\frac{1}{15}$th of the capacity, the gain would be $4 - \frac{4}{3} + \frac{1}{3} = 3$ inches, and so on, the improvement increasing in proportion to the room for improvement; that is to say, in proportion to the volume of air which escapes discharge. It would be a matter of opinion how much air would probably be trapped, but a horizontal air pump on a surface condenser, would, of all pumps, be most liable to this defect, on account of the small water delivery and the comparatively high speed which was usual.

Mr. Weighton had asked how he (Mr. Hamilton) would propose to increase the efficiency of the double-acting horizontal pump; and believing that the inefficiency was due to the above causes, he would suggest the fulfilment of the following conditions:—(1) The area of the free water surface should not undergo any sudden or rapid variation as it rises and falls. (2) The delivery valve should either spread all over this surface, or, if smaller than the surface when the latter is below its upper position, the bounding metal walls should be equally inclined inwards with an easy slope, so that when the water surface is just about to touch the bottom of the delivery valve the latter should cover the whole surface. (3) The suction valve should be so placed that towards the end of the stroke it will have little or no water over it, but should be completely covered when the bucket has made a small portion of the discharge stroke. (4) A water seal should be used where the trunk, rod, or plunger enters the pump, and the delivery valves and joints should be well covered with water. The condition 1 would lead to the condition that the bucket should be always completely immersed in water, and also to the condition that there should not be any irregularities or pockets in the delivery passages.

It was a very rare case in machine design in which all the conditions of efficiency in working could be carried out; for sometimes they would conflict with each other, sometimes constructive difficulties would have to be faced, or economy in manufacture considered; or again, want of space or of accessibility would step in to prevent their fulfilment. And so it would be with air pumps, which had not only to be efficient, but also accessible, and often were required to go into a cramped space; but he thought that in most cases the chief of the above conditions might be nearly fulfilled, especially if the pump were made much smaller for surface condensers than was usual. This, however, was a matter for further experiment, which was the best way of obtaining the object they all had in view, namely, the elucidation of the true mode of action of the air pump, and the increase of our knowledge how to secure the best results.

The PRESIDENT said he was sure they would all agree with him that the amount of research and thought that Mr. Hamilton had bestowed on this paper deserved from them their heartiest thanks. They were very much indebted to any one who would take up one part of the mechanism with which they had to deal from day to day and analyse it as thoroughly as Mr. Hamilton had done in this case. He could assure them, if all the members of that Institution had had as much difficulty with horizontal pumps as he had had in his lifetime they would be very thankful for any fresh information on the subject. It was one requiring further illustration in their drawing offices. Here was a good field for any of their young gentlemen who wished to advance in his profession, and advance his profession. He begged to move a hearty vote of thanks to Mr. Hamilton.

The motion was cordially acceded to.

CLOSING BUSINESS.

Articles of the Constitution and the Bye-Laws.

The **President** said this was the final meeting of the session of 1888-9, and there were some matters to be brought before them, in accordance with the bye-laws, for their decision. He begged to move on behalf of the Council that the following alterations or modifications be made in the Articles of the Constitution. These alterations had received the very careful attention of their Council, and it was for them to ratify or do otherwise as they thought proper that night. Probably they had not the Articles of Association before them, but he would indicate as clearly as he could what the modifications were. In the first place, in Articles VII. of the Constitution, the Council suggested for their adoption that the clause relating to Graduates should read:—

"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."

They might remember that there was a good deal of discussion on the question of increasing the subscription. This had been done with the view of meeting a certain number of objectors to that increase, by extending the age of Graduates from twenty-one to twenty-four, the Council supposed an age when he would be earning sufficient to make the difference between the guinea and half-guinea less of a hardship to him, and therefore that modification was proposed.

In Article IX. it was proposed that:—

"The Officers of the Institution shall be elected from and by members, and shall consist of one President, the Past-Presidents, *nine* Vice-Presidents, fifteen Councilmen, and an Honorary Treasurer."

The alteration there was from the word "six" to the word "nine." It was thought desirable, as a matter of policy, that their Vice-Presidents should number nine instead of six, in order that they might secure the services of a greater number of Councilmen on the Board. The next alteration was Article X.:—

"The President and Honorary Treasurer shall be elected annually. *Three* Vice-Presidents and five Councilmen shall be elected annually. The retiring Vice-Presidents and Councilmen shall be those who have served three years from their last election."

They would thus have three Vice-Presidents retiring each year, in the same way as a certain number of Councilmen was provided for by the next clause, the alteration being three Vice-Presidents instead of two Vice-Presidents. He should leave it to them to say whether they should be voted *en bloc* or taken separately.

The meeting having declared for the former, the President moved that Articles VII., IX., and X., be modified as suggested by the Council.

Mr. TATHAM seconded, and the proposal was unanimously adopted.

The PRESIDENT moved the following alteration in Bye-Law 6:—

"All subscriptions shall be payable in advance, and shall become due on the 1st of June 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 June following."

Mr. W. BOYD seconded the motion, and asked to be allowed to say a word or two in favour of the change proposed. Past and present Members of Council knew that one of the great difficulties they had to contend with was the payment of subscriptions. In carrying on the financial affairs of the Institution they would be able to get on very much better if members would only pay their subscriptions at the opening of the session, and though he did not happen to be present at the Council meeting when this alteration was adopted, yet, notwithstanding that, it had his entire approval. He might, without any breach of confidence he thought, take the liberty of saying that cases had been known in which gentlemen, who were members of this Institution, had justified themselves for not paying subscriptions on the ground that the mere fact of non-payment was tantamount to the resignation of their membership. Now, that was a very mistaken idea. He knew of no Institution in existence, and he was a member of a good many, where such an argument as that would hold water for a single moment, yet there it was an argument which was used against the Council to justify the non-payment of subscriptions. Of course if it were universally used the Institution would collapse. They could not get on without subscriptions, and accordingly these conditions had been drawn up, the effect of which was to cut the ground from underneath the feet of those who chose to use such an argument as that in future. It would be distinctly stated in the Bye-Laws of the Institution that resignation from the Institution must be a distinct and voluntary act, notified to the Secretary in a proper and businesslike way.

Mr. TATHAM—May I ask, if a member does not pay his subscription, will the Council stop sending the Transactions to him? If they can only get the Transactions that is all they want; many members never come near the Institution.

Mr. DUCKITT (Secretary) said that the bye-laws in regard to that affected only the current session for which a member would get the Transactions, but until he had paid he did not get the publications for the following session. A defaulting subscriber got the Transactions for one session, but that they could not help.

Mr. TATHAM—Could we not make some better regulations?

The PRESIDENT said he did not see how they could. They began the session nominally, or rather it terminated, on the 31st May in each year, and the next session began. The subscriptions were due on the 1st of June; but as a rule, very few of the subscriptions were paid before the first meeting in October, and some did not pay till this the last meeting of the session, or the last day of May. In the meantime the Transactions for the current session were going out, and if copies were only sent to those clear on the Treasurer's books, many of their members for whom they had a great regard notwithstanding the non-payment of their subscriptions, would be shorn of their important publications for the session. He thought their bye-law fairly met the case, and they must take the risk for one session.

ELECTION OF OFFICE-BEARERS.

The PRESIDENT said he had to declare that the following gentlemen had been elected by the Institution, or a certain number of the Institution, to fill the posts of President, Vice-Presidents, and Councilmen for the ensuing year. There had been sent in 110 voting papers out of 760 members—that was, only about 15 per cent. of the total membership voted; but the result of it was that they had done him the honour of electing him for another year as President. He thanked them now for the honour, and should do so again.

President—MR. F. C. MARSHALL.

Vice-Presidents—MESSRS. JOHN DICKINSON, WILLIAM GRAY, PERCY HALL, ARTHUR LAING, and ROBERT THOMPSON.

Hon. Treasurer—MR. B. G. NICHOL.

Councilmen—MESSRS. JOHN GRAVELL, L. RUSDEN, G. W. SIVEWRIGHT, J. C. STIRZAKER, and ALEX. TAYLOR.

As their President he had very great pleasure in welcoming those gentlemen, while sympathising with those not elected to their Council Board. He was quite sure the gentlemen selected would be a great help and addition to it.

EXCURSION TO FORTH BRIDGE.

The PRESIDENT called attention to the proposed excursion of the Institution to the Forth Bridge on Whit Tuesday, June 11th, and to the arrangements made for the occasion.

Mr. BOYD said that in the notice of the excursion there was a certain amount of doubt thrown upon the question as to whether the excursion would take place. Were they to understand that it would go on?

The PRESIDENT said that 140 members had already signified their intention of taking part in the excursion, and that it would take place was certain. A great many ladies were going, and though not members they would be very glad to see them.

VOTES OF THANKS.

Mr. BOYD said, it fell to him to propose a vote of thanks to their retiring President (Mr. F. C. Marshall) thanking him for his services in the chair during last year. Before passing on to what he had to say about Mr. Marshall, he should like to take this opportunity of congratulating the Institution that the excursion to the Forth Bridge was to come off. It was a matter in which (together with Mr. Marshall) he had felt a great deal of interest. He had been, he thought, three times to the Forth Bridge himself, and felt sure that nobody who would go there on the 11th June would feel his time or money had been wasted. He had seen the bridge in its initial stages, he hoped to see it on the 11th June nearing completion. It was certainly one of the most remarkable facts of the age, so far as Great Britain was concerned. Whether it was cut out by the Eiffel Tower or not he did not know. He had not had an opportunity of seeing that work, but he was quite prepared to rest the reputation of Great Britain, whether as a work of art or of usefulness, upon the Forth Bridge. He thought it would bear comparison with that of their neighbours across the channel. So far by the way. He was sorry that owing to various circumstances, some temporary and some permanent, he had not been able to attend the General Meetings of the

Institution during the last session as well as he would have liked. He trusted none of the members who had noticed his absence would think his interest had abated. His interest in the Institution was as keen and full as it was five years ago, and knowing something of its working, he knew the tax it must have been upon their President (and would be so again for another year, since he had been good enough to undertake the duties for another year) to control the working of the Institution. It had now arrived at a stage where it assumed very formidable proportions, and taking the chair for a couple of hours once a month was a very small part of the duties. The President had to discharge some most onerous duties for the welfare of the Institution. Then Mr. Duckitt had to be attended to, and he (Mr. Boyd) could assure them he was most pertinacious in being attended to, there was no getting rid of him, and of course all these things had to receive the attention of the President, and many other matters into which he need not now enter. Mr. Marshall had, he was quite sure, won the esteem and regard of the Institution, and their respect for the way in which he had conducted the business of the Institution at the General Meetings. He was quite sure he expressed the feelings of those listening to him that night when he asked them to join him in the proposed vote of thanks to Mr. Marshall for his conduct of the affairs of the Institution during the past session, and he begged to thank him personally, while he was sure the members of the Institution would join in thanking him for being good enough to spare from the very great claims they all knew were made upon his time a certain amount of time to conduct its affairs. During next session it was very important, because this coming autumn, as they knew, the British Association were about to visit Newcastle, and there was no doubt the Institution—he was going to say he hoped, but corrected himself and said he had no doubt the Institution would make itself felt during that visit as one of the scientific bodies which had a home in this district, not merely in Newcastle, but in the North-East district altogether; and he was quite sure it would be the wish of every member of the Institution that its vitality, influence, and general usefulness should be made clear to those who came to Newcastle. They could not be better represented, or have a better gentleman to call attention to the existence of the Institution than his friend, Mr. Marshall, who had been good enough to take the presidency for another year.

Mr. H. CHARLTON had very great pleasure in seconding the motion proposed by Mr. Boyd. As one of the members of the Council he had seen the great care and attention with which Mr. Marshall had presided over the business of the meetings, and he endorsed everything said by Mr. Boyd.

Mr. Boyd put the resolution to the meeting, and it was carried by acclamation.

The President assured the meeting he felt very much the kind words spoken by Mr. Boyd, and the hearty way in which they had been received. He considered they had done him the greatest honour they could have done in electing him to the office of President for another year. He was perfectly conscious, keenly conscious, that he was anything but a good chairman and that he had very often failed in the discharge of his duties. During last year he had not been able, from reasons many of them knew, to give that attention to the meetings which the interests of the Institution demanded. He had been absent, however, always very much to his regret. It was a great privilege to preside over an Institution of this nature and he felt it a great honour. He thought during the last year they had prospered abundantly. The Institution had grown in its membership largely; he did not know how many had been added in the year, but they now numbered some 750 members, and the progress this year had been certainly equal to any year, if not more than any year excepting the first, and this he held to be due not to any efforts of his or of the Council, but to the intrinsic value of the papers and of the meetings of the Institution. He was sure they would agree with him that the meetings during the past year had been of a very valuable character. In fact he knew, as he had the honour of saying at the dinner of the Institution of Mechanical Engineers, in London, on their behalf a few nights ago, he knew no institution which produced better papers than those of this Institution. He might refer to one of the circumstances of the year, a very important event, that of the Hartlepool meeting. They had inaugurated in that meeting what he hoped would be an annual gathering. It largely tended to increase the membership of the Institution and was, as they all felt, a most valuable meeting and one they could repeat very satisfactorily. As Mr. Boyd had said, they would have very much to do next year and make heavy claims upon his fellow Councilmen. He had found in the past year, as he was sure he should find in the year to come, ready help and much valuable assistance from those gentlemen with whom he had the pleasure of co-operating. One thing they had failed to do during the year that he hoped they should be able to accomplish during the ensuing year—they had failed to draw the Graduates of the Institution together in the way they all desired. He hoped it would be the object of each member of the Council, and each member of the Institution also, to urge upon the young members, the Graduates of the Institution, the desirability of forming an institution inside the Institution, where they might read and discuss papers in a way that would be of advantage to themselves. If they, the older men would point out to young men the great gain it was to write a paper, to read it, and to have it discussed, they should in the ensuing session be able to pull together a large number of their Graduates for the purpose of meeting from time to time. He wanted also to mention the subject of the library. They had got a very excellent library for a beginning, and let him commend to them the example of one of their members, Mr. William Cooper, who had presented to them seven or eight very valuable volumes, standard works, for the library. Perhaps some other friend would do likewise; what they wanted was books of reference for members to consult on shipbuilding and engineering questions. He ought to congratulate this Institution, he thought, on the position it had taken in the scientific world. He had the honour to be invited as their President to the dinner of the Institution of Mechanical Engineers, and of responding for the "professional institutions" of this country, amongst whom they were ranked, though the youngest, as one of the most important. It was something in five years to have risen to a position like that, and he was proud to represent them there. In regard to the question now pending at Lloyd's, their Institution as an Institution of Engineers and Shipbuilders took the same position along with the Naval Architects of London and the Engineers and Shipbuilders of Scotland, before Lloyd's Committee. As regards the wonderful work at the Forth Bridge he thought he had spoken on this subject before and it was not necessary he should repeat himself, but as a great engineering work, a work manifesting both magnificence of design and skill and technical detail, it contained abundance of lessons for every mechanic or any man desiring to call himself an engineer. They could visit no other work of such importance as the Forth Bridge, and he hoped every member of the Institution would take this excursion. He thanked them most heartily and sincerely for the honour they had done him in electing him to the honourable office for another year, and could assure them, his health being spared, no efforts of his should be lacking to make it a successful year.

On the motion of Mr. J. K. Sinton a vote of thanks to the Vice-Presidents and members of the Council was accorded by acclamation, after which the President declared the session closed.